FLOWER AND FRUIT DEVELOPMENT IN PROCESSING TOMATOES

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ABSTRACT

Processing tomato crops are mechanically harvested from a single destructive harvest. The timing of this harvest to coincide with the maximum yield of factory grade fruit is of considerable importance to the efficiency of the field operation. There is a lack of information regarding where the factory grade fruit is produced on the plant and for how long the yield of factory grade fruit is maintained at its maximum level in the field.

Two experiments were carried out in the Manawatu using the processing cultivars Castlehye 1204 Improved and UC 82B. The first experiment determined the time of flowering of all the flowers on the plant, the trusses in which these flowers were to be found and the position of these trusses on the plant. 132 days after planting all the plants were harvested and the number and position on the plant of the flowers which set fruit was determined. A normal distribution was found to satisfactorily describe the relationship between the number of flowers reaching anthesis and time. Plants on average carried up to 37 trusses. 65% of the yield was carried on the first 10 trusses to flower with 95% of the yield carried on the first 20 trusses to flower. The efficiency of trusses in producing fruit varied from 66% with the earlier flowering trusses down to negligible levels. Plants had up to 8 main order laterals and together with their attached sub laterals each carried from 4-5 trusses. The efficiency of flowering decreased with the position of the truss up the lateral. It was suggested that the competition

between trusses for assimilates is far more important within laterals than between laterals. These results have implications for both crop management and plant breeding programmes.

In the second experiment 9 successional destructive harvests were carried out commencing at the first sign of coloured fruit. Ethryl was not applied to the crop. The yield of red and factory grade fruit was found to peak sharply over time. The normal distribution curve was found to satisfactorily describe the relationship between time and the yield of both red and factory grade fruit and fruit numbers of these grades of fruit. Harvesting one week earlier or one week later than the optimum harvest date resulted in a loss of factory grade fruit of from 10-15 tonnes per hectare. The major cause for this rapid fall in yield from the optimum was due to an increase in the yield of red rotten fruit. In fact over half of the total number of fruit had rotted by 136 days after planting. This included a significant number of green fruit. The magnitude of this loss was only apparent because successional harvests were carried out. The total yield of fruit (all grades) was maintained over a considerable period as the loss in fruit numbers was balanced by the increase in mean fruit weight of the crop. The mean fruit weight of fruit did not increase once they had coloured. The percent soluble solids of red fruit decreased the week following any significant amount of rainfall.

In the light of this research the effect of ethryl on the maturity characteristics of processing tomato crops needs to be re-examined by the use of successional harvests. Reliable techniques also need to be developed to predict the time of optimum harvest as these results suggest that it is much shorter than is commonly thought. The importance of fruit rots in reducing yields and thus effecting the length of the optimum

harvest period is also apparent and is another area of research which requires further study.

In the first experiment, the Normal Distribution Curve was found to describe the frequency of flower anthesis versus time relationship in two processing tomato cultivars; Castlehye 1204 Improved and UC 82B. Early fruit setting flowers acted as a strong sink as 90% of the final yield was carried on the first 18 trusses. Yield contributing trusses followed a pattern of increasing distance from the root system the later they flowered. Competition for photosynthate was mainly within laterals but also there was some between lateral competition. Flower trusses exhibited decreasing efficiencies in producing red fruit the later first flower anthesis occurred on the flower truss.

In the second experiment, the yield of Factory Grade tomato fruit from the same two processing tomato cultivars peaked sharply over time. Harvesting one week earlier or later than the optimum harvest date resulted in a Factory Grade yield loss of up to 10-15 t ha^{-1} for both cultivars. The Normal Distribution Curve was found to describe the relationship between Factory Grade fruit weight and number over time for both cultivars. Both red and coloured fruit weight were also found to follow the Normal Distribution. Over half of the total number of fruit rotted by 136 days after planting. Percentage Soluble Solids of red fruit decreased as rainfall increased in the week preceding harvest, with the converse also shown to apply.

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INTRODUCTION

An important criteria for the successful harvesting of processing tomatoes, is that a high proportion of the fruit harvested is at the correct stage of maturity for processing. In New Zealand, processing tomatoes are generally harvested when a sample drawn from the crop indicates that optimum maturity has been achieved.

The objective of this study was to demonstrate how the time of harvest for two common cultivars of processing tomatoes used in New Zealand, is very critical and harvesting outside the optimum time can result in a large loss of potential yield. It was also decided to study the flowering pattern of the same two tomato cultivars to find which flower trusses were contributing to the yield of processing grade fruit.

CHAPTER ONE: LITERATURE REVIEW

1.1 VEGETATIVE DEVELOPMENT OF THE PLANT

1.1.1 DEVELOPMENT STAGES

1.1.1.1 FACTORS AFFECTING GERMINATION

SEED

The tomato seed is similar to many other seeds in that it consists of an embryo, endosperm, and testa. Also in common with other seeds the embryo comprises of the radicle, hypocotyl, two cotyledons and the shoot apex. Germination usually takes about 7-10 days under normal conditions; the primary root first appears and the arched hypocotyl then emerges, followed by the liberation of the cotyledons from the seed coat. The seed's ovoid shape does not generally lend itself for mechanical sowing, and is generally light in colour. Germination is controlled in part by genetic inheritance (Whittington and Fierlinger, 1972), however other factors influencing germination of the seed include the method and time of seed extraction (Kerr, 1963), and also treatments used to control seed borne diseases. Tomato seed stores well, retaining viability under a range of humidity and temperature; James, Bass and Clarke (1964) found germination of 90% after storage for 15 years. However Lorenz and Maynard (1980) reported the maximum life expectancy of tomato seeds stored under favourable conditions is four years for commercial purposes.

WATER

Tomato seed will germinate over a wide range of soil water potentials ranging from just above wilting point to field capacity (Lorenz and Maynard, 1980), although optimum conditions appear to be 50-75% field capacity (Fawusi and Agboola, 1980). Water requirements for imbibition of the seed has been shown to be satisfied after about 12 hours (Berrie and Drennen, 1971) and the germinating seed is not particularly sensitive to drying out until cell division has been initiated. Water uptake for germination is affected by temperature, water content and salinity of the soil. As tomato seed has a high demand for oxygen, water probably has the greatest influence on the seed by restricting oxygen availability especially at higher temperatures (Siegel and Rosen, 1962). Generally tomatoes are considered as being reasonably salt tolerant during germination

(Shalhevet and Yaron, 1973) but not at later stages of growth.

TEMPERATURE

Lorenz and Maynard (1980), report optimum germination temperatures for the tomato seed as being between 15°C and 30°C, however Mobayen (1980) found optimum germination occurred between 20°C and 25°C. Tomato seed exhibits variability in its ability to germinate at temperatures both above and below optimum, and this variability appears to be cultivar dependent (Thompson, 1974; Berry, 1969). Different cultivars have been known to germinate from as low as 8°C (Wagenvoort and Bierhuizen, 1977) to as high as 35°C (Berry, 1969).

LIGHT

Tomato seed generally germinates best in the dark, and in some cultivars light will actually inhibit germination (Mancinelli, Borthwick and Hendricks, 1966). These workers also found germination is slowed or inhibited by exposure to far red light, although this effect was found to be dependent on the cultivar and environmental conditions. Mancinelli, Yaniv and Smith (1967) found that phytochrome control was most evident at temperatures less than 20°C, and as temperature increased sensitivity to light decreased.

SEED TREATMENTS

There are many different treatments which have been applied to tomato seed in order to improve germination or growth of the resultant plant. Gray (1957) used a slurry of 5% GA (gibberellic acid) in a methyl cellulose carrier as a seed coating and observed an increase in seedling emergence. Thiram, which is often used as a seed fungicide dusting, has been shown to inhibit germination in tomato if used as a seed soak (Joshua, 1977). Other workers have observed that application of a specific nutrient to seed, which is to be sown in soils deficient in that particular nutrient, will increase growth and yield (Mohapatra and Kibe, 1971). Drought resistance of tomato plants can be increased by alternately wetting and drying the seed before sowing (May, Milthorpe and Milthorpe, 1962). Soaking tomato seed in salt solutions can increase the rate of germination (Ells, 1963).

Application of plant growth regulators to tomato seed have also been shown to affect germination and growth. Increases in germination, growth and yield were obtained by presowing treatments of NOA (naphthoxyacetic acid), CPA (chlorophenoxyacetic acid) and GA (Choudhoury and Singh, 1960).

1.1.1.2 VEGETATIVE DEVELOPMENT

STEM DEVELOPMENT

The tomato stem typically consists of phloem strands both inside and outside a cylindrical tube of xylem fibres, which surround a core of pith cells. It is covered in hairs and at the tip of the main stem there is the apical meristem where new leaves and flowers are initiated. Leaves are generally arranged on a 2/5 phyllotaxy. Between about 7 and 11 leaves the apex is transformed into a terminal inflorescence and further growth is from the leaf axils (Picken, Stewart and Klapwijk, 1986).

The rate of stem elongation generally increases with temperature, (Calvert, 1964) although the relationship between temperature, daylength and stem elongation appears to be complex. Went (1945) found the optimum night temperature for stem elongation was 30 ^{o}C in young plants and 13-18 ^{o}C in older reproductive plants. Calvert (1964) however also found elongation was determined by day temperature in young plants. Daylength appears to have varying effects on stem elongation. Kristoffersen (1963) showed the optimum daylength for stem elongation decreases as temperature increases or as plants grew larger. Shading may increase or decrease stem height depending on the time of the year and the age of the plant (Cooper, 1969). Both CO_2 enrichment (Hurd, 1968) and plant shaking (Heuchert and Mitchell, 1983) also affect stem elongation.

LEAF DEVELOPMENT

The tomato leaf is compound and of variable size, with the lowest leaves generally being the smallest (Aung and Austin, 1971). In the greenhouse, leaves are up to 0.5 meters long with a large terminal leaflet and up to 8 large lateral leaflets, which may also be compound. Leaflets are usually irregularly lobed with toothed edges, and covered with hairs of the same type as the stem.

In general, the rate of leaf production in young plants is independent of daylength (Kinet, 1977) and CO_2 enrichment (Hurd, 1968). Rates however increase with daily irradiance and temperature, but are constant in a constant environment (Calvert, 1959; Hussey, 1963). Effects of continuous light appear to be variable, but the usual effect is to inhibit leaf growth (Kristoffersen, 1963). The influence of photoperiod on the size of leaves appears to be cultivar dependent (Aung and Austin, 1971). Tucker (1981) showed that a brief irradiance with red light delays senescence and stops losses of chlorophyll and protein.

ROOT DEVELOPMENT

In a cross section of the root, the xylem forms a cylinder in the centre of the root, with two lateral wings. The phloem completes the vascular tissue by filling out the space between the wings and forming a cylinder (Picken, Stewart and Klapwijk, 1986). This in turn is surrounded by an endodermis, a three or four layered cortex and an epidermis. Lateral roots arise from behind the growing tip and grow through the cortex. Adventitious roots will develop in favourable conditions from the stem, particularly near the base, but also on the underside of stems which may be in contact with the soil.

Generally the shoot/root dry weight ratio increases as plants grow, but increases more slowly and reaches lower levels in higher irradiances (Kristoffersen, 1963). Went (1945) found that a higher greenhouse temperature decreased the rate of root growth and increased the shoot/root dry or fresh weight ratio. Hurd, Gay and Mountifield (1979) examined root growth during the early fruiting phase. They found root growth ceased during this period although it later resumed, but if flowers were removed from the plant then root growth was better.

Many workers have examined the effect of increasing root temperature on the subsequent growth of the roots or other parts of the plant, particularly with the advent of the Nutrient Film Technique. Dry matter production appears to increase with root temperature up an optimum for young plants at about 30^{o}C, with the optimum decreasing with plant age (Hussey, 1965). Other workers have examined the benefits of root zone warming on outdoor crops by the use of polythene mulches (Vandenburg and Tiessen, 1972). Leaf area is increased by growing plants in a higher root temperature, unless light is low (Gosselin and Trudel, 1984). Shoot growth is more enhanced by root temperature than is root growth, although this response is dependent on the nutrition the plant is receiving (Gosselin and Trudel, 1984).

1.1.2 GROWTH FORMS

1.1.2.1 INDETERMINATE

Indeterminate plants, if not subjected to any form of training, are characterized by large sprawling bushes, which continue to grow and spread as long as the plant is still alive. Each leader of the indeterminate plant actually consists of a series of lateral shoots that normally produce three leaves, or more rarely four leaves, and a terminal inflorescence. Extension of the leader is by the growth of the bud in the axial of the last formed leaf of the preceding shoot. As this bud grows, the inflorescence above it is pushed to one side and the main leader becomes

continuous (Silvy, 1974). This pattern is repeated indefinitely in indeterminate plants. Further branches, often called laterals, arise from the older leaf axials usually after a period of dormancy, although in commercial production these are usually "pinched" out with the result the plant appears as one main stem, which may be several meters long, carrying the inflorescences. Such plants are not suitable for mechanical harvesting.

1.1.2.2 DETERMINATE

Determinate cultivars are similar to indeterminate cultivars, although after about the fifth inflorescence the plant branches tend to terminate (Hillier, 1978). Termination is achieved by the growing point in the axial of the last formed leaf of the primary shoot, being transformed into an inflorescence without the initiation of further leaves. Strong axillary buds which develop at the base of the primary shoot, lateral buds and also higher on the shoot, undergo limited extension in a similar manner. Axillary buds on laterals and sub laterals also follow this pattern with some more strongly determinate cultivars terminating after the production of only two inflorescences per branch (Hillier, 1978). The true bush gene (sp) appeared as a spontaneous mutation in a Florida tomato field in 1914 (Malone, 1984). Lateral growth in plants with this gene terminates at the same distance from the centre of the plant and the plants are more floriferous than the normal (sp+) indeterminate plants. Determinate cultivars are invariably used for mechanical harvesting systems.

1.1.2.3 DWARF

Dwarf tomato plants are characterized by an upright growth habit, short internodes, strong stems, concentrated fruit ripening and a high harvest index (Hillier, 1978). One advantage of dwarf cultivars is that the fruit is held above the soil surface, however plants tend to lodge when fruit ripening is occurs. Fery and Janick (1970) found dwarf and miniature vine types had the greatest maturity concentration at low populations but not at high populations, when compared to indeterminate, determinate, and jointless cultivars. Another two workers Emery and Munger (1970a) showed dwarf and jointless vines yielded less than determinate and indeterminate vines at two different populations.

1.1.2.4 MINIATURE

Miniature cultivars appear to have received little attention by research workers. While plant size appears to be very small, Fery and Janick (1970) report fruit size to be as large as those of dwarf plants. Plant stature is probably too small to allow the plant to be successfully used under current agronomic practices (Hillier, 1978).

1.1.2.5 JOINTLESS

Jointless cultivars are so named because they carry a gene that is responsible for an unusual fruit separation method. In normal plants there is an abscission layer that develops in the region known as the joint, or reflexed portion of the pedicel. This abscission layer is fully developed by the time the fruit is mature, and it enables separation of the fruit with the attached pedicel base and carpel rosette (Hillier, 1978). Jointless genotypes do not develop this abscission layer to the same degree, and separation occurs above the carpel rosette. The jointless phenotype has additional leaves before the first inflorescence, with a reduced number of flowers per inflorescence on both indeterminate and determinate plants compared to jointed plants (Emery and Munger, 1970a). Determinate jointless plants have unrestricted apical growth, and in this sense are indistinguishable from indeterminate plants. Indeterminate jointless vines are distinguished further, by having a high frequency of inflorescences reverting to vegetative growing points after forming 3-4 flower buds. Fruit maturity on jointless cultivars is generally delayed because of the additional leaves before the first inflorescence (Emery and Munger, 1970a).

1.1.3 ATTRIBUTES FOR PROCESSING TOMATO VARIETIES

A large amount of breeding work has been carried out in the attempt to find the most suitable cultivar of tomato for processing. Most have been cultivars which have been bred for once-over machine harvesting. For machine harvesting, plants must be determinate, small and compact with concentrated fruit setting. During harvest the fruit should separate easily from the plant without the pedicel and calyx. The jointless pedicel gene (j-2) has been bred into many cultivars to help achieve this aim (Malone, 1984). The fruit must be firm enough to withstand mechanical handling in a ripe condition, and remain on the bush in an acceptable condition for at least four weeks, since harvesting schedules cannot be precise (Lorenzen and Hanna, 1962).

Fruits for whole peel should weigh 50-60 grams, be of pear or elongate shape for ease of packing, peel

readily, remain firm and exhibit a deep red colour after removal from the can (Malone, 1984).

Fruit for paste or pulp production should have the following processing requirements (Quinn and Crowther, 1976):

(a) a solids content of at least 5 per cent, and also a low acidity and a high sugar content;
(b) a low preparation loss (skin, fibre and seed);
(c) the resultant paste should have a flavour as near to that of the fresh fruit as possible;
(d) the strong red colour of the fruit should be retained during processing;
(e) the paste should have a good texture and consistency (high pectin content).

1.2 FLOWERING

1.2.1 FLORAL MORPHOLOGY

Inflorescence development in the tomato begins as a small bump on the shoot apex as the growing point changes from a flat to a high dome (Greyson and Sawhney, 1972). This rapidly develops into the first flower of the inflorescence, and a lateral growing point begins to grow below the first flower and forms the second flower. The inflorescence continues to develop from a series of lateral growing points until, in simple a inflorescence, seven to twelve flowers are formed.

As the floral laterals develop, the axis of the inflorescence is formed by the alignment of the basal portion of the lateral, with the youngest flowers at the far end (Lewis, 1953). A compound inflorescence is formed when the axis begins to branch, and as many as three hundred flowers may be found on a single inflorescence (Lewis, 1953).

Technically the flowers of the tomato are described as hypogynous and regular. Greyson and Sawhney (1972) found the sepal primordia are produced in a helical sequence at 135 degree intervals, followed by petal primordia and stamen primordia, also in helical sequence. At the start of growth, flower buds are enclosed inside the calyx. As growth continues the sepals separate to expose the petals, which then extend to beyond the calyx. As the petals open, the corolla changes colour from pale yellow to deep yellow. The anther cone, surrounded by style and stigma, is exposed when the petals are reflexed at full opening. When fruit set occurs the ovary and calyx remain, while the closed petals, style and stigma are all abscissed.

An abscission layer is formed between the flower and the elongated axis of the inflorescence. This is shown by a groove which runs around the pedicel. Separation of the flower at this layer may occur before or after the flower opens, and this often occurs in the

first and last formed flowers (Abdul, Canham and Harris, 1978) while the flower bud is still very small.

At any point in time an inflorescence may have small fruits, open flowers and unopened flower buds (Hayward, 1938).

1.2.2 FLOWER DEVELOPMENT

1.2.2.1 FLOWER INITIATION

Hurd and Cooper (1970) showed that flower initiation starts in many tomato cultivars within three weeks of cotyledon expansion, as the third oldest leaf reaches a length of just over 10mm. However, until a period of nine days has passed after cotyledon expansion, both the timing of initiation and the stage of growth at which initiation occurs may be influenced by the environment in which the developing seedling is placed (Lewis, 1953).

Environmental factors which influence the initiation of flowers during this early period of seedling growth include temperature, diurnal temperature, irradiance, photoperiod and carbon dioxide concentration. Combinations of these factors also have differing effects on flower initiation. Nearly all of the research work carried out in this area has been concerned with indeterminate type tomatoes, and it can only be presumed that determinant tomatoes behave in a similar manner.

i) Temperature

Calvert (1959), using tomatoes grown in growth cabinets, demonstrated that plants grown at 15^{o}C initiated flowers up to 13 days earlier than those grown at 25^{o}C. He also found with plants grown at 15^{o}C produced eight leaves before the inflorescence, whereas those grown at 27^{o}C produced 14 leaves. While leaf temperature appears to influence flower initiation, raising root temperature has no effect (Phatak, Wittwer and Teubner, 1966).

In a later experiment, Calvert (1964), working with an indeterminate cultivar Ailsa Craig, demonstrated that when the initiation of the first inflorescence was accelerated by low temperature, there was a delay in the initiation of the second inflorescence. Leaf number was also compensated for, as while there were less leaves below the first inflorescence, there was an increase in the number of leaves between the first and second inflorescences.

ii)Diurnal Temperature

Calvert (1957) suggested that the mean of the day and night temperatures, over a period of 24 hours, determines the number of leaves preceding the first inflorescence, and that therefore high day temperatures can compensate for low night temperatures. Lewis (1953) reached a similar conclusion. This effect occurred during the period beginning at cotyledon expansion, and ending approximately nine days later, with the number of leaves minimized with low temperature, and maximized with high temperature. Commercial greenhouse tomato growers have recognised this factor by having day/night temperature changes in the greenhouse with resultant savings in fuel.

iii)Irradiance

Many workers have demonstrated the effects of low irradiation during seedling growth on inflorescence initiation (Calvert, 1959; Wittwer, 1963). Again using growth rooms, Calvert (1959) showed that reducing the illuminance level from 10000 to 2500 lux, delayed flower initiation by up to 29 days and allowed up to approximately seven more leaves to be produced before the inflorescence was initiated. Light effects were more marked at high temperature (25^{o}C) than low temperature (15^{o}C).

Hussey (1963) found the rate of leaf initiation prior to inflorescence initiation, is increased by decreases in irradiance and by increases in temperature. Plants grown under differing combinations of irradiance and temperature can therefore exhibit the same ratios of leaves to flowers.

iv)Photoperiod

The effects of photoperiod in promoting flower initiation appear to be fairly minor. Wittwer (1963) found the effect of extending the day by the use of low intensity artificial lighting from incandescent lamps, was to increase the number of leaves below the first inflorescence, but however, these effects were only found in plants grown at 18^{o}C and not at 13^{o}C. In studying the effects of short-day treatment on tomato flower initiation, Aung (1976) showed that the advancement in time of flower opening due to short-days, was associated with a small reduction in the number of leaves formed below the first inflorescence. Hurd (1973) demonstrated that plants grown in short days initiated inflorescences after producing one or two fewer leaves than plants grown in long days, although growth in dry weight and in leaf area was markedly lower in the short-day treatment.

v)Carbon Dioxide

An advancement of the date of anthesis in the first inflorescence by as much as seven days, may occur

in response to carbon dioxide enrichment of the atmosphere to 800-2000 ppm. (Wittwer and Rob, 1964). However, there is no evidence to suggest that carbon dioxide enrichment also acts to reduce the interval between the development of successive inflorescences higher on the plant.

1.2.2.2 DEVELOPMENT

Temperature appears to be the major factor in controlling the rate of development of flowers after they are initiated. Calvert (1964) showed that flowers developed more rapidly at a mean air temperatures of 20°C than at 16°C, with an advance of up to 12 days recorded for the first anthesis in the first inflorescence. Earlier flowering was also promoted in the second inflorescence. Other workers (Hurd and Cooper; 1967,1970) found that tomato plants grown at low temperature (10°C) for 14 days after the initiation of the first inflorescence, retarded flower development. Flower opening was up to 18 days later than in plants grown for a corresponding period at 15°C. Day, rather than night temperatures, are more important in promoting flower development (Lake, 1967).

Floral morphology is also affected by temperature. Numbers of parts of the flowers are generally increased with reductions in temperature (Sawhney, 1983). Flower abscission increases with high temperatures, although this may be as a result of failure to set fruit rather than as a result of the temperature alone (Levy, Rabinowitch and Kedar, 1978).

Abortion of flower buds is likely to increase under conditions of high temperature. The limiting factor appears to be an insufficiency of enough carbohydrates to meet the demands of the young plant. Calvert (1969) grew tomato plants in growth rooms, and found flower abortion was greatest when a high temperature-low light regime was applied from the time of macroscopic bud visibility. The sensitive stage from the first inflorescence continued for 10-15 days. However, high temperatures applied at an earlier stage in the life of the plants reduced the incidence of flower abortion, probably as a result of increasing the leaf area.

Kinet (1977) found increases in daily irradiance-time integrals reduced the incidence of flower bud abortion. He also found that in plants given the same daily radiant exposure, the incidence of flower abortion was greater in those grown in long days than in short days.

Carbon dioxide enrichment, often practiced by commercial greenhouse tomato growers, and its effect on flower abortion was examined by Calvert and Slack (1975). These workers found 53% flower abortion at ambient levels, 26% at 600 ppm., 15% at 1000 ppm. and 11% at 1400 ppm., clearly demonstrating the advantages of this practice.

1.2.3 FLOWERING PATTERN AND THE EFFECTS OF THE SOURCE SINK RELATIONSHIPS

Lewis (1953) concludes that there are three main factors affecting the size of the inflorescence in tomatoes; (1) a major gene, (2) a system of polygenes, (3) the environment. During the period of approximately 9-23 days after cotyledon expansion, the tomato seedling becomes sensitive to environmental effects for the number of flowers in the first inflorescence (Calvert, 1957,1964). Using indeterminate tomato cultivars, Calvert found the sensitivity for the number of flowers on higher trusses occurred at weekly or longer intervals, depending on the cultivar and presumably the growth rate. Lewis (1953) concluded that treatments given from the time of cotyledon expansion to the emergence of the first inflorescence, have an effect which may last until the fifth inflorescence.

Many workers have examined the effect of temperature and light on branching of the inflorescence during its initiation. Lewis (1953) found low temperature of 14^{o}C from expansion of the cotyledons to the appearance of the first inflorescence, caused an increase in flower production as compared to plants raised at 25-30^{o}C. Calvert (1959) showed that plants initiated up to eight more flowers per inflorescence when grown at 13^{o}C than at 18^{o}C, with the effect increasing at higher irradiances. Aung (1976) showed that plants grown at 16^{o}C produced up to four more flowers per inflorescence than those grown at 24^{o}C and up to eight fewer than those grown at 13^{o}C. The overall effect of low air temperatures on flowering and yield of tomatoes is large, and can not be offset by increasing root temperatures (Papadopoulos and Tiessen, 1983).

When growing tomato crops carrying only the first inflorescence, Hurd and Cooper (1967) found there was an interaction between irradiance and temperature on flowering. In conditions of high irradiance a reduction in temperature from 15^{o}C to 10^{o}C doubled the number of flowers formed and caused branching of the inflorescence, but when irradiances were low the effect of temperature was much reduced. As found by Calvert (1964), the mean diurnal temperature appeared to be more important in the control of branching and flower numbers, rather than day or night temperature alone.

Other workers have studied the effect of cooling the root system, rather than the shoot, on flowering. Phatak, Wittwer and Teubner (1966) found root cooling increased flower number, and concluded that while shoot temperature may affect flower number by influencing branching of the inflorescence, root cooling influences the number of flowers on a simple inflorescence.

Neither photoperiod (Hurd, 1973) nor carbon dioxide levels (Hurd, 1968) appear to influence the number of flowers formed.

There is plenty of evidence to show that flowering is influenced by both the vegetative and reproductive parts of the shoot system, in a complex source/ sink relationship. Where light was limiting growth, Lake (1967) showed that the development of flowers in the first inflorescence could be promoted by removal of the growing tip. Murneek (1926) noted that the presence of fruits on a plant could lead to a decrease in inflorescence size and abortion of the flower buds. Floral development is promoted by the removal of axillary shoots or young developing leaves (Leopold and Lam, 1960; Hartmann, 1978). Russel and Morris (1982) concluded that the inflorescence was in competition with the shoot tip when assimilates were in short supply. Further evidence of this competition is provided by Hussey (1963). By removing the first two true leaves, Hussey showed initiation of the inflorescence was hastened in seedlings grown in low light and high temperature. He concluded that the initiation of the inflorescence depended on the supply of assimilates to the apex, and that high temperatures acted to divert assimilates away from the apex towards the developing leaves.

Other workers have suggested that young leaves may affect flowering by the production of plant growth regulators, as well as competing for assimilates (Leopold and Lam, 1960; Abdul and Harris, 1978).

Removal of expanded cotyledons from tomato seedlings may delay the initiation of the first inflorescence (Hussey, 1963), while removal of expanded foliage leaves may inhibit development of the individual flowers and induce flower abortion (Russel and Morris, 1982).

While the effects of removing roots on flowering has been studied by several workers, it is difficult to conclude as to whether the effects are as a result of the root removal, or from the resultant effects of root removal on shoot growth. An example of the confusion caused by this, is that while Cooper and Hurd (1968) found roots were in competition with inflorescences for assimilates, Cooper (1971) observed no effect of root pruning on inflorescence development.

1.2.4 THE INFLUENCE OF CULTURAL FACTORS ON FLOWERING, FRUIT SET AND YIELD

1.2.4.1 PLANT SPACING

The effects of increasing plant population to a level where individual plants are competing for nutrients, light and air, is to reduce the yield per plant, resulting from fewer fruit set per plant (Vittum and Tapley, 1957). This effect in turn has been shown to be a result of fewer flower trusses, less flowers on a truss and a lower fruit set (Reeve and Schmidt, 1952; Zahara and Timm, 1973; Fery and Janick, 1970). There

is also a trend towards smaller fruit size with closer spacing (Reeve and Schmidt, 1952; Nicklow and Downes, 1971).

Fery and Janick (1970) grew several different vine types at varying populations, and concluded that as interplant competition increases, intraplant competition becomes more important, until eventually only flowers on the earliest trusses are able to set fruit. This results in a concentrated yield. The experiment clearly demonstrated that regardless of vine type, there was an asymptotic relationship between population and total fruit yield.

1.2.4.2 IRRIGATION

The effects of water stress appear to vary according to the time, severity and duration of the stress, and also with other environmental factors. Conditions of favourable light, reduced water supply, or increasing salinity, will result in retarded flower development (Gates, 1955; Dumbroff and Cooper, 1974). Where light conditions are not so favourable, water stress may promote floral development (Klapwijk and de Lint, 1974; Cooper, Hurd and Gisbourne, 1966).

Rudich, Zamski and Regev (1977) carried out an extensive study into the effects of drip irrigation on the yield and quality of the processing tomato cultivar VF 317. Using a plant population of 60,000 plants ha^{-1}, these workers divided the growing season into five stages;

A = Period of germination, emergence and establishment of plants
B = Stage of vegetative growth, from thinning to the beginning of flowering
C = Stage of flowering, fruit set and the beginning of fruit development
D = From the end of stage C until approximately 20% of the fruit begins to change colour
E = Stage of fruit ripening

Flowering was not affected by irrigation in stage B, and this is further supported by Salter (1958), who found yield was decreased if water was applied before fruiting. Irrigation applied in stage C resulted in very vigorous vegetative growth, and an increase in fruit set. Highest yields resulted from irrigation in both C and D stages.

Other effects of irrigation may include a reduction in the incidence of blossom end rot in susceptible cultivars (Tan and Dhanvantari, 1985). Moore, Kattan and Fleming (1958) found that tomato fruit firmness was reduced by high fertilizer and irrigation levels.

In a later experiment Rudick (1979) examined the interaction of phosphorus fertilizer and soil mulching

with polythene. The number of flowers per plant in mulched and phosphorus-fertilized plots, was double that of unfertilized plots, resulting in a much higher yield. As the plants were unirrigated, it was concluded that the result was obtained because of higher moisture levels allowing the plant to utilise the phosphorus fertilizer.

1.2.4.3 FERTILIZER

Flower initiation is shown to be delayed when nitrogen, phosphorus and potassium are in short supply (Takahashi, Eguchi and Yoneda, 1973), however this may have been as a result of a retardation of the growth and development of the whole plant rather than specific effects on flowering. Research work into the effects of applied nitrogen levels on flowering are confusing. Fisher (1969) found no effect of differing nitrogen levels on flower initiation in plants grown at low light levels, and at a minimum temperature of 15.5^{o}C. However the same worker observed that low levels of nitrogen in solution culture, resulted in delayed opening of the flowers. Previously however, Wittwer and Teubner (1957) found that a reduction in nitrogen supply resulted in the formation of one or more leaves before the first inflorescence was initiated at temperatures between 18-21^{o}C but not at 10-13^{o}C. They also found that increases in nitrogen supply can produce increases in the number of flowers in the first inflorescence, and in the lower temperature range. Ryan, Smillie and McAleese (1972) observed a decrease in the number of flowers in the first inflorescence due to the application of nitrogenous fertilizers in the glasshouse during the winter. These workers correspondingly found an increase in flower number when the supply of potassium was increased. Other workers (Lambeth, 1948; Wilcox, 1964) have found increasing N reduced early yield or delayed anthesis. Nichols, Nonnecke and Phatak (1973) found a reduced concentration of harvest in determinate tomatoes outdoors, after N,P and K were applied at high plant populations, a conclusion which is supported by earlier work by Nicklow and Downes (1971). Under some conditions, a shortage of nitrogen can result in an increase in the incidence of flower abscission. Retarded flowering and abortion of flowers can be caused by low levels of potassium or phosphorus (Besford and Maw, 1975; Menary and van Staden, 1976).

The size of the inflorescence and the number of flowers may be reduced when seedlings are raised in small pots (Cooper and Hurd, 1968; Morgan and Clarke, 1975), probably as a result of the restriction of water or nutrient supply.

1.2.4.4 PLANT GROWTH REGULATORS

The application and effects of plant growth regulators on tomato plants has received a large amount of attention by researchers throughout the world. Many diverse chemicals have been applied with differing effects recorded. In interpreting the effects of growth regulators on flowering, it is often difficult to distinguish between direct action of the chemical at the site of flowering, and correlative effects of growth responses occurring elsewhere in the plant.

The application of GA3 to young seedlings appears to have varying results depending on the amount and method of application. Brown, Jackson and Burlingham (1968) found that treatment of plants with GA3 could produce an increase, or decrease in the time between flower bud appearance and fruit set. Opening of the first flower may be unaffected, retarded, or promoted by application of GA3, depending on the genotype of the tomato and the experimental conditions. An increase in the number of leaves formed below the first inflorescence may result from application of GA3 to young seedlings (Wittwer and Tolbert, 1960; Aung and Austin, 1970). The general effect of GA3 is to reduce the number of flowers formed on the inflorescence, but this however varies greatly with the cultivar and amount of growth regulator applied.

GA3 is also important in controlling the growth and development of floral organs. In growing mutant forms of tomato plants Phatak, Wittwer and Teubner (1966) demonstrated that application of GA3 can promote stamen development similar to that occurring in normal forms. The role of gibberellins in controlling flower abortion is conflicting, as both decreases and increases in the incidence of abortion have been reported after application of these growth substances (Kinnet, 1977; Brown, Jackson and Burlingham, 1968). Sawhney (1984) concluded that the type of tomato fruit produced following GA application is dependent on the timing of the treatment, the amount and kind of GA applied, and the cultivar under investigation.

The growth retardant chlormequat chloride, when applied to young tomato plants, can decrease the number of leaves formed below the first inflorescence (Wittwer and Tolbert, 1960). Used as a soil drench this chemical can also increase the number of flowers in the first inflorescence (Abdul, Canham and Harris,1978). These latter workers found chlormequat chloride less effective in increasing flower numbers if plants also received an application of GA3, and hypothesized that the chemical increased flower number by inhibiting the synthesis of endogenous gibberellins. This chemical is effective in promoting the growth of individual flowers and reducing flower abortion under adverse light conditions (Nourai and Harris, 1983). These workers suggested that abortion of the flower buds occurred when vegetative parts of the shoot system

were in competition with the inflorescence for metabolites or growth substances, and that the growth retardant acted to reduce or remove this competition. Read and Fieldhouse (1970) observed a greater concentration of harvest by using Alar as a flower "cut off" spray after desired fruit set had been achieved.

Cytokinins and auxins will both increase inflorescence size (Menary and van Staden, 1976). Kinetin supplied to the roots of tomato seedlings grown in solution, delayed flowering and increased the number of leaves formed below the first inflorescence (Menary and van Staden, 1976).

Indeterminate and determinate type tomatoes have been shown to behave in different ways when treated with the same chemical. Abdul, Canham and Harris (1978) found no flowering response to the application of daminozide (Alar) when working with an indeterminate type tomato, while Read and Fieldhouse (1970) showed the same chemical applied in the same manner promoted branching of the inflorescences and increased flower number per inflorescence in determinate cultivars of tomato.

When growing indeterminate type tomatoes there may be and advantage in promoting abscission of flowers and flower buds with a view to limiting the number of fruit formed, and hence increasing the fruit size (Velaith and Ferguson, 1973). The flowers produced late in the season often do not have adequate time to develop into marketable fruit, and so the removal of these flowers will ensure less immature fruit. Growth regulators which show activity as deblossoming agents include ethephon, daminozide and sodium 2,3-dichloroisobutyrate-N-dimethylamino succinamic acid (Velaith and Ferguson, 1973)

1.3 FRUIT DEVELOPMENT

1.3.1 FRUIT SETTING

The term fruit set can be defined as "to denote the proportion of flowers which appear to reach anthesis normally, and which subsequently set fruit of a marketable size" (Picken, 1984).

Nearly all modern tomato cultivars are self-pollinated and generally the mature pollen is ready for transfer at the time of anthesis. The stigma is receptive from about two days earlier and remains so for up to 4 days or more (Smith, 1935). Fertilization of the ovules marks the inception of fruit growth for seeded tomato fruit. In practice, fruit set is not considered a great problem in field grown tomatoes, although high temperature at night (>26^{o}C) or during the day (>40^{o}C) and low temperatures (<10^{o}C) at night are most damaging (Ho and Hewitt, 1986). Fruit set in greenhouse grown tomatoes can often be difficult,

especially under low light and temperature conditions experienced during the winter months in many countries and artificial aids are sometimes used in these situations.

1.3.1.1 POLLINATION

The quantity off viable pollen formed is the most important criterion in pollen production (Picken, 1984). Low light levels, as can be experienced in winter greenhouse production, will adversely effect the development of pollen as a result of carbohydrate stress (Howlett, 1936). Pollen production is also influenced by temperature. High temperatures (40oC) and low temperatures (10oC) will both affect production and viability of pollen (Picken, 1984). Pollination is achieved when the anthers dehisce and allow several hundred pollen grains to fall on to the stigma. Successful transfer of pollen grains to the stigma is dependent on the length of the style, which for self pollination must lie within the tip of the anther cone. The length of the style is controlled genetically (Rick and Dempsey, 1969) and also by the environment (Rudich, Zamski and Regev, 1977), and either poor light or high temperature may cause excessive length of the style. Adherence of the pollen on the style may be reduced if the relative humidity is below 70% or temperature is outside the range 17-24oC (van Ravestijn, 1970).

The successful growth of the pollen tube to the ovules and the number of germinating pollen grains determines the number of fertilized ovules. The degree of germination and the growth rate of the pollen tube increases with temperature between 10^{o}C and 35^{o}C, but is reduced outside this range (Dempsey, 1970).

1.3.1.2 FERTILIZATION

Fertilization occurs when nuclei from pollen tubes penetrate viable ovules. Exposure to high temperature can have adverse effects on fertilization or on the processes which immediately precede or follow it (Picken, 1984). The main effects of temperature are on the speed at which fertilization occurs. There appears to be little information on the effects of light on fertilization in the tomato.

1.3.1.3 PARTHENOCARPIC FRUIT FORMATION

Parthenocarpy in tomatoes is well reported, and denotes the seedless condition in fruits. Parthenocarpy may be natural or artificially induced. Natural parthenocarpy can be as a result of genetic control or may be as a result of environmental conditions. Artificial parthenocarpy occurs as a

result of application of pollen extracts or various chemicals including growth regulators (George, Scott and Splittstoesser, 1984)

The degree to which natural parthenocarpy is expressed often depends on an interaction between the environment and genotype. Factors such as low temperature (Foster and Tatman, 1937), daylength, light intensity and quality, temperature-light interactions (Osborne and Went, 1953) influence natural parthenocarpy.

Application of chemicals to induce fruit set are often made in greenhouse culture and also less frequently outdoors. Auxins have been regularly found to cause parthenocarpy (Gustafson, 1937), as has application of gibberellic acid to the flowers (Wittwer et al, 1957). Commonly used growth regulators and their application rates are summarized by Ho and Hewitt (1986).

There are problems associated with parthenocarpic fruit set however. Fruit abnormalities such as malformations, puffiness and hollowness have all been reported with parthenocarpic fruit setting (Rylski, 1979). Fruit size is also influenced (Davis et al, 1965b), although this effect appears to be dependent on the environment (Dempsey and Boynton, 1965). A positive result of parthenocarpy in tomato is sometimes an increase in percent soluble solids (Falavigna, Baino and Soressi, 1978).

1.3.2 FRUIT DEVELOPMENT

1.3.2.1 GROWTH RATE

The cumulative growth rate during fruit development can be described by a sigmoid curve, which can be divided into three periods (Ho and Hewitt, 1986).

Period 1; Slow growth for 2-3 weeks when the gain of fruit weight is less than 10% of the final weight. This growth results mainly from cell division and some initial cell enlargement.

Period 2; Rapid growth for 3-5 weeks. This means that most of the fruit weight is accumulated by the mature green stage. This growth results from cell enlargement only.

Period 3; Slow growth for 2 weeks when there is little gain in fruit weight but in which intensive metabolic changes take place.

Rate of fruit growth is affected by temperature as respiration, starch synthesis and assimilate import are all temperature dependent (Walker and Ho, 1977).

The final fruit size is influenced by the number of seeds, with seed number and fruit weight directly correlated within a cultivar (Dempsey and Boynton, 1965). However, the relationship is different among trusses of the same crop, or under different growing conditions (Rylski, 1979). The precise role of seeds in the initiation and control of fruit growth in the tomato has not been determined, although it has been suggested that they may be sources of auxin which stimulate fruit swelling (Ho and Hewitt, 1986).

Fruit size is also influenced by the amount of solar radiation received (Ho and Hewitt, 1986)and also by CO_2 enrichment in the greenhouse (Davies and Windsor, 1967). Water stress results in smaller fruit, mainly as a result of a shorter fruit growth period (Salter, 1958). Manipulation of fruit size can be achieved by controlling the electrical conductivity of nutrient solutions in nutrient film technique growing (Ho and Hewitt, 1986).

1.3.2.2 SOURCE/SINK RELATIONSHIPS

The demand and supply of assimilate in the tomato plant is complex. At the time that the first inflorescence begins to flower, the stem is supplied by the upper leaves, the apex by the basal leaves, and the roots by the middle leaves. Interestingly, the inflorescence only attracts a small amount of assimilate supplied by the leaves adjacent to the inflorescence, and on the same side of the stem (Russel and Morris, 1983). When three fruiting trusses are growing rapidly, they are the biggest sinks and are supplied by the middle leaves, the apex by the upper leaves and the roots by the lower leaves (Khan and Sagar, 1969). When the plant has many trusses, supply becomes localized, although there is a considerable degree of overlap. A truss is supplied by at least 12 leaves immediately above and below it, but mainly by the three subtended leaves (Khan and Sagar, 1969).

As the inflorescence develops, the competition between reproductive and vegetative organs changes. Initially the apex is the stronger sink, and in conditions of low light the inflorescence may abort (Cooper, 1964). As suppliers of assimilates for the first flowering truss also supply the roots and leaves, there is considerable competition between these organs. Treatments such as removal of young leaves at the apex (Leopold and Lam, 1960) or root restriction (Cooper, 1964) will therefore result in a reduction of flower abortion. The side shoot below the inflorescence will also compete with the flower truss for assimilates and therefore its removal can improve fruit set (Ho and Hewitt, 1986). Since the truss becomes a stronger sink as the fruit develop, a heavy fruit load can even result in root death (Ho and Hewitt, 1986). The method of control for the partitioning of assimilates between

vegetative and reproductive organs is unknown, but is thought by some authors to be under the influence of plant hormones (Ho, Sjut and Hoad, 1982).

Both temperature and light have major influences on the competition between vegetative and reproductive parts of the tomato plant. When the supply of assimilates is limiting, such as under conditions of low light, the initiating truss (weak sink) and flowering truss (moderate sink) will have less call on the assimilates than the new leaves (strong sinks) (Kinet, 1977). This may result in flower abortion although this effect can be alleviated by supplying CO_2 during winter in the greenhouse (Cooper and Hurd, 1968). Temperature can have large effects on the partitioning of assimilates. With the same day temperature (18^{o}C) Yoshioka and Takahashi (1981) found that low night temperature (8^{o}C) enhanced import of assimilates by the stem and roots, while high night temperatures (18^{o}C) enhanced import by the fruit.

The influence of water on vegetative and reproductive growth is well known by commercial greenhouse tomato growers. Earlier and better fruit set can be achieved in winter greenhouse growing by reduced watering. On a more scientific basis Cooper and Hurd (1968) found water stress restricted vegetative growth and encouraged reproductive growth.

Competition between trusses on the same plant is well reported. Hurd, Gay and Mountifield (1979) demonstrated suppression of later trusses by fruiting trusses can be prevented by removal of two thirds of flowers from all trusses. Slack and Calvert (1977) found if a truss is removed from any position on the plant, compensating growth will be found in the other trusses on the plant, with total fruit yield being up to 92% of yield had the truss not been removed.

Differential growth of tomato fruits on the same truss may be as a result of competitive effects between fruits (Ho and Hewitt, 1986). Proximal fruit on a truss have a higher rate of starch accumulation and reach a larger size than those in distal positions if assimilate supply is adequate (Ho and Hewitt, 1986). Proximal fruit may have a higher potential growth strength which is possibly determined before fruit set, and fruit set later may fail to grow if there is already a heavy load on the truss. It is possible for distal fruit to grow to the same size or bigger if distal fruit are set artificially at the same time, or even before the proximal one (Bangerth and Ho, 1984). Early set fruit may compete better than a later set one because of its bigger size, or because it suppresses the growth of the later set fruit by producing inhibitors (Bangerth and Ho, 1984).

1.3.2.3 CHEMICAL CHANGES

As the fruit grows there is an increasing amount of water accumulated, until 20 days after fertilisation the dry matter is reduced to 5-7%, at which level it remains until harvest (Gustafson, 1926). Carbon content of the dry matter remains at a level of about 39% throughout development of the fruit. The levels of nitrogen and phosporus reduce slightly while the level of potassium remains constant (Ho and Hewitt, 1986).

Glucose and fructose account for half the dry matter of a ripe tomato and 1.7 to 4% of the fresh weight, depending on the cultivar (Ho and Hewitt, 1986). The sugars arrive at these levels after being at about 2% of fresh weight at two weeks after fertilisation. Sucrose, which is the major imported assimilate, remains at a low level throughout fruit development (Walker and Ho, 1977).

Starch is accumulated during the period of rapid growth and accounts for as much as 30% of the daily accumulated dry matter at day 20 after anthesis (Walker and Ho, 1977). Starch starts to breakdown when the fruit absolute growth reaches its maximum, and the starch content is about 1% dry matter at the mature green stage. Since the breakdown of starch is associated with a rapid accumulation of reducing sugars, there is a high correlation between the starch content in green fruits and the total soluble solids contents of ripe fruits among cultivars (Dinar and Stevens, 1981).

Organic acids such as citric and malic acid increase during fruit development with the sap of a mature green fruit having a pH of 4 (Ho and Hewitt, 1986).

1.3.3 FRUIT RIPENING

1.3.3.1 PHYSIOLOGY

Ripening is dependent on a wide range of separate synthetic as well as degenerative reactions (Grierson and Kader, 1986). The coordination of ripening appears to be under the control of plant hormones, but is influenced by genetic and environmental factors.

The changes in fruit composition which occur during ripening are summarized in Table I.

Degradation of starch, and production of glucose and fructose
Loss of chlorophyll
Synthesis of pigments such as B-carotene and lycopene
Increase in soluble pectins resulting from wall softening and degradation
Production of flavour and aroma compounds
Increase in the ratio of citric acid to malic acid
Increase in glutamic acid
Breakdown of toxic alkaloids

Table I Changes in Composition During Ripening (Grierson and Kader, 1986)

Tomato fruit is considered to be a climateric fruit in that, at the onset of ripening, respiration increases, rises to a maximum which is named the climacteric peak, and subsequently declines slowly (Grierson and Kader, 1986). The increase in respiration is associated with an increase in the production of CO_2 and also ethylene.

1.3.3.2 ETHYLENE PRODUCTION AND APPLICATION

Ethylene synthesis first occurs in the vicinity of the seeds when the fruit begins to ripen. It then diffuses through intercellular spaces and induces other cells to begin ethylene production (Grierson and Kader, 1986). Ethylene synthesis is important as it stimulate the cells to undergo other physiological and biochemical changes required for ripening. The mechanism by which it does this is unknown, however Grierson and Kader (1986) support the theory that there are specific ethylene binding sites which, in the presence of ethylene, stimulate a coupling reaction that alters the activity of biochemical pathways required for ripening.

The application of ethylene generating compounds such as ethephon (2 chloroethyl phosphonic acid) to stimulate ripening has received a lot of attention by research workers and is regularly practiced by commercial tomato growers. When ethephon is applied to plant tissue, it breaks down to liberate ethylene

(Baqar, Edwards and Lee, 1975). Russo, Dostal and Leopold (1968) were the first to show that ethephon could advance the ripening of tomato fruit, which was quickly confirmed by field experiments of Robinson, Wilczynski and Dennis (1968). Since then many other workers have demonstrated the effectiveness of ethephon treatment in increasing the quantity of usable fruit for a single destructive machine harvest (Baqar , Edwards and Lee, 1975; Mutton, 1978). Ethephon application appears not to affect soluble solids or titratable acids (Splittstoesser and Vandemark, 1971).

Recommendations for the time to apply chlorethephon vary. This is because the ideal time to apply chlorethephon is dependent on the cultivar, plant density, concentration of flower set, and climatic conditions. Sims et al, (1979) indicate that if red and pink fruit (including breakers) are running 5 to 15% of the total fruit in the field and the mature greens are running 50 to 65%, ethephon should be applied. These researchers also report that chlorethephon does not affect the pink and red fruit present at treatment time but does cause a higher percentage of immature green fruit to reach the mature green stage sooner. Other workers recommend chlorethephon be applied when approximately 25-30 % of the fruit are 'usable' (Baqar , Edwards and Lee, 1975; Dostal and Wilcox, 1971; Bussel and Dallenger, 1972). Current practice in New Zealand is to apply chlorethephon, if required, when approximately 15-20% of the fruit is in the coloured or red grades (O'Connor, 1987).

The results of Mutton (1978) and Bussel (1973) indicate that moisture levels in the soil at the time of treatment and after treatment are responsible for the variable effects often found with chlorethephon in the field situation.

It is also possible to delay tomato ripening by inhibiting either the action or synthesis of ethylene by applying ethylene biosynthesis inhibitors (amino-oxyacetic acid and alpha-aminoisobutyric acid) (Edwards, Henderson and Saltveit, 1984). In theory it may be possible to delay tomato fruit ripening until the optimum number of mature green fruit accumulate, and then apply chlorethephon to maximize the amount of ripe fruit. In practice however these workers did not find an increase in the marketable yield when a process tomato crop was exposed to this procedure.

1.3.4 FRUIT QUALITY FOR PROCESSING

1.3.4.1 GRADES

Since colour is usually an indicator of tomato ripeness, there have been several subjective rating scales and colour charts which have been developed for classifying ripeness stages of fresh market tomatoes. Most authors dealing with tomatoes made their own classifications of these colour changes, distinguishing from four to fifteen different stages. An experiment carried out by Stenvers and Stork (1976) showed that the changes in colour associated with ripening correspond closely with changes in softness, specific gravity, internal ethylene concentration and respiration. These classifications are equally applicable to processing tomatoes. The United States Department of Agricultural Standard chart is shown in Tables II and III (USDA, 1976).

Score	Class	Description
1	Green	Entirely light to dark green, but mature.
2	Breaker	First appearance of external pink, red or tannish yellow colour; not more than 10%
3	Turning	Over 10% but not more than 30% red, pink or tannish yellow
4	Pink	Over 30% but not more than 60% pinkish or red
5	Light red	Over 60% but not more than 90% red
6	Red	Over 90% red;desirable table ripeness

Table II. Ripeness Classes of Tomatoes

Green fruit may be further devided into various maturity classes as shown in Table III.

Score	Class	Description Based on Internal Examination	Average Number of Days to reach the breaker stage at 20°C
1	Immature Green (Grass Green)	No jelly-like material in any of the locules; seed are cut by a sharp knife upon slicing the fruit	>10
2	Partially mature green	Jelly like material formed in at least one, but in less than all locules;seeds are well developed	>5 to 10
3	Typical mature green	Jelly like matrix in all locules: seeds are not cut by a sharp knife upon slicing the fruit	>1 to 5
4	Advanced mature green	Typical mature green with some internal red colouration	1

Table III. Maturity Classes of Green Tomatoes

1.3.4.2 FIRMNESS

One of the more important criteria for processing tomato fruit is firmness (Malone, 1984). Firmness is especially important in the modern-day processing tomato industry with machine harvesting, and the effect of crushing from the large amount of fruit which is carried on bulk transporters from the field to the factory. Without firm fruit, losses of fresh weight would be very high during both harvesting and transporting.

Evaluation of tomato firmness can be destructive or non-destructive. Non-destructive determination of fruit firmness is achieved by the use of instruments which measure the resistance of the fruit to deformation force (Kader, Morris and Chen, 1978). Destructive evaluation involves the use of penetrometers (pressure testers), shear presses and cutting instruments. Hamson (1953) describes a pressure tester used to measure firmness in tomatoes. He found the results from such an instrument were not dependent on the diameter of the tomato but were related to the pectin content of the fruit, which was also confirmed by Mohamed, El Sayed and Erickson (1966). While fruit firmness appears to be mainly under genetic control, there is also some degree of influence from environmental conditions under which the fruit is grown (Tomes, 1963).

1.3.4.3 SOLUBLE SOLIDS

Soluble solids content of tomato fruit is determined by measuring the refractive index of the juice, and expressing the answer in terms of percent sucrose (Burgmans and Lill, 1985). This is misleading because other compounds such as organic acids, soluble pectins and salts contribute to the refractive index, and often the soluble sugar (sucrose, fructose and glucose) content is much less than the soluble solids content. Soluble solids percentage is also described as Degrees Brix, which again gives percent sucrose however free sugars represent more than 60% of the soluble solids in tomatoes (Salunkhe, Jadhav and Yu, 1974). In general, the sugar content, and therefore percent soluble solid content of tomato fruit is a function of the stage of maturity. It increases uniformly from small and green mature to large and red ripe tomatoes (Salunkhe, Jadhav and Yu, 1974), although other workers found little change in percent soluble solids after the pink ripe stage (Hanna, 1961; Liu and Luh, 1977). There appears to be considerable variation in % soluble solids within a cultivar and between cultivars (Hanna, 1961). For processing, a soluble solids content of at least 5% is required (Quinn and Crowther, 1976). Tomatoes of higher solids give a

higher case yield per ton of tomatoes (Salunkhe, Jadhav and Yu, 1974) and is therefore of interest to processing companies. There are several factors which can cause changes in soluble solids contents of tomatoes, such as the varietal characteristics, spacing between plants, the number of fruit per plant, the level of fertilizer used, irrigation, horticultural practices, availability of light, soil properties and day and night temperatures in the tomato field (Liu and Luh, 1977).

The negative correlation between water consumption and % soluble solids has been shown by several workers (Moore, Kattan and Fleming, 1958; Wight et al, 1962; Rudick et al, 1977; Williams and Sistrunk, 1979), although this effect appears to be cultivar dependent. There is no clear physiological explanation for this relationship (Amble and Sinnadurai, 1977), although inhibition of fruit growth without any decline in the synthesis and transport of assimilates may be the cause of an accumulation of assimilates in the fruit. Hewitt, Dinar and Stevens (1982) indicate that the accumulation of glucose and fructose in the fruit may be as a result of osmotic adjustment.

Stevens and Rudich (1978) reported that soluble solids content is inversely correlated with yield, and attributed this relationship to the inability of leaves to produce sufficient photosynthate to maintain high yield and high fruit solids. Hewitt and Stevens (1981) found, when studying two determinant tomato cultivars, increasing solids levels in tomato fruits with increasing leaf area. This was consistent with earlier results of Davies, Massey and Windsor (1958); MacGillivray, (1960); Emery and Munger (1970b); Zahara and Timm (1973) and Fisher (1975). Conversely soluble solids in fruit can be reduced progressively with increases in defoliation of leaves (Wolk, Kretchman and Ortega, 1983). Later work by Hewitt, Dinar and Stevens (1982), also working with determinate tomatoes, suggests that fruits of some cultivars may have a greater sink strength than fruit of other cultivars resulting in higher % soluble solids. This has implications in process tomato breeding as while large leaf areas are undesirable as it is often associated with scattered fruit set (Hewitt and Stevens, 1981), high soluble solids are required.

In general, the levels of the major nutrients have little effect on the sugar content and therefore % soluble solids of tomato fruit, but high nitrogen fertilization does appear to have an adverse effect (Hobson and Davies, 1971).

Soluble solids are strongly influenced by the solar radiation received acting on the supply of leaf assimilates. Fruit from countries with high solar radiation have a higher sugar content than those from the United Kingdom (Winsor and Adams, 1976).

1.3.4.4 VINE STORAGE

There is little published work on the ability of processing tomato fruit to withstand decay if left on the plant after ripening. Rick (1978) refers to processing cultivars with "square round" shape withstanding decay on the plant before harvesting better than other shapes. Burgmans and Bussel (1983) report that soft fruit cracking in wet weather causes difficulties when conducting machine harvesting, as such fruit must be discarded. Soil rot of processing tomatoes caused by Rhizoctonia solani is a major problem in southern United States (Murphy, McFerran and Goode, 1984). These workers found genetic inheritance played a major part in determining the resistance of tomato cultivars to soil rot. Ethephon application was also found to reduce the percentage of rot by accelerating ripening and reducing the exposure time to the pathogen, and also by causing partial removal of the foliage thereby reducing the humidity around the fruit. Fruit shape, resistance to puncture pressure and fruit rot tolerance were found to be highly correlated by Werner, Sanders and Henderson (1980).

1.4 THE PROCESSING TOMATO INDUSTRY IN NEW ZEALAND.

1.4.1 AREAS GROWN

Processing tomatoes are grown in New Zealand mainly for the production of tomato paste, although a small area is also planted for whole peel and tomato juice production. There are two main areas where processing tomatoes are grown, these are Hawke Bay and Gisborne. In 1987 there was 200 ha planted in Hawke Bay and 300 ha planted in Gisborne (Davis 1989, pers. comm.).

1.4.2 CULTIVARS

The two main cultivars grown in New Zealand are Castlehy 1204 Improved and UC 82B although a small amount of Castlelong and VF 145 7878 are still grown in the Hastings area (Davis 1989, pers. comm.). Other cultivars grown for whole peel usage include Ohio 7814 and Ohio 7870. New cultivars are continually being imported from overseas and trialled for use in NZ.

1.4.3 ESTABLISHMENT METHODS

Cell transplants are the main method by which processing tomatoes are established. Older establishment techniques of direct seeding and bare root transplants are still used by more traditional growers, but only for small areas.

1.4.4 PLANT SPACING

The most common spacing used is 1.5 m. centre to centre beds, with 0.2-0.3 m. in row spacing, giving a population of 22000-33000 plants ha^{-1}. Another spacing which has been trialled in recent years is a 1.8 m centre to centre bed with plants in a double row, but still at a population of 22000 plants ha^{-1} (Davis 1989, pers. comm.)

1.4.5 POST ESTABLISHMENT CARE

1.4.5.1 FERTILIZER

As with most crops, fertilizer application in process tomatoes is normally based on a pre-plant soil test. Typical target soil test values are shown in Appendix 4. Generally base dressings of lime and phosphate are required on New Zealand soils (Anon, 1977), with phosphate applications being particularly important for early established crops. Nutrient uptake values are shown in Table IV;

Plant Part	Yield (t ha^{-1})	Nutrient Uptake (kg ha^{-1})		
		N	P	K
Fruits	75	112	11	202
Vines		90	12	112

(Clarke et al, 1986)

Table IV. Nutrient Uptake Levels

1.4.5.2 WEED CONTROL

Weed control in process tomato crops is generally carried out by a mixture of chemical and mechanical means. Metribuzin (Sencor^R DF) and napropamide (Devrinol^R 50) applied post-transplanting are the two most commonly used herbicides. Trifluralin (Treflan^R) is also sometimes used pre-transplanting. Modern spray application and cultivation equipment are generally guided by the beds on which the crop is growing, allowing mechanical cultivation to be carried out in close proximity to the growing plants. Solanaceous weeds such as nightshades can often become a major problem in process tomato crops (Anon, 1977) due to herbicide resistance, and therefore hand weeding is still required in some crops.

1.4.5.3 IRRIGATION

In many areas of New Zealand process tomatoes are not irrigated, apart from a small amount of water and nutrient which is applied at transplanting by machine. This is mainly due to the non availability of low cost irrigation water in some of the areas used for growing process tomatoes, particularly near Gisborne. In Hawke Bay many growers have water available and generally irrigate at the three critical stages of growth;
(1) at the time of sowing or transplanting,
(2) during blooming and fruit set, and
(3) over the period of fruit enlargement.
(Sims, 1975)

Generally process tomato cultivars tend to be shallow rooting and suffer from a lack of moisture after a relatively short dry period (Anon, 1977). Irrigation applications should be light and regular to keep the top 0.3 m (where the bulk of the roots are) well supplied with water.

1.4.5.4 PEST AND DISEASE CONTROL

Many different pests and diseases may cause problems on process tomatoes in New Zealand. Fungal diseases such as leaf mould, early and late blight, sclerotinia, and verticillium wilt can make the crop unmarketable unless a regular spray program is adhered to (Anon, 1977). Bacterial diseases including tomato blast, bacterial spot, and tomato speck may also cause problems. Pests in the form of caterpillars, aphids and thrips may cause damage to both the tomato plant and fruit. A complete spray programme is shown in Appendix 2.

1.4.5.5 CHLORETHEPHON APPLICATION

Foliar applications of chlorethephon are often applied to process tomato crops to accelerate ripening and to concentrate maturity (Dostal and Wilcox, 1971). Chlorethephon is not used on all process tomato crops in New Zealand, as each crop is assessed on an individual basis as to whether application of this expensive chemical is required. Current practice is to apply chlorethephon, if required, when approximately 15-20% of the fruit is in the coloured or red grades. The recommended application rate is 2 litres ha^{-1} of chlorethephon in 340 litres ha^{-1} of water applied as a light wetting spray (O'Connor, 1987).

1.4.6 HARVESTING

Machine harvesting is carried out on nearly all process tomato crops grown in New Zealand. Fruit is harvested into large bulk bins on trucks and trailers, which are then driven to the processing factory. A small amount of hand harvesting is carried out by some growers if conditions are too wet for machines to enter the field.

A crop is assessed as ready to harvest by shaking a length of row and determining the percentage of fruit in various grades; rotten/diseased, split, red, coloured, and green. While levels vary depending on the season, the crop is generally considered harvestable from 75% red to 7 days after 75% red (Davis 1989, pers. comm.).

1.4.7 YIELDS

Average yield in New Zealand varies considerably depending on the year, district and grower. It is generally considered that an average yield of 50 t ha^{-1} can be expected, although yields of up to 75 t ha^{-1} of marketable fruit have been achieved by individual growers (Davis 1989, pers. comm).

1.4.8 MARKETING

There are two methods by which a grower may be financially rewarded for process tomato crops grown on his land;

1)The processing company may lease the land from the grower on which the tomatoes are to be grown. It is then the companies responsibility to establish, manage and harvest the crop.

2)The tomato crop is grown on a contract basis for the company, with both the number of tons required and price agreed by both parties, before the season commences. The company will offer technical assistance to the grower and usually be responsible for harvesting the crop.

While crops are sampled when entering the processing factory, growers are not paid on the basis of soluble solid percentages, however there is increasing interest in a pricing structure based on tomato solids overseas (Tyler and May, 1984). Crops may be downgraded on the basis of weed growth and other extraneous material among the harvested tomatoes.

CHAPTER TWO: EXPERIMENT ONE

FLOWERING DEVELOPMENT IN TWO PROCESSING TOMATO CULTIVARS

2.1 INTRODUCTION

In an experiment carried out at Lawn Road, Hastings (Davis, 1989) comparing transplanting methods in processing tomatoes, factory grade yield was found to peak sharply over the multiple harvests which were carried out. This finding was contrary to what was previously thought, which was that factory grade yield remained at optimum levels for several weeks. This study also high lighted a lack of published information about where on the tomato plant the yield of factory grade fruit is produced. The following experiment was designed to examine the flowering pattern and to determine which flowers produced fruit of two important processing varieties of tomatoes grown in New Zealand. In an experiment carried out at Lawn Road, Hastings, New Zealand (Davis, 1989) comparing transplanting methods in processing tomatoes, factory grade yield was found to peak sharply over the multiple harvests which were carried out. This finding was contrary to what was previously thought, which was factory grade yield remained at optimum levels for several weeks. After reviewing other relevant research, it was decided to investigate further.

In this experiment the pattern of flower anthesis and fruit maturity of two processing tomato cultivars was studied in an attempt to understand why yield peaked in this way.

2.2 MATERIALS AND METHODS

2.2.1 PRODUCTION OF CELL TRANSPLANTS

Cell transplants were used to establish the experiment. Seed of the two processing tomato cultivars Castlehy 1204 Improved and UC 82B, were sown in cell trays on October 2nd, 1986.

These cultivars were chosen as they are the two main cultivars of tomato grown in New Zealand for the production of pulp and paste (Davis, 1989 pers. comm.). Seed was obtained from J. Wattie Canneries Ltd., Hastings.

The cell tray used was a 'Hassy 308' containing 308 seedlings at a density of 1284 plants/m^2 (Hiron and

Symonds, 1985). Each cell contained 15 mls. of media consisting of a 95:5 (by volume) sieved (5 mm mesh) sphagnum peat moss : coarse washed river sand with lime and fertilizers added (Appendix 1).

Single seeds were sown in each cell and germinated on a heated (21°C) capillary bench in a glasshouse, which was heated to 16°C and fan ventilated at 22°C. By October 6th. cotyleton expansion of the seedlings had occurred with both cultivars, and the temperature in the glasshouse was then lowered to heating at 12°C and ventilation at 18°C. A bacteriocide was applied on the 24th. October and a fungicide on the 27th. October, which were the only therapeutants applied at seedling stage (Appendix 2).

A regular program of liquid feeding the seedlings (Hiron and Symonds, 1985) was followed with a total of five applications of 100 ppm. Nitrogen and 166 ppm. Potassium applied during the period of cotyleton expansion to planting (Appendix 3).

2.2.2 PREPARATION OF THE FIELD AREA

The experiment was established on a Tokomaru Silt Loam type soil in the Horticultural Field Plots at Massey University. In late August a grassed area, in which the experiment was to be established, was subsoiled and deeply ploughed. A soil test indicated that levels of nutrients and soil pH were satisfactory (Appendix 4). On 29th. September 60 Kg Ha^{-1} of Nitrogen as Urea was applied to the experiment area and the soil was cultivated to a seedbed tilth with two passes of a tractor mounted rotary-hoe. No further applications of fertilizer were made.

Trifluralin (Treflan^{R}) was sprayed on the area at a rate of 3.0 L Ha^{-1} in 400 L Ha^{-1} of water and cultivated in using two passes at rightangles of a rotor-tiller to a depth of 100 mm. The experimental plots were then pegged out.

2.2.3 TRANSPLANTING

On 31st. October, 29 days after sowing , the transplants were removed from the glasshouse after liquid feeding, and planted in the field. Plants were transplanted into rows 1.5 m apart and 200 mm. apart in the rows.

Depth of planting was to a midway point on the stem between the depth in the transplant cell and the cotyletons, with the soil being carefully firmed around each plant. All transplants planted in the experimental area were chosen from the centre of the trays. The size of the Castlehy 1204 Imp. transplants was generally larger than the UC 82B transplants (Table V).

CULTIVAR	MEAN HEIGHT TO APEX FROM MEDIA LEVEL (mm.)	DRY WEIGHT (SHOOT) (g/plant)
Castlehy	79.42 (S.E. 0.48)	0.10 (S.E. 0.015)
1204 Imp.		
UC 82B	58.22 (S.E. 0.43)	0.07 (S.E. 0.026)

Table V. Size of transplants at planting.

The experiment was planted over a four hour period with 16 mm. of water applied by overhead irrigation as soon as planting was completed.
Diazinon^{R} granules were applied to the base of each plant at a rate of 0.2 g. per plant and Mesurol^{R} slug pellets were sprinkled over the experimental area at a rate of 8 Kg Ha^{-1}. A rabbit proof electric fence and a gas driven bird-scarer were installed to provide protection from rabbits and birds.

Plate I. Experimental area after planting

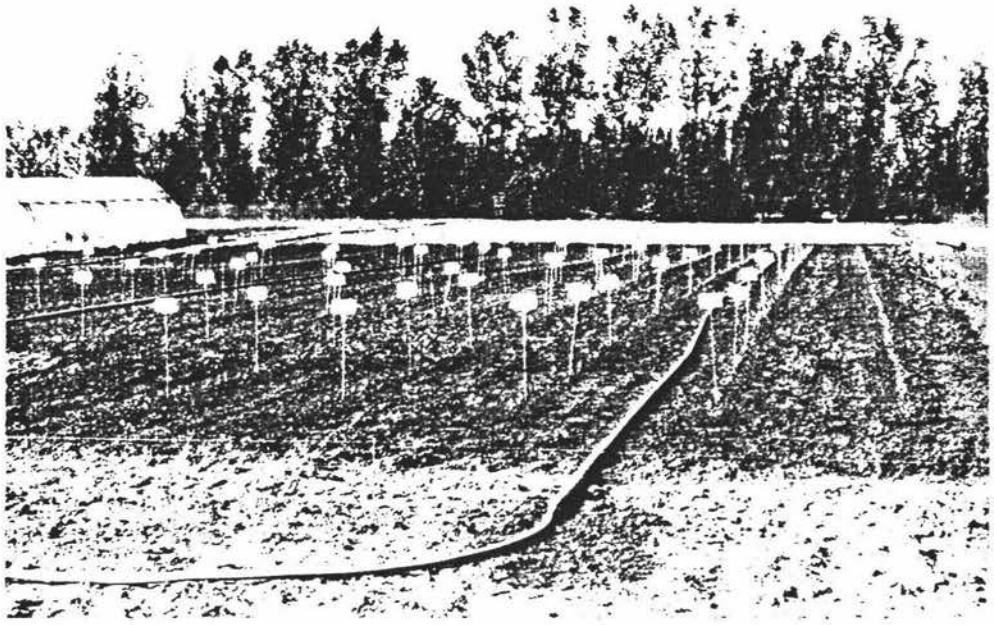
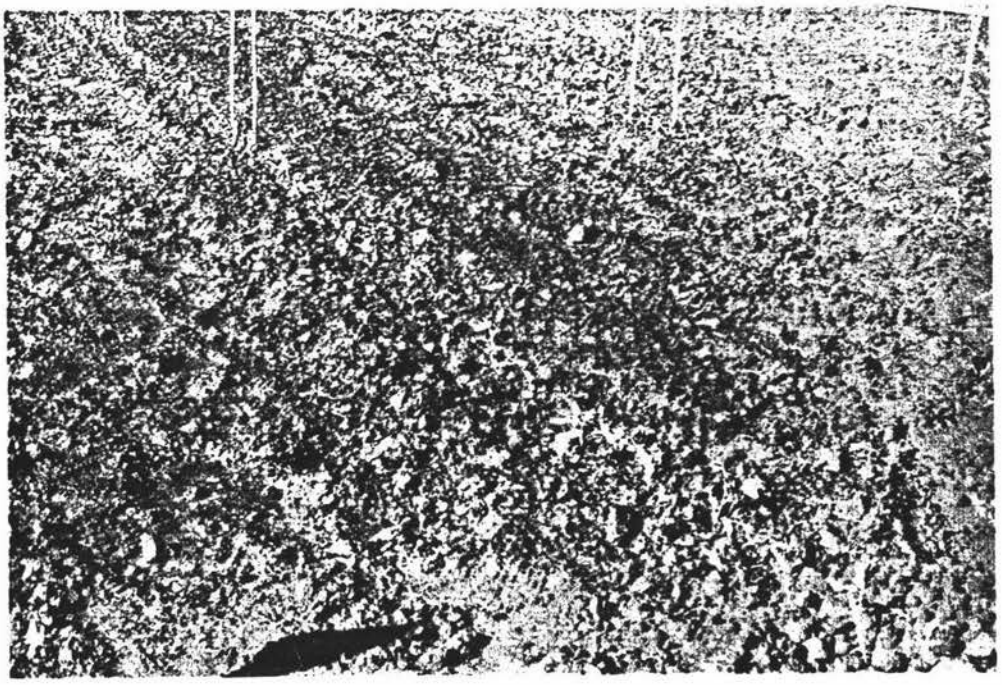


Plate II. Plants one day after planting



2.2.4 MAINTENANCE OF THE EXPERIMENT AFTER ESTABLISHMENT

A regular commercial process tomato spray program (Anon, 1977) was followed throughout the experiment (Appendix 2). Soil moisture tensionmeters were installed to a depth of 150 - 200mm. in the centre of each quadrant of the experiment to indicate when irrigation was necessary. Irrigation was applied when the mean soil moisture suction reached 0.35 bars (Hausenbuiller, 1978). This occurred 6,11,20,35,43,54 and 61 days after planting with the 16mm. of water applied on each of these occasions, reducing soil moisture suction to 0 bars. The experimental area was weeded manually 30,55 and 83 days after planting to remove late germinating weed seedlings.

2.2.5 EXPERIMENTAL DESIGN

A randomized complete block design was used with three blocks. Each block consisted of 10 plants of which 4 plants were used for recording data, with a guard plant at each end of the block. Three guard plants were established at either end of each row, and a row of guard plants was established either side of the experimental area. In total, twelve plants of each cultivar were used for recording data.

2.2.6 RECORDING AND ANALYSES OF DATA

Flowering commenced 40 days after planting. When anthesis of the flower of a particular truss occurred, the truss was labelled, numbered and the date recorded. As further flowers opened on a truss their date of anthesis was determined. This was done by counting the number of flowers open on each recording day, and deducting from this total the number of flowers open the previous recording day. Data was recorded every two to three days. Flower dates were recorded until flowering ceased 88 days after planting.

All labelled plants were harvested 132 days from planting by cutting at ground level and carefully lifting each plant onto a tray, which was then transferred into the field laboratory. Occasionally fruit became separated from the truss with which they were associated and these were put to one side and disregarded for the analysis of the experiment. The position of trusses on the plant was carefully drawn and the numbers of red, coloured and green fruit on each truss recorded.

Plate III. Towards the end of flowering.

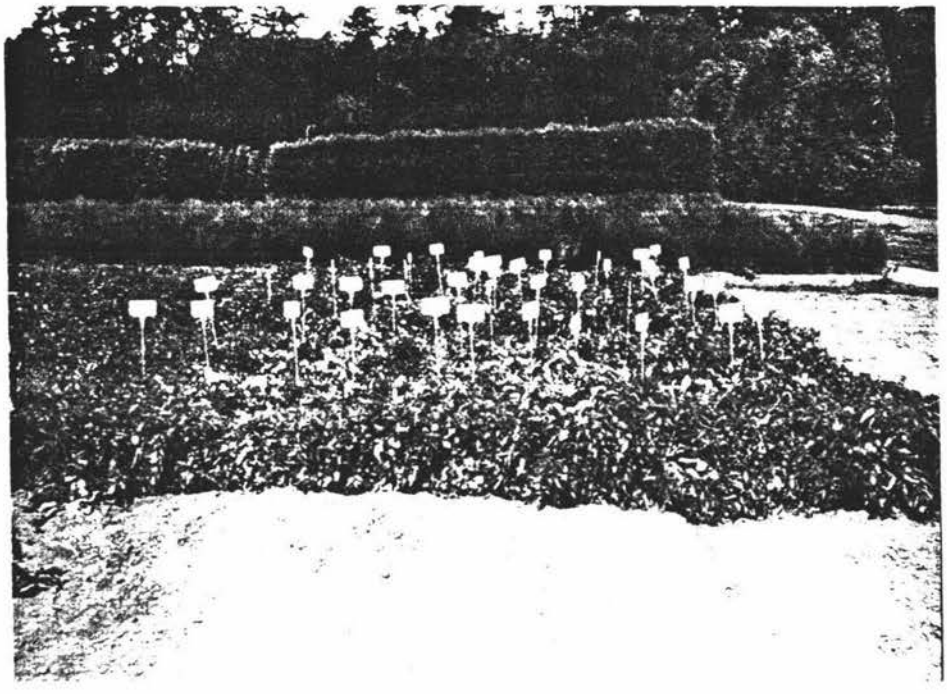


Plate IV. A closeup of the flower recording tags.

2.3 RESULTS

All data was analysed using the SPSS and MINITAB computer software packages. SPSS MANOVA was used in the analysis variance.

2.3.1 FLOWERING PATTERN FOR ALL FLOWERS

Dates of flowering were converted into the number of days from when the first flower opened for that particular cultivar. The frequency (Davis et al, 1965b) of the number of flowers open on each recorded day was calculated on a per plant basis and, as data was recorded at 2-3 day intervals, frequencies over three day periods were averaged (Appendix 5). A Normal Distribution Curve (Nichols,1965) was generated from this frequency data for each cultivar and as the analysis of variance showed there was no significant differences in the calculated Normal Curve Statistics for each cultivar, the data for each was combined and a new Normal Curve generated from the combined data. The time-frequency distribution is a similar analyses to one used by Davis et al (1965b) in an experiment examining fruit set and load in tomatoes.

The Normal Distribution Curve generated from the combined data for both cultivars for the number of flowers opening per day, is presented in Fig. 1. The peak occurred at 28.5 days from commencement of flowering and flowering had virtually ceased after a total of 45-52 days.

Statistics for the Normal Distribution are presented in Appendix 7.

2.3.2 FLOWERING PATTERN FOR FLOWERS WHICH PRODUCE FRUIT

Fruit data was treated in the same manner as flowering data, by assuming that the first opening flowers on a truss produced the fruit. The data is presented in Appendix 6.

The Normal Distribution Curve generated from the combined data from both cultivars for the number of flowers opening per day which produced fruit is presented in Fig. 2. The peak occurred at 21.5 days from commencement of flowering and flowers which produced fruit had virtually ceased after a total of 38 days.

Statistics for the above Normal Distribution are presented in Appendix 7.

2.3.3 TRUSS POSITION ON THE PLANT

Data for this part of the experiment was combined for both cultivars. As only trusses with numbers 20 or less were shown to be important in contributing to the yield of the plant, only these trusses were considered.

Each plant in the experiment was drawn diagrammatically. The average number of first order laterals radiating from the base of the plant was determined as 8. The main stem was classified as a lateral. The position of the trusses on each plant were placed on these 8 laterals in order of occurrence along the lateral from the base. Where there were trusses on second order laterals, the point of attachment of the second order lateral to the main lateral determined the siting of the trusses on the lateral. All trusses on the second order laterals were considered before the next trusses past the point of attachment.

While individual plants were variable, three arcs at increasing distance from the base were identified as being the levels where groups of truss numbers could be expected to be found. The diagrammatic representation of the position of the trusses on a typical plant, which could be seen in the two cultivars under study is presented in Diagram 1. Trusses 1-10 are located in Arc one on the plant, trusses 10-15 in Arc two and trusses 15-20 in arc three.

Plate V. UC 82B plant with the fruit attached.

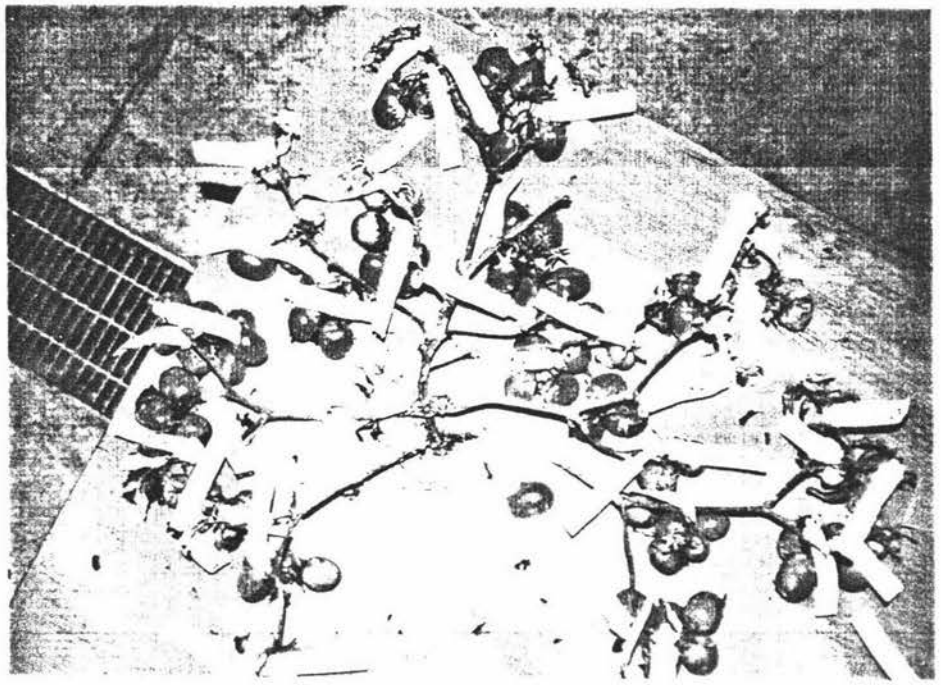
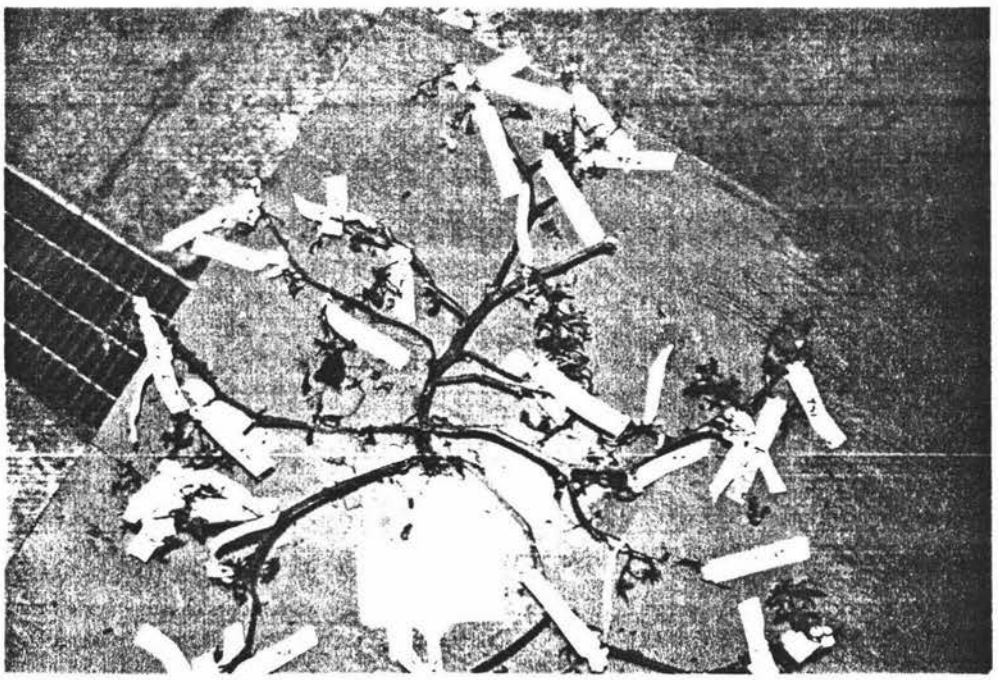


Plate VI. UC 82B plant after the fruit was removed.



2.3.4 RELATIONSHIP BETWEEN TRUSS POSITION AND FRUIT DEVELOPMENT

The efficiency of the truss in producing red, factory grade (red and coloured), and red, coloured and green fruit was arrived at by dividing the number of fruit produced on each truss by the number flowers which opened on each truss. Cumulative percentages of the number of fruit produced on each truss in all of these grades were also calculated.

Data showing the efficiency of flower trusses in producing fruit is presented in Appendix 8 and also in Figs. 4,5 and 6. Cumulative percentage of the number of fruit data is shown in Appendix 9 and presented graphically in Figs. 7,8 and 9.

2.4 DISCUSSION

2.4.1 GENERAL DISCUSSION

The closeness of the fit of the raw data and generated data for flowering can be seen in Figs. 1 and 2. The curve derived from raw data is similar to that produced by Marlowe, Overman and Schuster (1983) for numbers of flower clusters on a indeterminant tomato plant. Fig. 3 provides the best overall picture of what is happening - initially curves are very similar up to day 16. This must mean that virtually all the early flowers set fruit. In other words, it is the order of flowering that is more important (at least initially), rather than on which truss the flower is situated. These results are similar to those of Davis et al, (1965a and 1969) and also to findings of Rudich et al, (1977). The figure also clearly demonstrates the excess flowering capacity in the plant.

Figs. 4-6 demonstrate that 90% of the yield is carried in the first 18 trusses and the fruit load falls with increasing truss number. Figs. 20-21 support this conclusion, and also that the fall is due to fewer flowers setting, rather than the lack of flowers. These results were similar to those of Wolf and Rudick (1988) who found that 30-40% of the final dry-weight yield was contributed by fruits set during the first week of flowering. This can be explained by the first opening flowers setting fruit and acting as a sink for photosynthate and preventing further flowers setting (Hurd, Gray and Mountifield, 1979; Slack and Calvert, 1977; Wolf and Rudick, 1988). This effect also concentrates the yield, because the fruit on each plant is restricted to the earliest trusses (Fery and Janick, 1970; Reeve and Schmidt, 1951).

The position of these yield contributing trusses on the plant (Diagram 1) follow a pattern of increasing

distance from the root system, the later the truss begins to flower. If the data from Figure 23 is examined in conjunction with data from Fig. 6, some interesting conclusions can be drawn.

From Figure 23;	From Fig. 6;
Arc 1 contains trusses 1-10	Trusses 1-10 provide 65% yield
Arc 2 contains trusses 10-15	Trusses 10-15 provide 20% yield
Arc 3 contains trusses 15-20	Trusses 15-20 provide 10% yield

This provides evidence that the source sink unit may well be the lateral - ie. there is little movement of source between first order laterals, and sinks mainly compete with each other on a basis of individual first order laterals. Figs. 6 and 9 provide data that shows there is some competition between laterals, because the efficiency falls from trusses 1-10. It would appear therefore, that the main competition is within laterals, although there is some competition between laterals.

It is interesting to note that both the numbers of flowers which produce fruit, and the yield of factory grade fruit (Fruiting Pattern Experiment) follow a Normal Distribution Curve (Figs. 15 and 17). This indicates that the time from flowering to maturity remains constant for both early and later flowers which set fruit. This is because as most of the yield contributing fruit was set on the first 18 trusses over a short time period, it is likely that all of these fruit would have been subjected to very similar environmental conditions.

In comparing the efficiencies of trusses in producing red, factory grade, or all grades of fruit, it can be seen that trusses with low numbers (those that had the earlier first opening flower) mainly produced red fruit, while those flowering later produced green fruit (Figs. 17-19). This is also shown in comparing the cumulative percentages of fruit produced in these grades (Figs. 7-9). There is little difference between Castlehy 1204 Imp. and UC 82B in efficiencies of trusses or cumulative percentages of the number of fruit.

2.4.2 COMMERCIAL IMPLICATIONS

The major commercial implication of this experiment is linked with the relatively few flower trusses which contribute to the factory grade yield of the two commonly used processing tomato cultivars in NZ. To maximize yield, care should be taken to ensure optimal conditions are provided for the crop at least until the first 20 flower trusses have flowered. This may involve altering irrigation and fertilizer programs to coincide with this period of plant growth (Fery and Janick, 1970).

2.4.3 RESEARCH IMPLICATIONS

As the data presented in this experiment appears to be unique when examining published literature on the subject, the experiment needs to be repeated with other processing tomato cultivars and in other districts before it can be accepted with total confidence. The experiment should also be repeated at different plant spacings and fertiliser levels to examine what influence these two factors have on the flowering frequency curves.

The experiment may provide data for use in breeding new cultivars of processing tomatoes. If flowering was concentrated over a shorter time period on the plant, more flowers would set since they would not be in competition with developing fruit. This in turn would probably result in smaller fruit, but a net higher factory grade yield.

In much the same manner, if later flowers do not contribute significantly to the yield, then the initiation and growth of these trusses represents a wasteful drain on photosynthate which could be otherwise used by the developing fruit. Application of growth retardants as a flower "cut off" spray after desired fruit set has been achieved (Read and Fieldhouse, 1970) should be also investigated.

CHAPTER THREE: EXPERIMENT TWO

FRUITING PATTERN IN TWO PROCESSING TOMATO CULTIVARS

3.1 INTRODUCTION

In an experiment carried out at Lawn Road, Hastings (Davis, 1989) comparing transplanting methods in processing tomatoes, factory grade yield was found to peak sharply over the multiple harvests which were carried out. This finding was contrary to what was previously thought, which was that factory grade yield remained at optimum levels for several weeks. This suggests that the relationship between the fruit maturity characteristics and time, of the important processing tomato varieties grown in New Zealand may not be as simple as was first thought and needs to be studied further.
The following experiment was carried out to use multiple harvest with two processing tomato varieties to determine the pattern of fruit development that occurs with respect to both the number and yield of the various maturity grades of fruit over time.

3.2 MATERIALS AND METHODS

3.2.1 INTRODUCTION

The establishment and management of the plants in this experiment is described in Chapter Two (Sections 2.2.1 - 2.2.4)

Plate VII. Fruiting pattern experiment early February, 1987.

Plate VIII. Fruiting pattern experiment after the first harvest.

3.2.2 EXPERIMENTAL DESIGN

The treatments consisted of 2 cultivars and 10 harvests. A randomized complete block design was used with 20 plants per plot, and 2 guard plants between plots. Each plot measured 4.4 m. long. Three guard plants were planted at the end of each row, and a guard row was planted along each side of the experiment. The experimental area was 36.0 m. long by 16.5 m. wide and contained 80 plots (4 blocks x 2 cultivars x 10 harvests).

3.2.3 DATA COLLECTION

The first harvest for each cultivar was taken when fruit was first colouring. This occurred 17th. February, 1987 which was 108 days after planting, and a further eight harvests were taken at weekly intervals.

Plants were cut off at ground level using secateurs and shaken until most of the fruit was removed. Any fruit adhering to the plants was removed by hand. Fruit from each 20 plant plot was taken into the field laboratory and sorted into grades as described in Table VI.

GRADE	DESCRIPTION
Red	Completely red with little of no orange showing.
Coloured	Showing some degree of red or orange.
Grass Green	Some seeds were sliced when the fruit was cut.
Mature Green	Seeds were not cut when the fruit was cut.
Red Rotten	Fruit which was all or partly over mature.
Green Rotten	Fruit which had partly or completely rotted while still green.
Small	Less than 25 mm. in diameter.

Table VI. Tomato fruit grades

Grading was achieved by first passing the fruit over a grading table which allowed all fruit less than 25 mm. to fall through a grid. At the same time both green and red rotten grades were also removed. The red, coloured and green grades were then sorted, with every green fruit sliced to determine whether it was grass green or mature green. Red and coloured grades combined, represented a factory grade (fruit considered acceptable for processing by local standards - Davis, 1988 pers. comm.).

Each grade of fruit was then weighed and red, coloured and both green grades were counted.

A random sample of 10 red fruit was drawn from each plot, and soluble solids determined using a hand held refractometer. Some plots in the first harvest did not have 10 red fruits, and therefore all red fruit available in these plots was used for the soluble solid determinations.

Plate IX. Transport of fruit from the field.

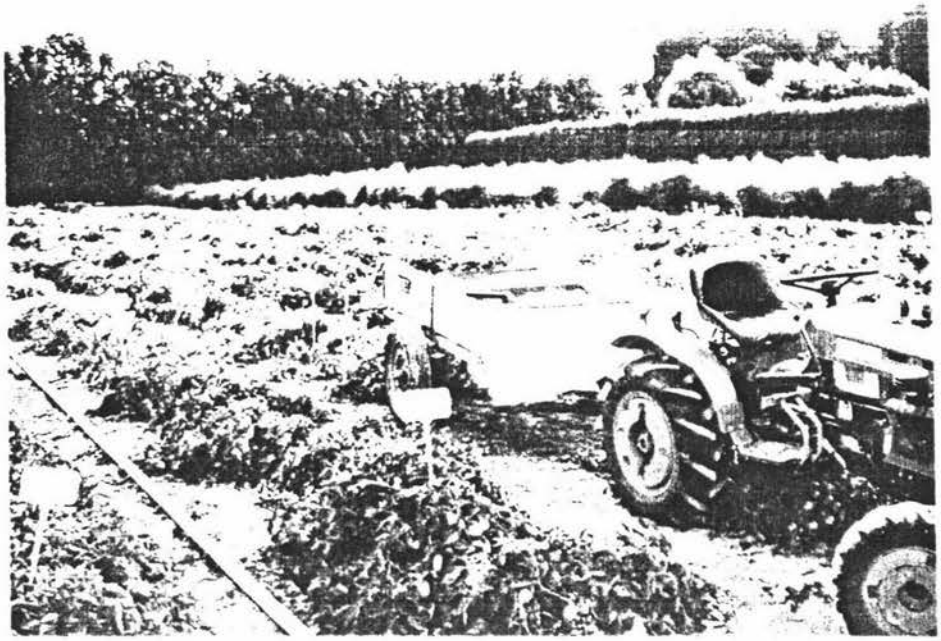
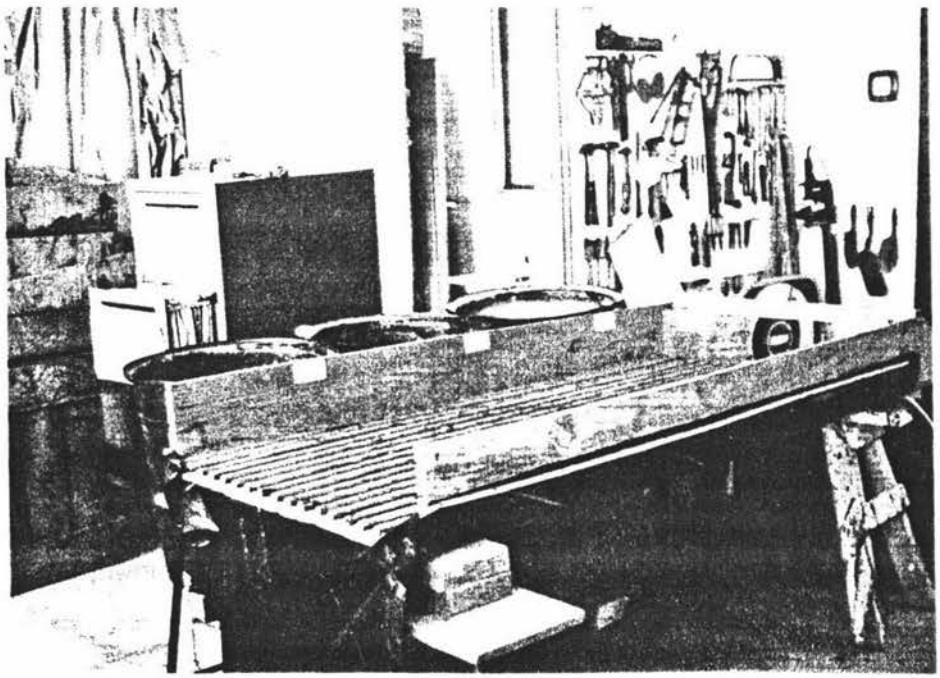


Plate X. Grading table



3.2.4 ANALYSIS OF DATA

Where applicable, data was analysed using the SPSS and MINITAB computer software packages. SPSS MANOVA was used in the analysis variance calculations.

Fruit weights were converted to a per hectare bases. An analysis of variance was carried out on this data for each cultivar and nine harvest dates, in both the red and factory (red and coloured fruit combined) grades of fruit. A multiple regression of fruit weight against harvest date for each cultivar was then calculated, and a quadratic function fitted to each block for these grades. Normal Distribution Curves, as described by Nichols (1965), were also fitted to each block and proved to give a better fit to the original data than the quadratic equations. Thus only normal distribution curves are reported in the results.

Total fruit weight, and total fruit weight excluding rotten and small, was determined by adding all the appropriate grades of fruit for each harvest date. Similarly, grass green and mature green fruit weights on each harvest date were added to give total green fruit, as were red rotten fruit and green rotten fruit to give total rotten fruit

Numbers of fruit were converted to a per hectare bases. Total number of fruit, total number of green fruit, and the number of factory grade fruit were determined in a similar manner to fruit weight totals.

Mean fruit weights for each cultivar were determined by dividing the total weight of fruit in each grade, by the total number of fruit. An analysis of variance was carried out on red fruit soluble solid data for cultivars and harvest dates.

Plate XI. Fruit from the first harvest.

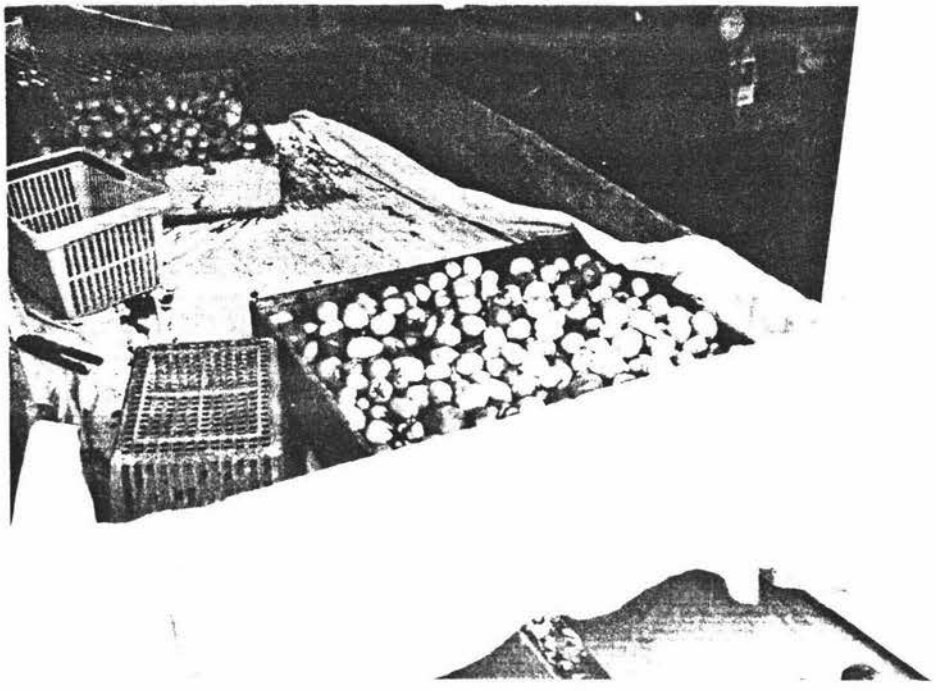
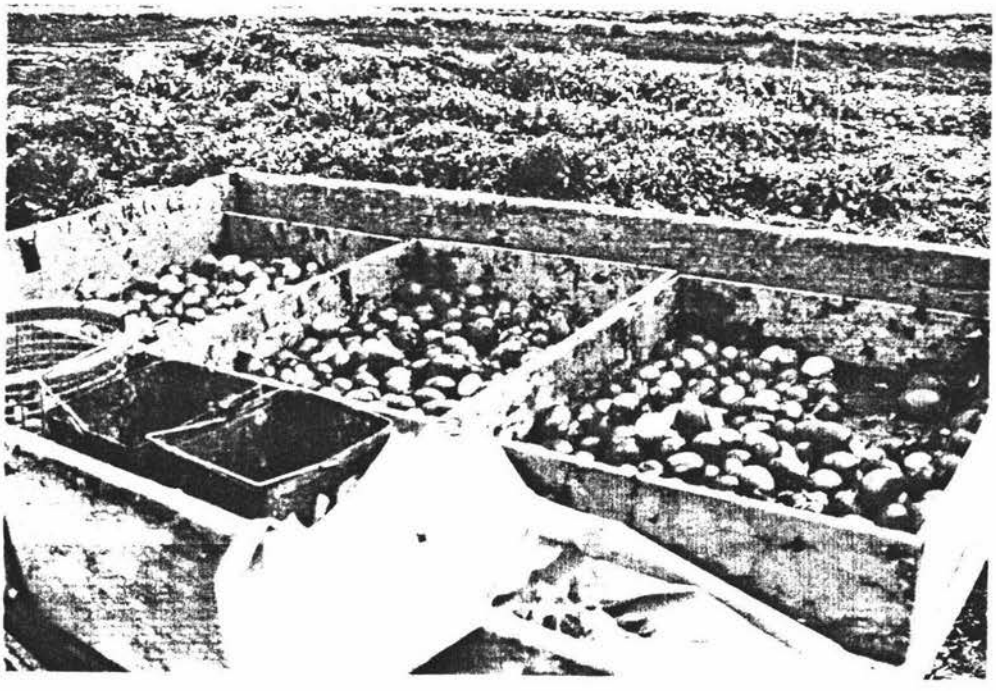


Plate XII. Fruit from the last harvest.



3.3 RESULTS AND DISCUSSION

3.3.1 PATTERN OF FRUIT MATURITY

Fruit weight raw data expressed as kilograms per hectare, is presented in Appendix 10, while fruit number raw data is shown in Appendix 11. Individual fruit weight raw data is presented in Appendix 12.

3.3.1.1 GREEN FRUIT

The total weight of green fruit for both varieties (Fig. 10 and 12) increased slightly from planting and then declined, rapidly at first, over the remainder of the harvesting period. The total number of green fruit (Figs. 18 and 19) showed a similar pattern, except that there was no initial increase in fruit numbers, and there was a "bulge" in an otherwise smooth decline at 129 days from planting. Mean fruit weight of green fruit (Figs. 20 and 21) increased over the harvesting period. This would be because the green stage was when fruit were making their greatest claim on assimilates and thus their individual weights were increasing. The decline in fruit size at 129 days was probably due to the "bulge" in the fruit number curves at this stage. The reason for this bulge is unknown. The rapid increase in fruit size for UC 82B (Fig. 21) was in response to the "dip" in fruit numbers that occurred at this time.

Green fruit is comprised of the two grades grass green and mature green. The yield of grass green fruit for both cultivars peaked over the period 108-115 days after planting (Figs. 11 and 13) and then declined. The yield of mature green fruit peaked at a later stage (122-129 days), which was to be expected as grass green fruit became green fruit. The fruit numbers of these two grades (Fig. 18 and 19) were of a similar order for much of the experiment. The number of grass green fruit was greater than the number of mature green fruit until the 129-136 day period for both cultivars. This change was to be expected as grass green fruit became mature green fruit.

It appears therefore that these plants maintained similar numbers of grass and mature green fruit, which suggests that fruit move from grass green to mature green stage, with respect to number, at much the same rate as they move from mature green to coloured fruit. Mature green fruit numbers peaked earlier than mature green fruit weight peaked. Thus, the peak in fruit weight was due to an increase in fruit size of mature green fruit.

The decline in number and weight of all grades of green fruit was to be expected as the fruit on the plant progressed from immature to more mature stages.

3.3.1.2 COLOURED, RED AND FACTORY GRADE FRUIT

For both cultivars, the fresh weight of the respective grades of fruit peaked in the expected order. Thus green fruit weight peaked first followed by coloured and then red fruit (Figs. 10 and 12). The numbers of coloured and red fruit followed a similar pattern to their respective fruit weights (Figs. 18 and 19). The closeness of this relationship is demonstrated by the mean fruit weight, which did not vary for either cultivar during the harvesting period (Figs. 20 and 21). The corollary of the size of the coloured and red fruit, suggests that by the time fruit had reached this stage of maturity, they were no longer major sinks for carbohydrates. Red fruit weight was greater than coloured fruit weight, as fruit spent a much longer period of time in this grade classification.

Factory grade fruit was a combination of coloured and red fruit. The relationship between weight of fruit, and fruit numbers was similar to that for coloured and red fruit (Figs. 10 and 12, 18 and 19)

3.3.1.3 ROTTEN FRUIT

Red rotten fruit increased to a peak at 157 days from planting for both cultivars and then decreased slightly from this peak over the next seven days (Figs. 11 and 13). This pattern of rotten fruit production is similar to that for red fruit (Figs. 10 and 12). This is to be expected since if red fruit is not harvested, then given time, it will move into the red rotten grade. The large peak for red rotten fruit was due to the accumulation of fruit in this grade. The decrease in the weight of red rotten fruit at the end of the experiment, is the result of overall loss of fresh weight as the fruit decayed. This drop is larger in Castlehy 1204 Imp. and occurs earlier due to the earlier peak weight of red fruit than UC 82B (Figs. 10 and 12). Smaller total amounts of red rotten, and therefore total rotten fruit produced by UC 82B, are the result of correspondingly lower weights of red fruit produced by this cultivar.

Green rotten fruit peaked at 129-136 days and then fell (Figs. 11 and 13) in both cultivars. The total weight of rotten fruit follows the same pattern as for red rotten fruit because of the comparatively small weight of green rotten fruit (Figs. 10 and 12).

3.3.1.4 SMALL FRUIT

The weight of small fruit was maintained at very low levels and decreased over the harvesting period

for both cultivars (Figs. 10 and 12). The fall in weight of small fruit was due to the average overall increase in mean fruit weight, which in turn is caused by an increase in the individual green fruit weight (Figs. 7 and 8). This is also supported by the fact that a large proportion of the small fruit at all harvests was green fruit. Some of this small fruit would have been set late, and did not swell due to competition for assimilates.

3.3.1.5 TOTAL FRUIT PRODUCTION

Both cultivars showed an increase in the total fruit weight between 108-115 days from planting (Figs. 10 and 12). This is the result of increases in the weight of green fruit. Later total fruit weight fell as the increase in fruit size slowed and could not keep up with weight loss of rotten fruit. Total numbers of fruit decrease over this period (Figs.9 and 10) and this clearly demonstrates that rots were accounting for many fruit which were not then recorded. The fall in total numbers of fruit is very pronounced, with over half of the fruit rotted by 136 days after planting. Thus total fruit weight was being maintained by the overall increase in fruit size (Fig. 20 and 21).

3.3.2 MATURITY CHARACTERISTICS OF PROCESSING GRADES OF FRUIT

The Normal Distribution Curve fitted to the weight of red fruit data, (Appendix 13) shows a rapid rise from the first harvest, reaching a maximum near the middle of the harvest period, and then falling rapidly to the last harvest day for both cultivars (Figs. 14 and 16). It follows, that as individual fruit weights of red fruit are were generally constant over the harvest period, then a Normal Distribution Curve fitted to the numbers of red fruit shows similar trends (Appendix 13).

Both factory grade fruit weight and number Normal Distribution Curves follow the same pattern, as demonstrated by the red fruit (Appendix 13, Figs. 15 and 17). Table VII shows predicted maximum yield/ numbers of red fruit and factory grade fruit (mean of the Normal Curve) and days to maturity for both cultivars

CULTIVAR	GRADE	MAXIMUM PREDICTED WEIGHT ($t\ ha^{-1}$)	MAXIMUM PREDICTED NUMBER ($x\ 1000\ ha^{-1}$)	PREDICTED HARVEST DATE (Days from planting)
Castlehy	Red	62.0	959.9	140.0
UC 82B	Red	56.8	964.2	144.7
Castlehy	Factory	87.9	1385.8	136.3
UC 82B	Factory	78.7	1398.5	139.5

Table VII. Predicted maximum weight, numbers of red fruit and harvest date for Red and Factory Grades of fruit.

These curves correspond to the Normal Distribution Curves representing the flowering data in the first experiment (Figs. 1-3). The peak yield of both factory grade and red fruit in Castlehy 1204 is larger, and occurs 3-4 days earlier than UC 82B. However, peak flowering period has been shown to occur over the same time for both cultivars, and this indicates a slightly longer period from anthesis to maturity for UC 82B.

3.3.3 SOLUBLE SOLIDS

The analysis of variance showed there were no significant differences between the cultivars in red fruit soluble solid readings. Data from the two cultivars (Appendix 14) was therefore combined over the harvest period (Fig. 22). Rainfall data which fell over the previous week before harvest is also presented (Fig. 22, Appendix 14)

The combined results of both cultivars indicate that the general trend was for soluble solids to increase over the harvest period (Fig. 22). There are major fluctuations in this general trend however, and these can be explained by examining the rainfall over the previous week before harvest. Where rainfall was significant, then soluble solids decreased. The opposite also applies, if there was little rain, then solids increased. This result supports the work of other research workers (Crowder, 1970; Moore, Kattan and Flemming, 1958.).

A high soluble solids reading for the first harvest is probably the result of the low number of fruit that were available to test at this harvest, causing experimental error to occur.

Plate XIII. First harvest.

Plate XIV. Second harvest.

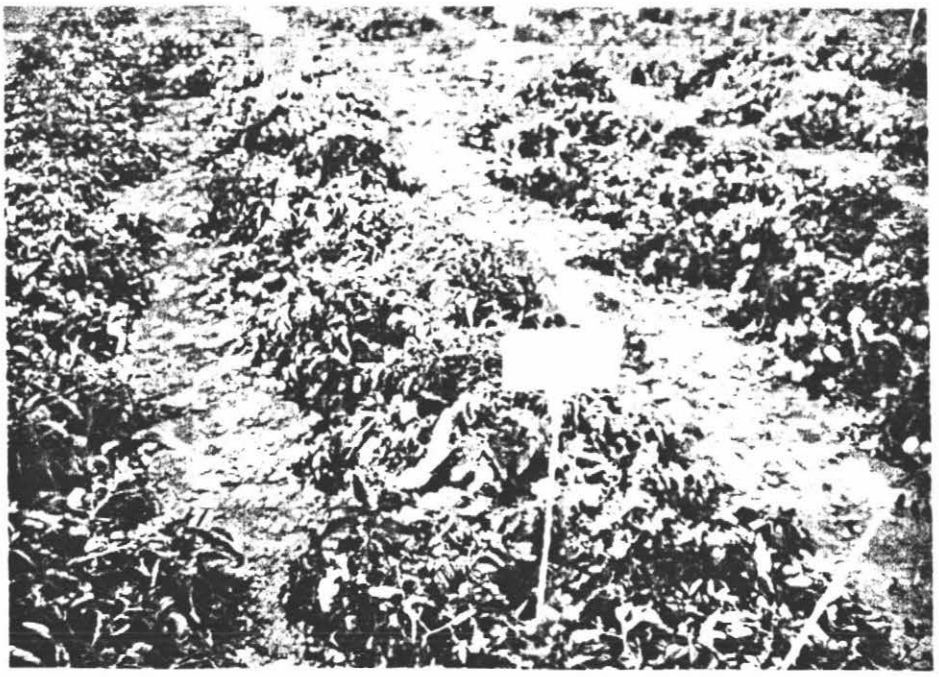


Plate XVII. Fifth harvest.

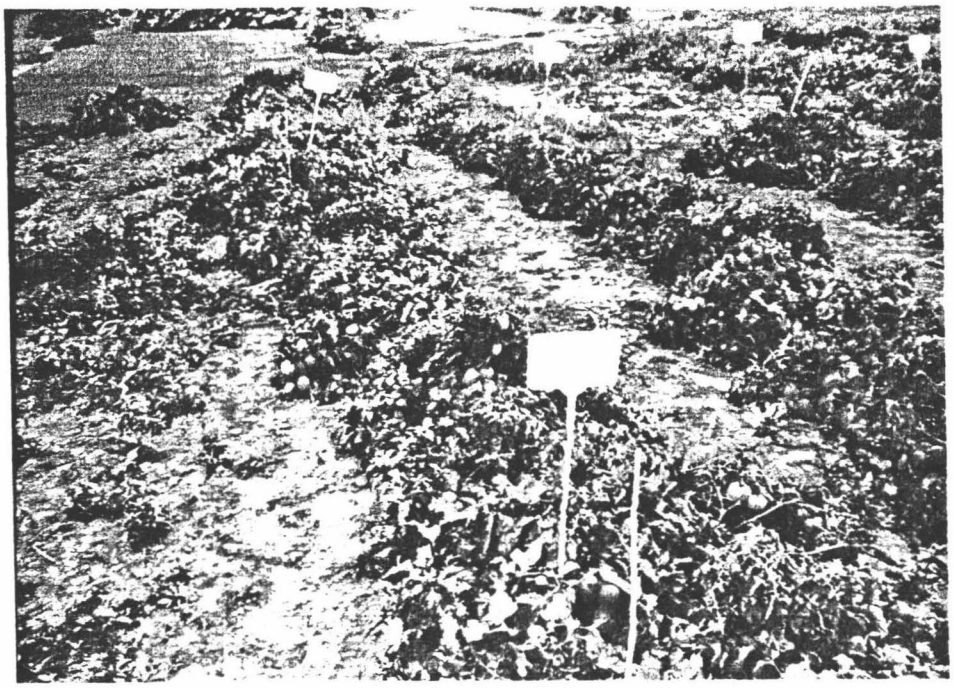


Plate XVIII. Sixth harvest.

Plate XIX. Seventh harvest.

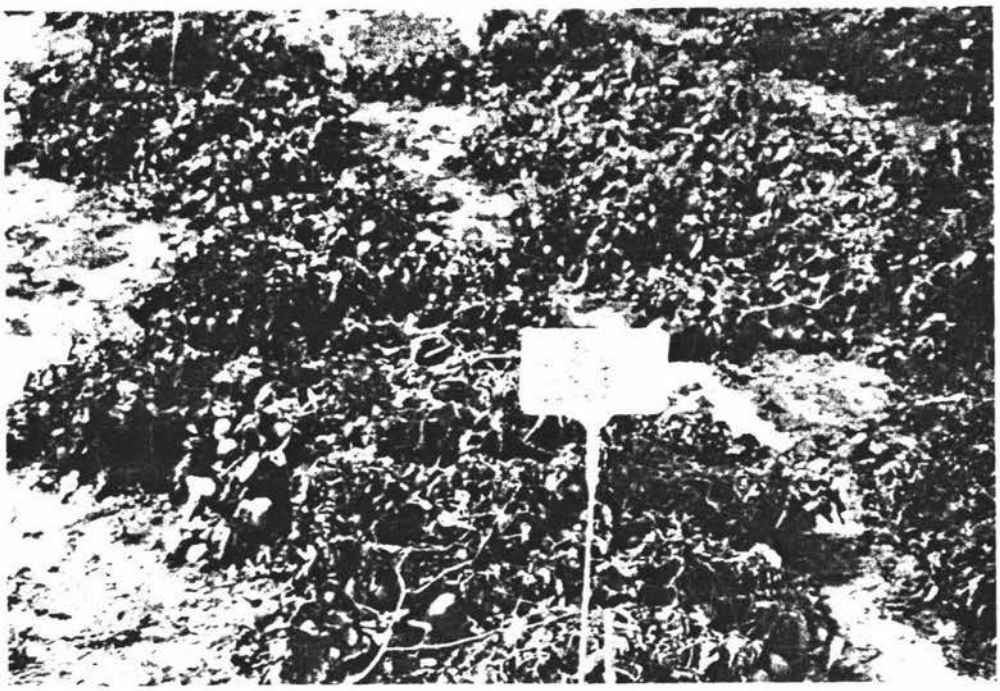
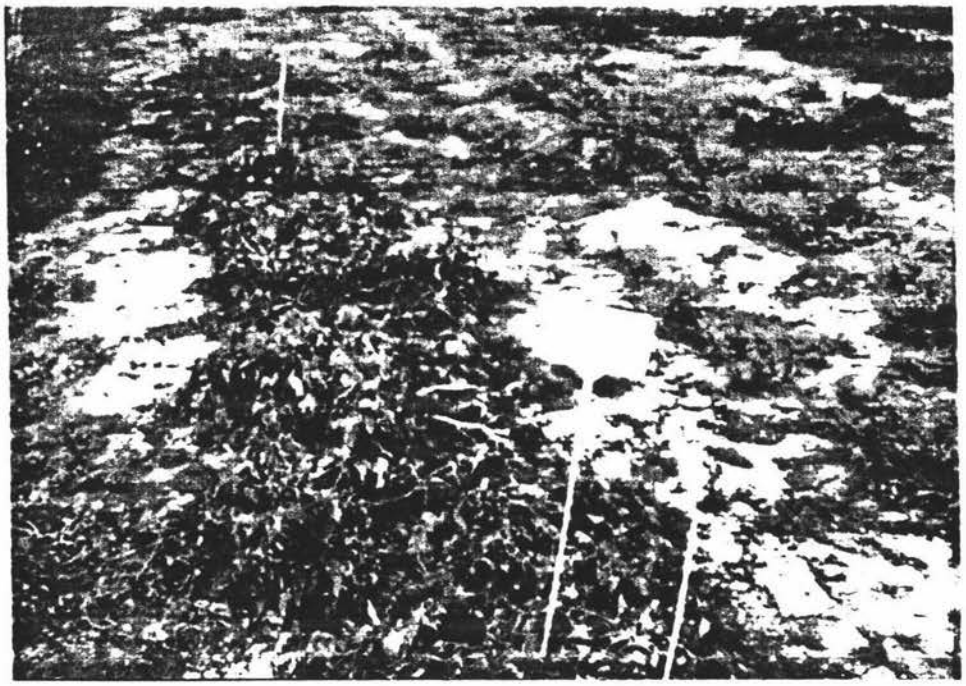


Plate XX. Eighth harvest

Plate XI. Nineth harvest



3.3.4 COMMERCIAL IMPLICATIONS

The yield of red and factory grade fruit is of importance to processing companies producing tomato based products. Generally an assessment of when to harvest processing tomato crops is made by shaking out a length of row, and assessing the proportions of fruit weight in various grades. A crop is considered harvestable until 7 days after the proportion of red fruit is 75% (Davis, 1988 -pers. comm.). While processing companies would ideally choose to have all tomato fruit harvested in the red grade, in practice fruit generally enters the factory in a mixture of coloured and red fruit, which may be in the worst possible case factory grade, containing all coloured fruit, or in the best possible case, red grade not containing any coloured fruit.

The weight of factory grade or red fruit in this experiment demonstrate that the choice of harvest date is very important, and shows how concentrated the yield is as a result of the close spacing (Fery and Janick, 1970). A potential loss of 10-15 t ha^{-1} (Figs. 14-17) may be the result of harvesting a week earlier or later than the optimum, with a consequence of loss of potential profit. This concentration of yield has been demonstrated by other experiments (Nelson, Wilcox and Bennett, 1972), although not by using multiple harvests, as in this experiment. Other research workers have tried to predict the optimum harvest date of process tomato crops by a variety of methods, such as transplanting date (Austin and Ries, 1965), stem diameter (Austin and Ries, 1965; Austin and Dunton, 1970) or day-degrees (Grey, 1981; Warnock and Isaacs, 1969) with limited success and accuracy.

Some, but not all, processing tomato crops in New Zealand are treated with the ethylene generating chemical chloroethephon (Ethrel^{R}). The effect of this chemical is to ripen fruit that is in the mature green grade, therefore accelerating progress into the coloured and red grades. How this chemical affects the maturity characteristics pattern of the red and factory grade fruit has yet to be determined.

The trend of decreasing soluble solid readings with increasing rainfall shown in this experiment, once more outlines the importance of withholding irrigation water well before harvest. In addition, it also shows the vagaries of the New Zealand climate may result in widely changing soluble solid readings from day to day and year to year.

3.3.5 RESEARCH IMPLICATIONS

The sharp peak in red and process grade fruit yields over time, has also been demonstrated by Davis

(1989), also using the process tomato cultivar Castlehy 1204 Improved.

Overseas workers have demonstrated an accumulation of yield prior to a once over harvest (Wilcox, 1970), but there is little work which examines the decline in yield once the optimum harvest date is passed. Bussel (1971) showed large changes in ripe fruit yields using three harvests at 5-7 day intervals, but however using soft fruited cultivars. Marlowe, Overman and Schuster (1983) demonstrate a decline in 'total number of marketable fruit per plant' past an optimal harvest date, but their experiment was with an indeterminant cultivar.

Other research workers have demonstrated that the application of fertilizer may result in the reduction of once-over harvest yield of process tomatoes (Nichols, Nonnecke and Phatak, 1973; Nicklow and Downes, 1971; Doss, Evans and Johnson, 1975.). It would be interesting to examine the effects of differing fertilizer levels and the interaction of these levels with differing plant densities, on the yield of process grade fruit over time in a similar manner to this experiment.

Work with chlorethephon application requires re-examining in light of the results obtained in the above experiment. Most research workers have used an arbitrarily chosen optimum harvest date to determine the most suitable length of time between application of chlorethephon, and maximum yield of process grade fruit (Bussel, 1973; Baqar, Edwards and Lee, 1975). This experiment has shown that this arbitrarily chosen harvest date may be not be the optimum date.

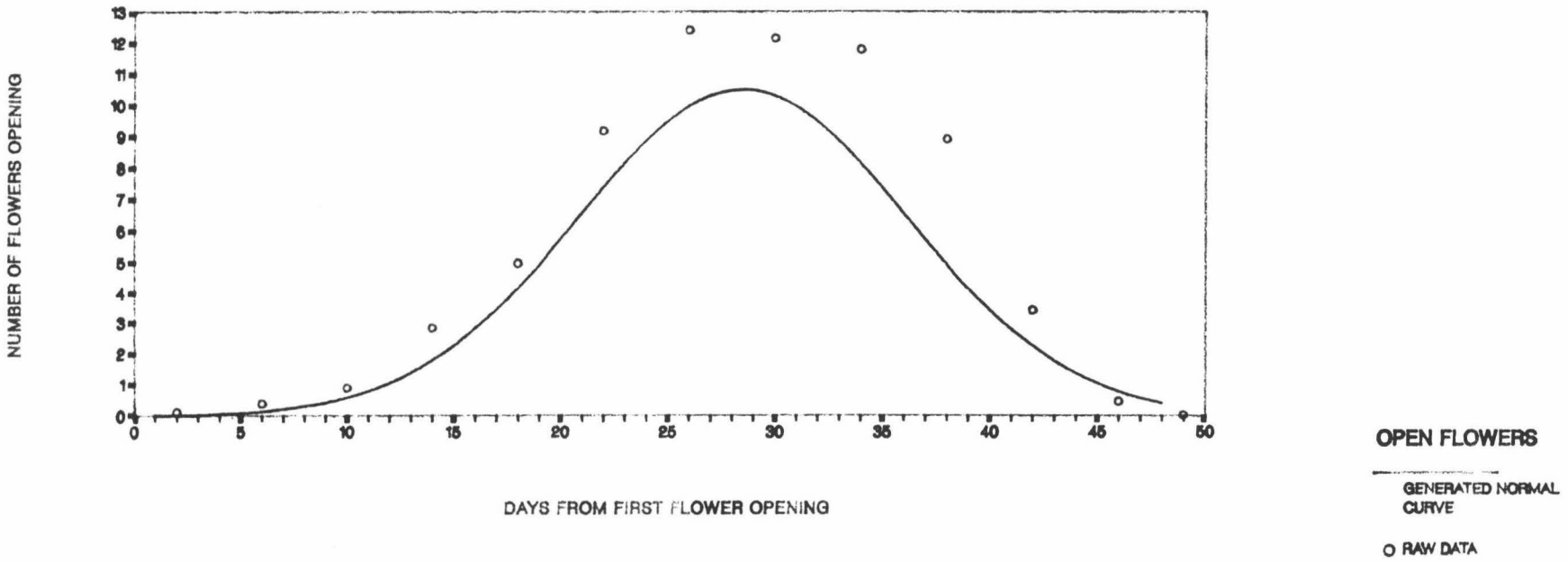
Further research, therefore, needs to be carried out with other process tomato cultivars, in conjunction with the application of chlorethephon. Provided enough data is collected over several sites and years, it may be possible to predict the optimal harvest date with some certainty, by sampling process tomato crops. Bussel and Halligan (1982) propose such a method of predicting optimum time of harvesting, by summation of degree days from application time of Ethephon which could provide a basis for such research. In the same way the use of ethylene biosynthesis inhibitors (amino-oxyacetic acid and alpha-aminoisobutyric acid) (Edwards, Henderson and Saltveit, 1984) to delay ripening until the optimum number of mature green fruit accumulate, and then apply chlorethephon to maximize the amount of ripe fruit, should be investigated.

The results of this experiment also questions the validity of once over harvests being used in variety trials of process tomatoes, and in other studies where the treatments may influence the maturity characteristics of the crop. Other methods of following the 'once-over harvest' yield of process grade (marketable) fruit such as the 'cumulative harvest' method (MacNab and Pennypacker, 1981) should be reexamined in light of this experiment.

As over half of the fruit had rotted by 136 days after planting, research is also needed into causes of poor vine storage in processing tomatoes. This could involve a search for better fungicides to control fruit rotting problems, or plant breeding for a better vine storage cultivar.

FIGURE I.

NUMBER OF FLOWER OPENINGS PER DAY PER PLANT (COMBINED DATA cvs. CASTLEHY 1204 AND UC 82B)



NUMBER OF FLOWER OPENINGS PER DAY PER PLANT WHICH PRODUCE FRUIT (COMBINED DATA cvs. CASTLEHY 1204 AND UC 82B)

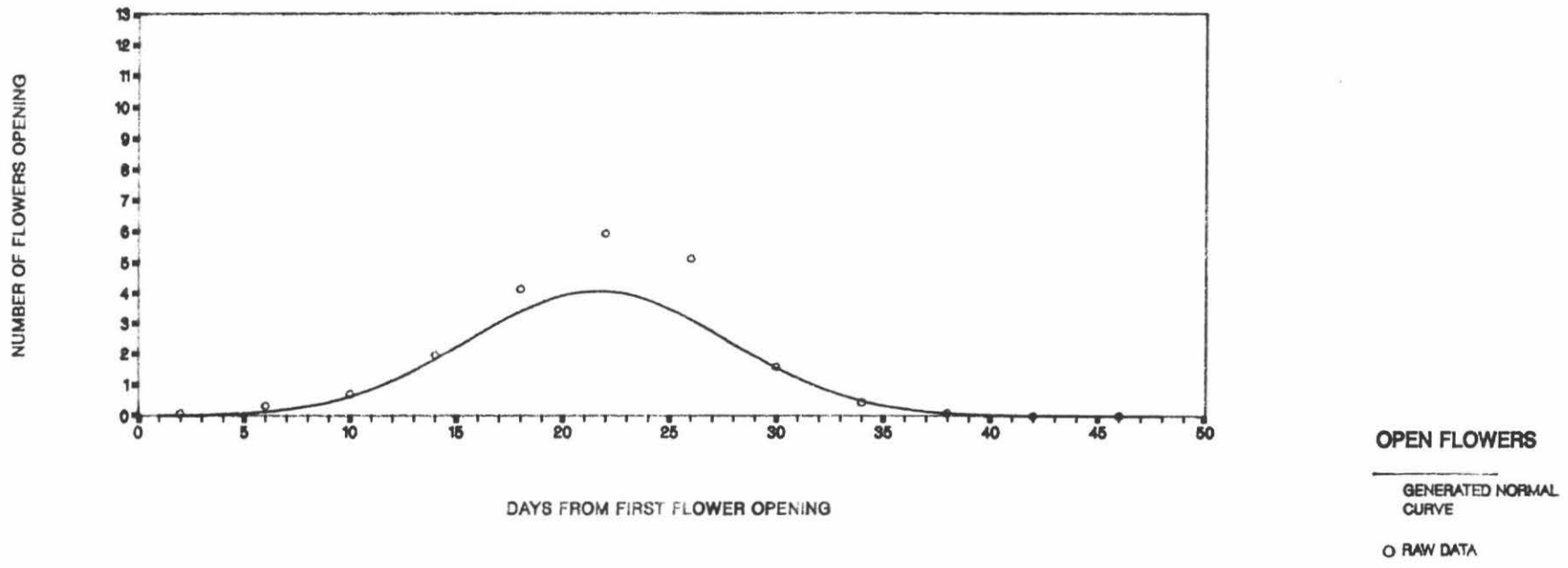


FIGURE II.

NUMBER OF FLOWER OPENINGS PER DAY PER PLANT WHICH PRODUCE FRUIT (COMBINED DATA cvs. CASTLEHY 1204 AND UC 82B)

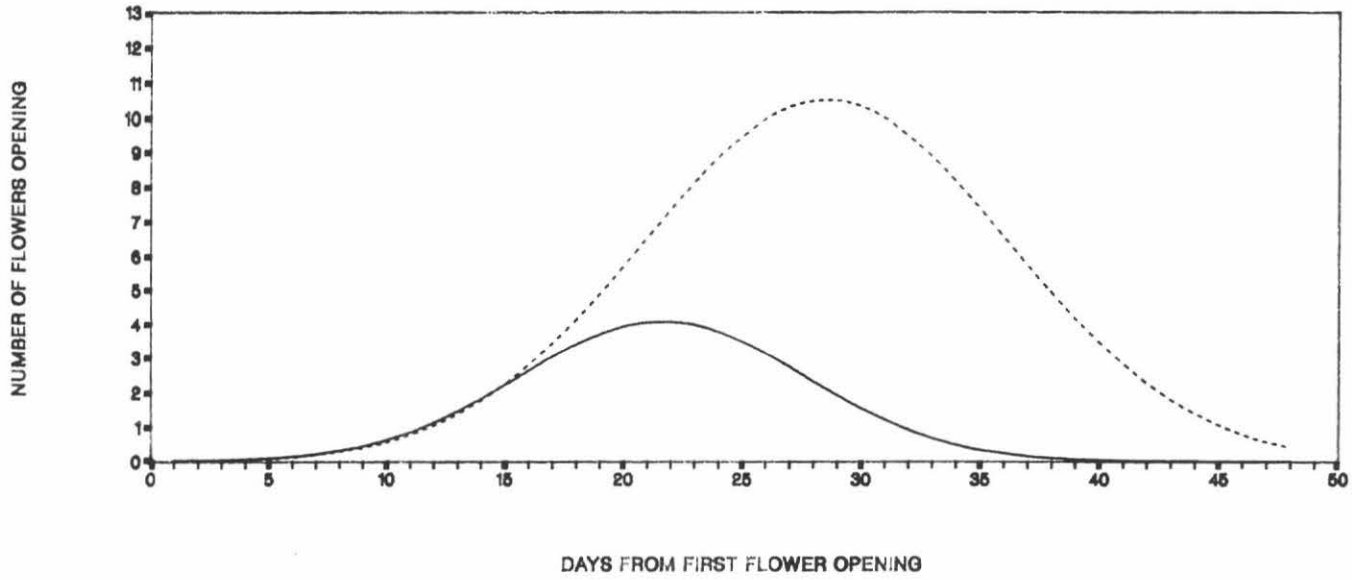


FIGURE III.

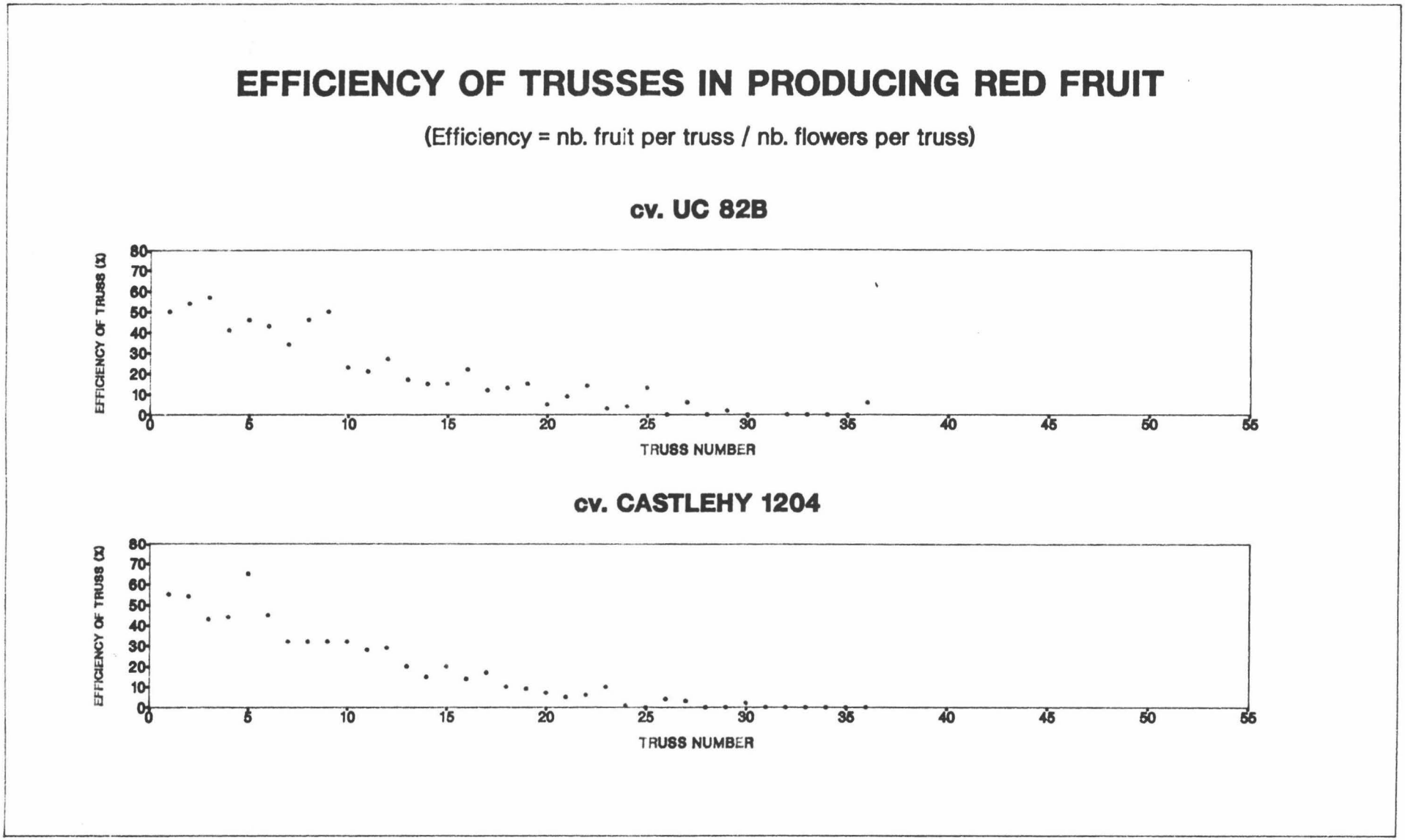

EFFICIENCY OF TRUSSES IN PRODUCING RED FRUIT
(Efficiency = nb. fruit per truss / nb. flowers per truss)
cv. UC 82B
EFFICIENCY OF TRUSS (%)
TRUSS NUMBER
cv. CASTLEHY 1204
EFFICIENCY OF TRUSS (%)
TRUSS NUMBER

FIGURE IV.

EFFICIENCY OF TRUSSES IN PRODUCING FACTORY GRADE (RED AND COL.) FRUIT

(Efficiency = nb. fruit per truss / nb. flowers per truss)

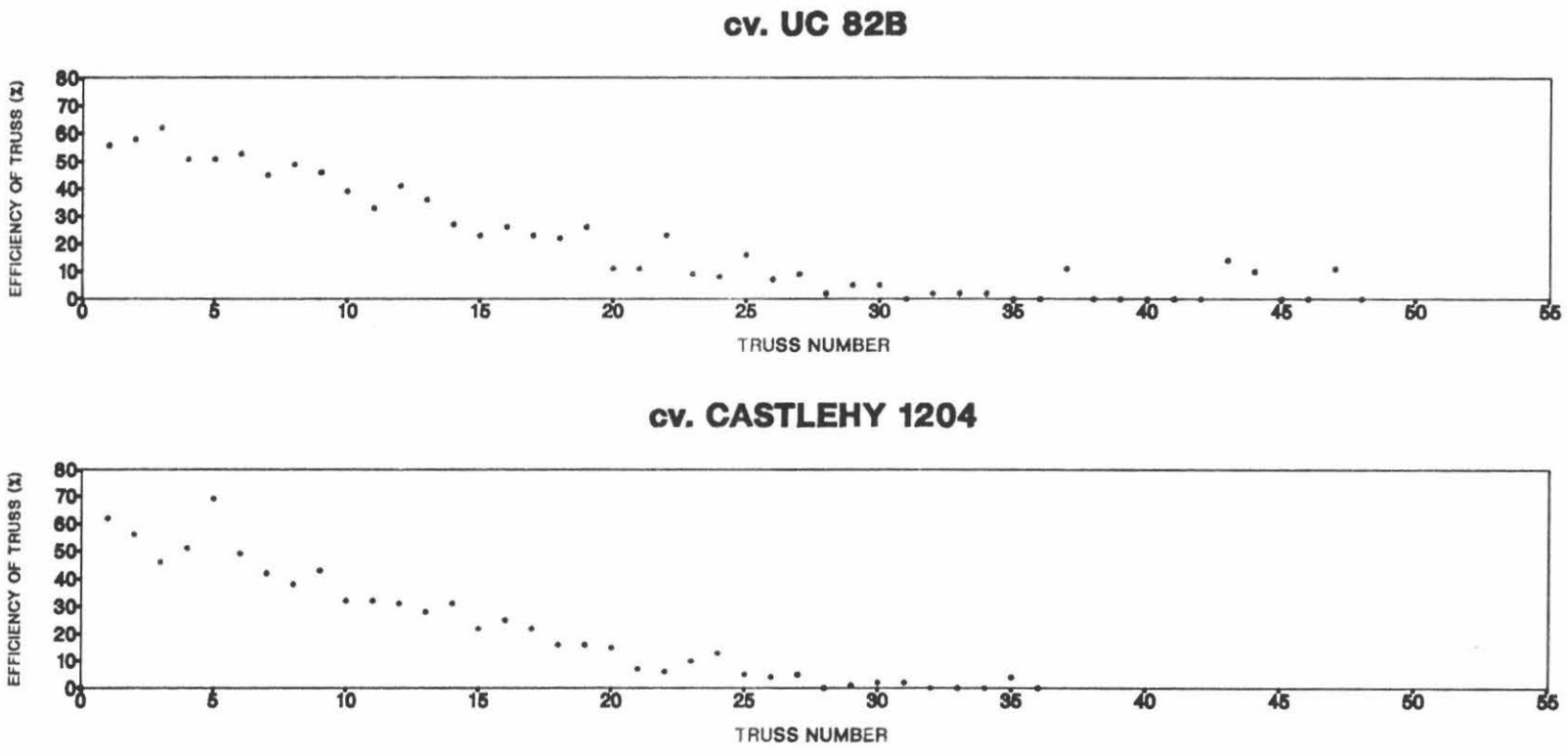


FIGURE V.

EFFICIENCY OF TRUSSES IN PRODUCING RED, COLOURED AND GREEN FRUIT

(effic = number of fruit per truss / number of flowers per truss)

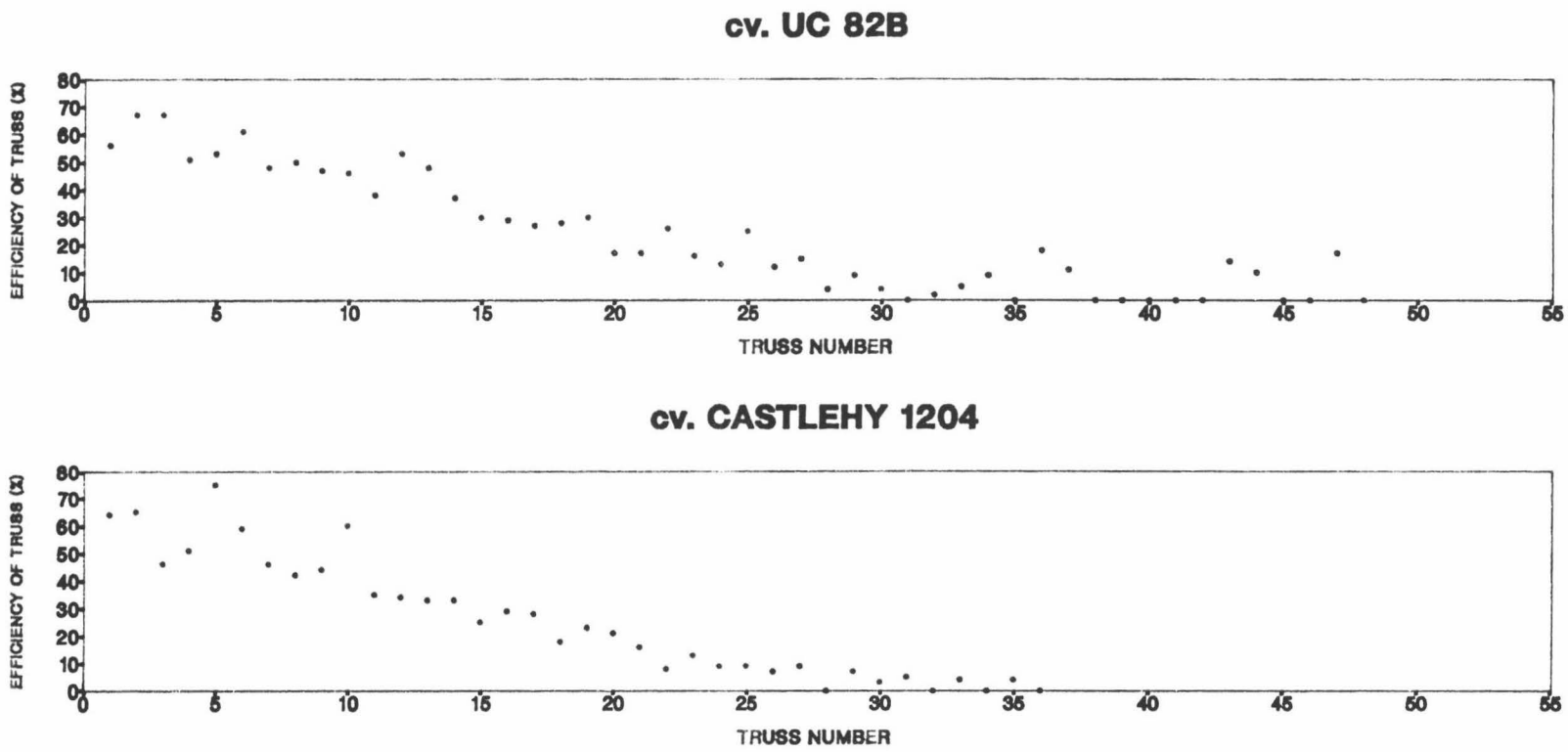


FIGURE VI.

CUMULATIVE PERCENTAGE OF THE NUMBER OF RED FRUIT PRODUCED ON EACH TRUSS.

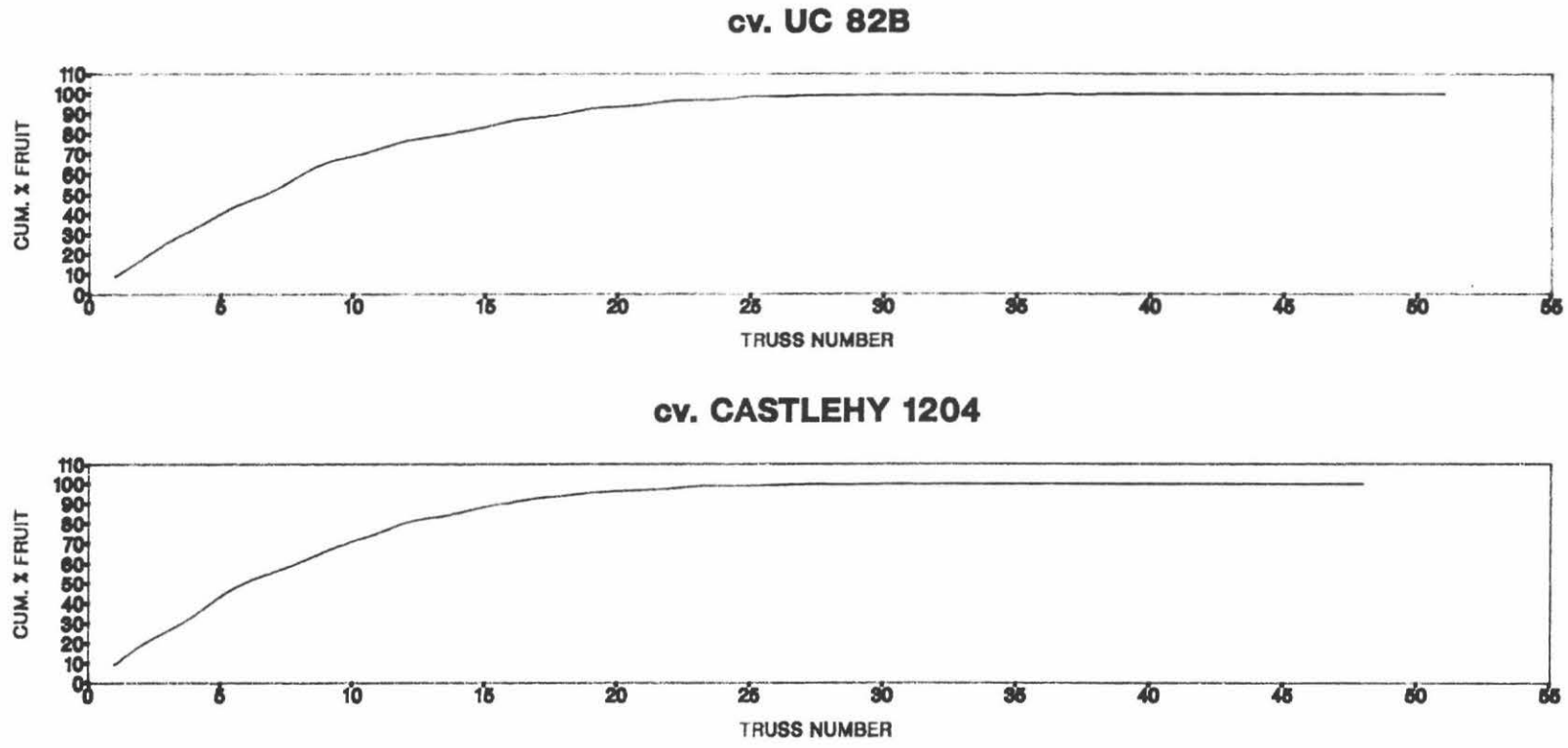


FIGURE VII.

CUMULATIVE PERCENTAGE OF THE NUMBER OF FACTORY GRADE (RED AND COLOURED) FRUIT PRODUCED ON EACH TRUSS.

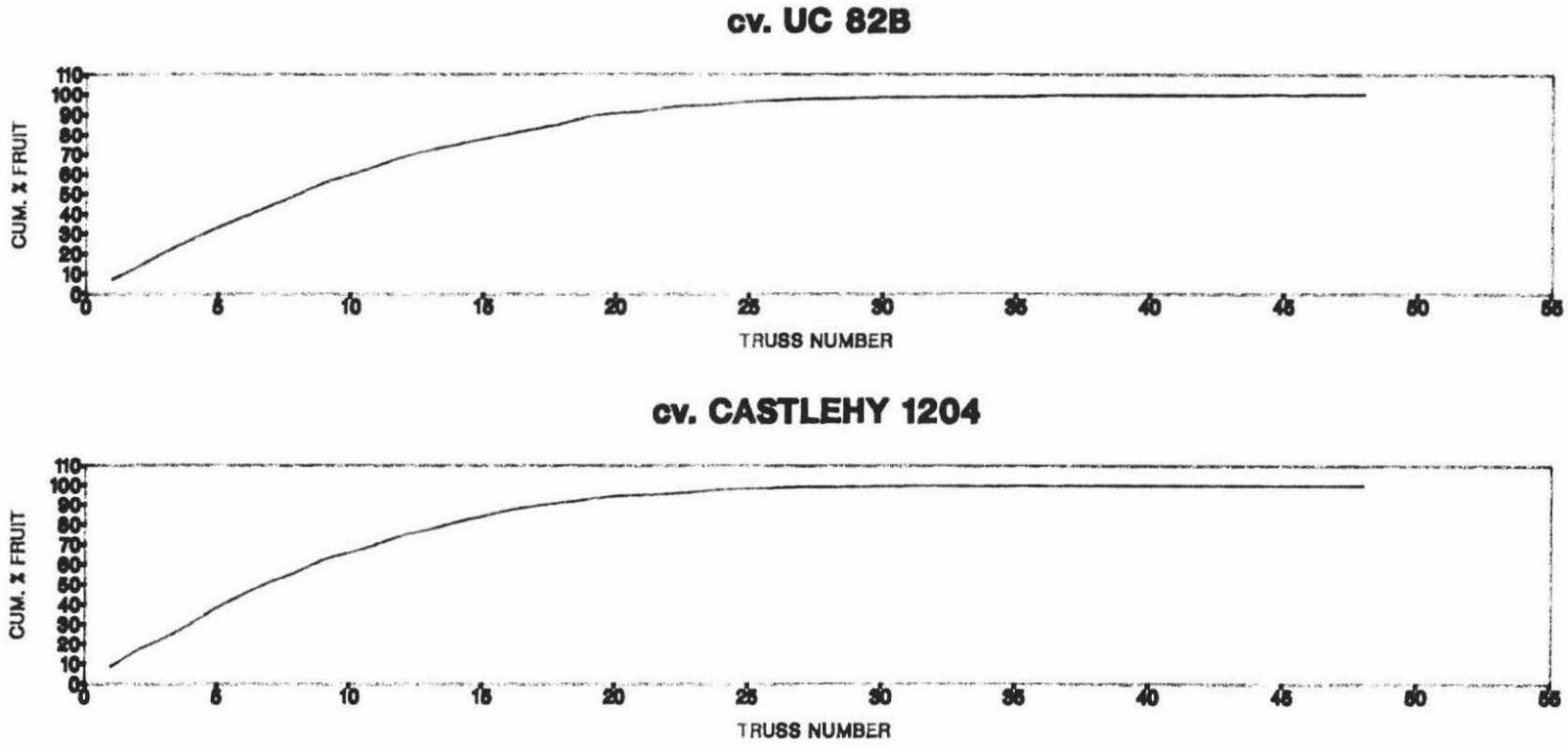


FIGURE VIII.

CUMULATIVE PERCENTAGE OF THE NUMBER OF RED, COLOURED AND GREEN FRUIT PRODUCED ON EACH TRUSS.

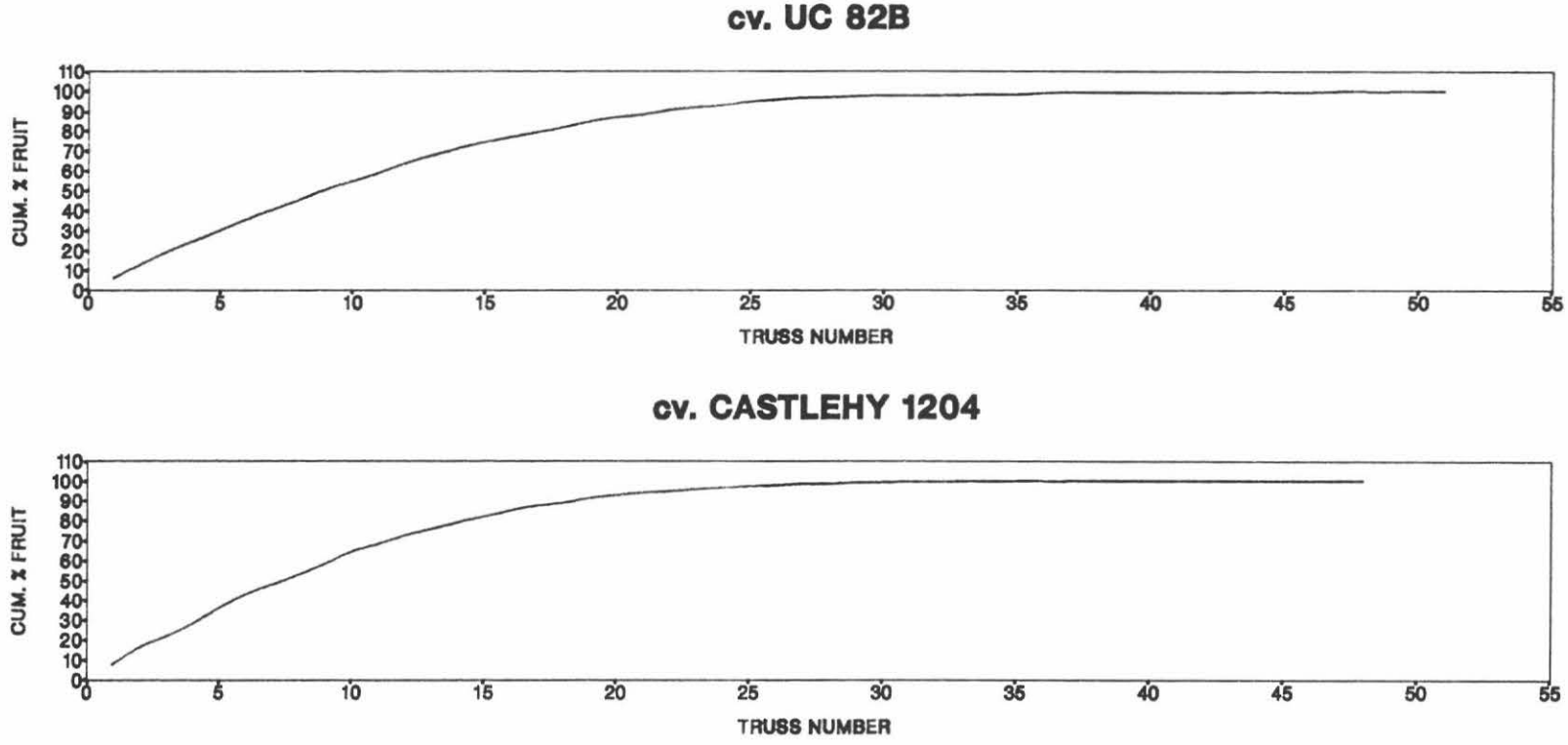
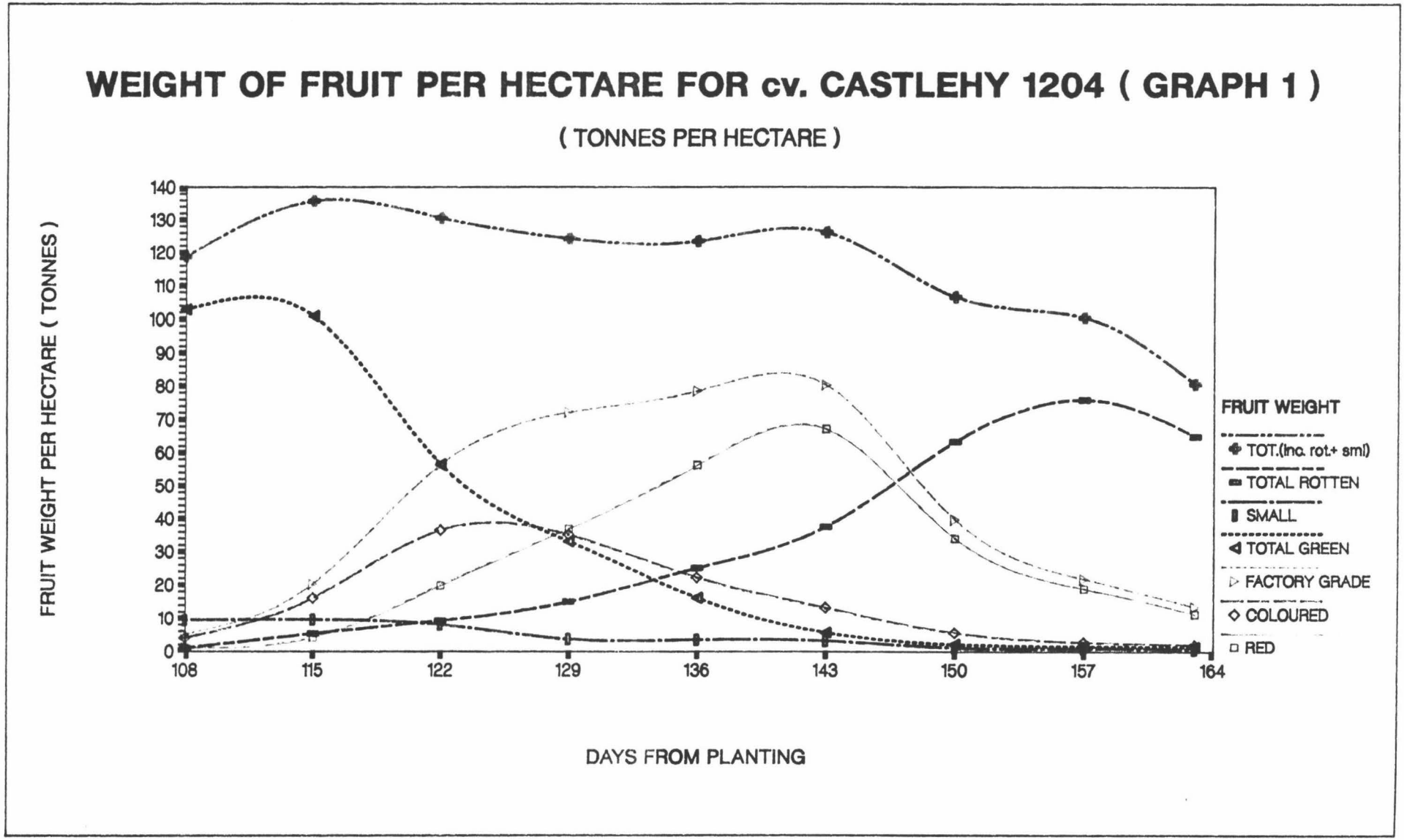


FIGURE IX.

FIGURE X.


WEIGHT OF FRUIT PER HECTARE FOR cv. CASTLEHY 1204 (GRAPH 1)
(TONNES PER HECTARE)
FRUIT WEIGHT PER HECTARE (TONNES)
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
108
115
122
129
136
143
150
157
164
DAYS FROM PLANTING
FRUIT WEIGHT
TOT.(Inc. rot.+ sml)
TOTAL ROTTEN
SMALL
TOTAL GREEN
FACTORY GRADE
COLOURED
RED

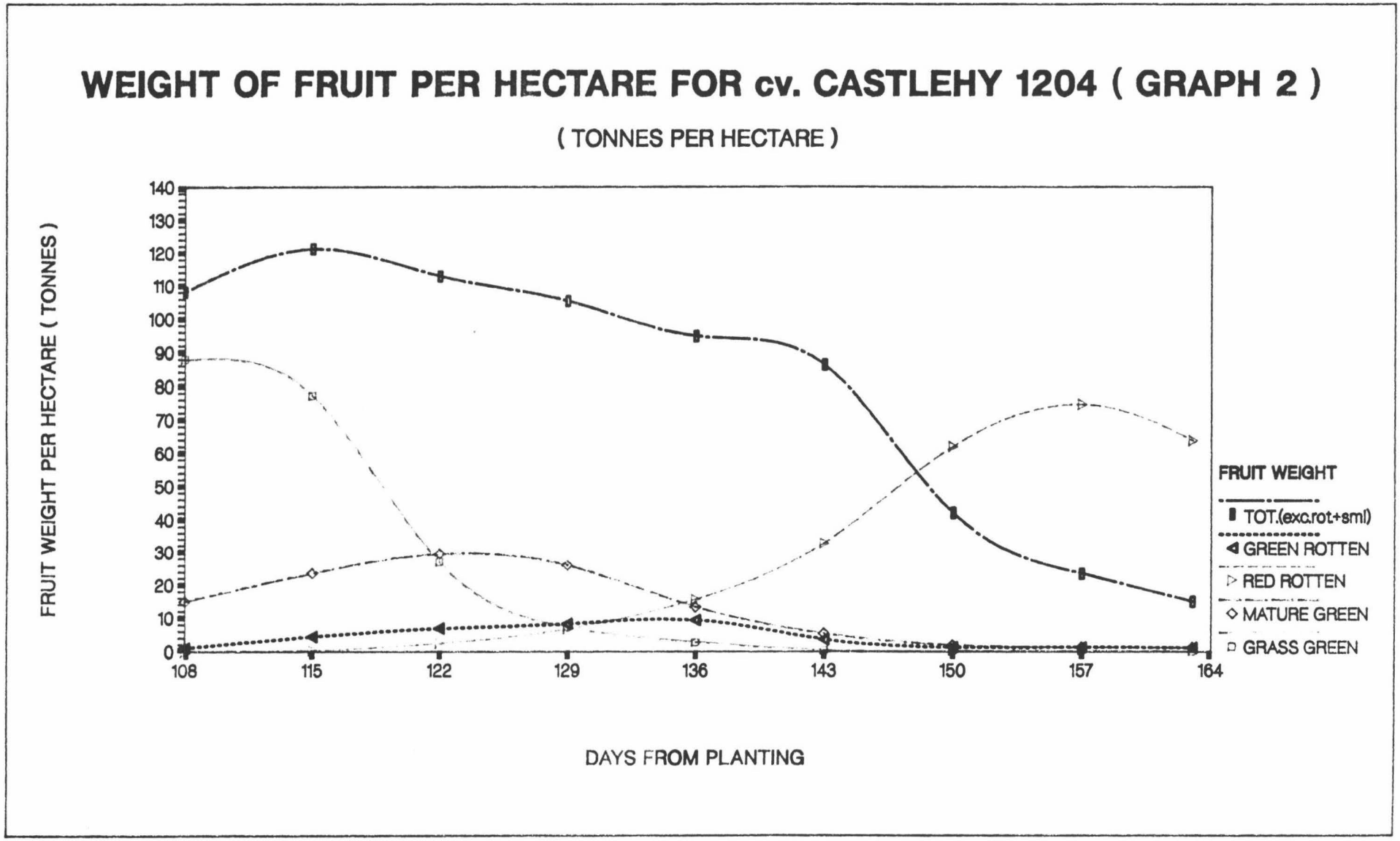

WEIGHT OF FRUIT PER HECTARE FOR cv. CASTLEHY 1204 (GRAPH 2)
(TONNES PER HECTARE)
FRUIT WEIGHT PER HECTARE (TONNES)
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
108
115
122
129
136
143
150
157
164
DAYS FROM PLANTING
FRUIT WEIGHT
TOT.(exc.rot+sml)
GREEN ROTTEN
RED ROTTEN
MATURE GREEN
GRASS GREEN

FIGURE XI.

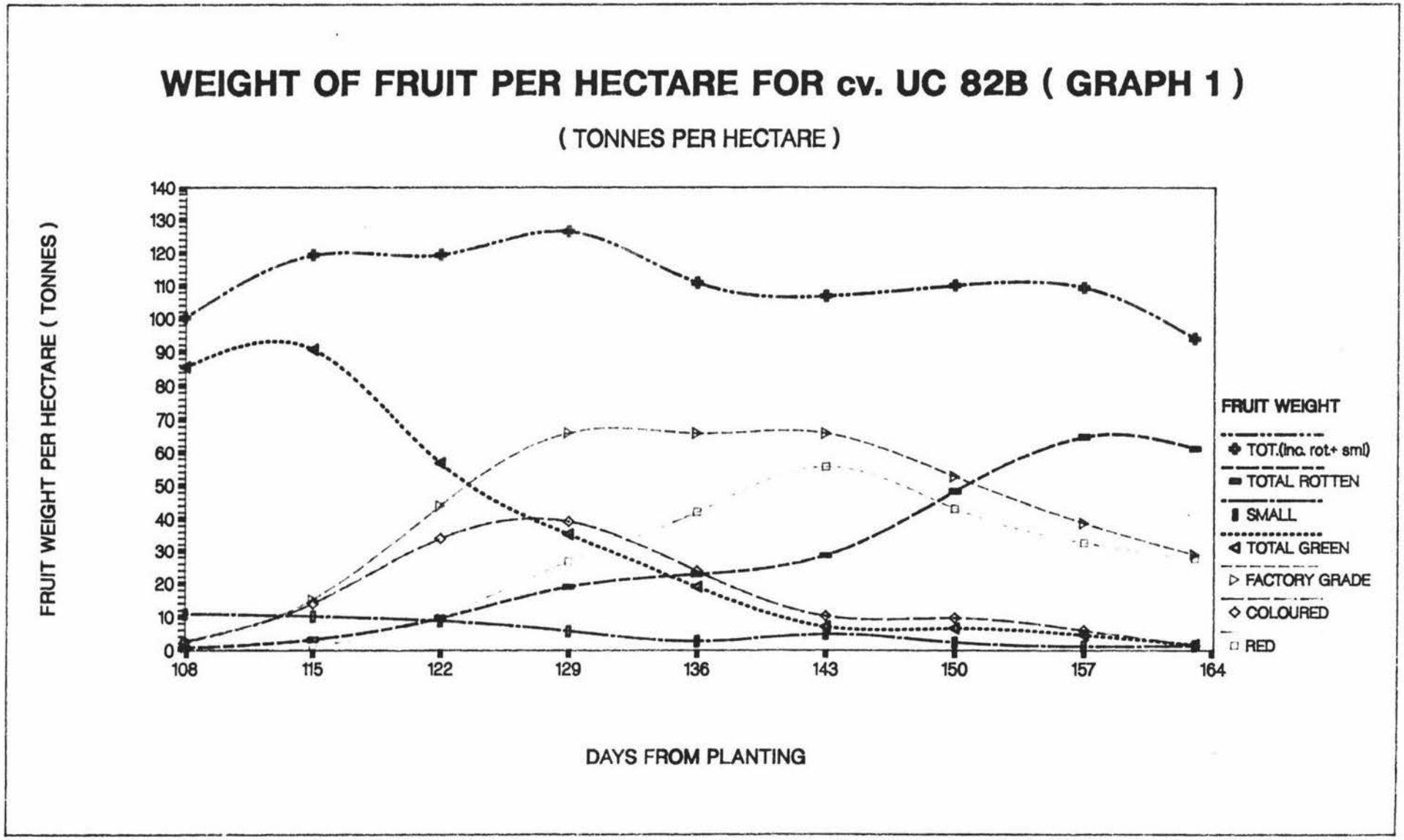

WEIGHT OF FRUIT PER HECTARE FOR cv. UC 82B (GRAPH 1)
(TONNES PER HECTARE)
FRUIT WEIGHT PER HECTARE (TONNES)
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
108
115
122
129
136
143
150
157
164
DAYS FROM PLANTING
FRUIT WEIGHT
TOT.(Inc. rot.+ sml)
TOTAL ROTTEN
SMALL
TOTAL GREEN
FACTORY GRADE
COLOURED
RED

FIGURE XII.

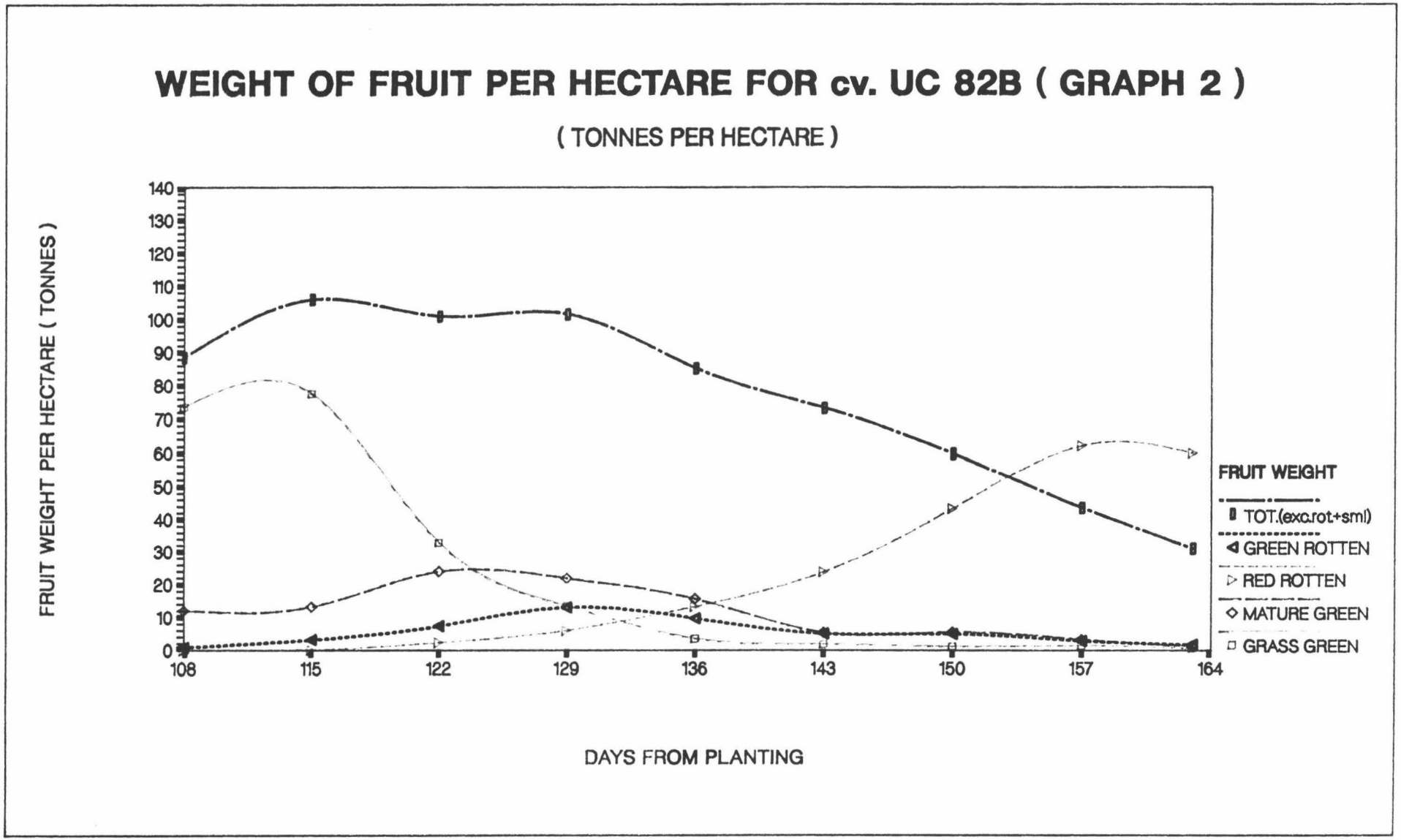

WEIGHT OF FRUIT PER HECTARE FOR cv. UC 82B (GRAPH 2)
(TONNES PER HECTARE)
FRUIT WEIGHT PER HECTARE (TONNES)
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
108
115
122
129
136
143
150
157
164
DAYS FROM PLANTING
FRUIT WEIGHT
TOT.(exc.rot+sml)
GREEN ROTTEN
RED ROTTEN
MATURE GREEN
GRASS GREEN

FIGURE XIII.

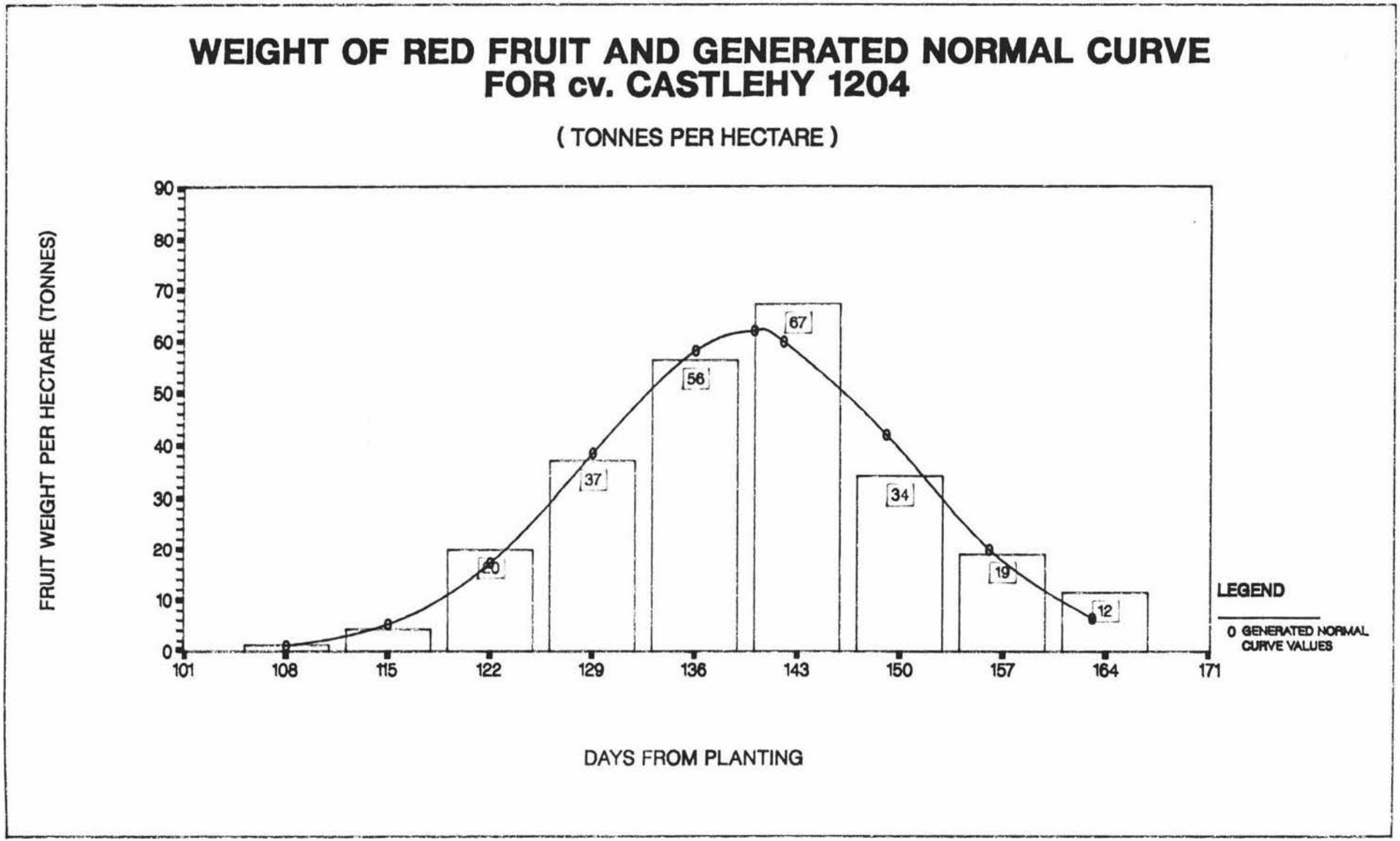

WEIGHT OF RED FRUIT AND GENERATED NORMAL CURVE
FOR cv. CASTLEHY 1204
(TONNES PER HECTARE)
FRUIT WEIGHT PER HECTARE (TONNES)
90
80
70
60
50
40
30
20
10
0
101
108
115
122
129
136
143
150
157
164
171
67
56
37
20
34
19
12
LEGEND
0 GENERATED NORMAL CURVE VALUES
DAYS FROM PLANTING

FIGURE XIV.

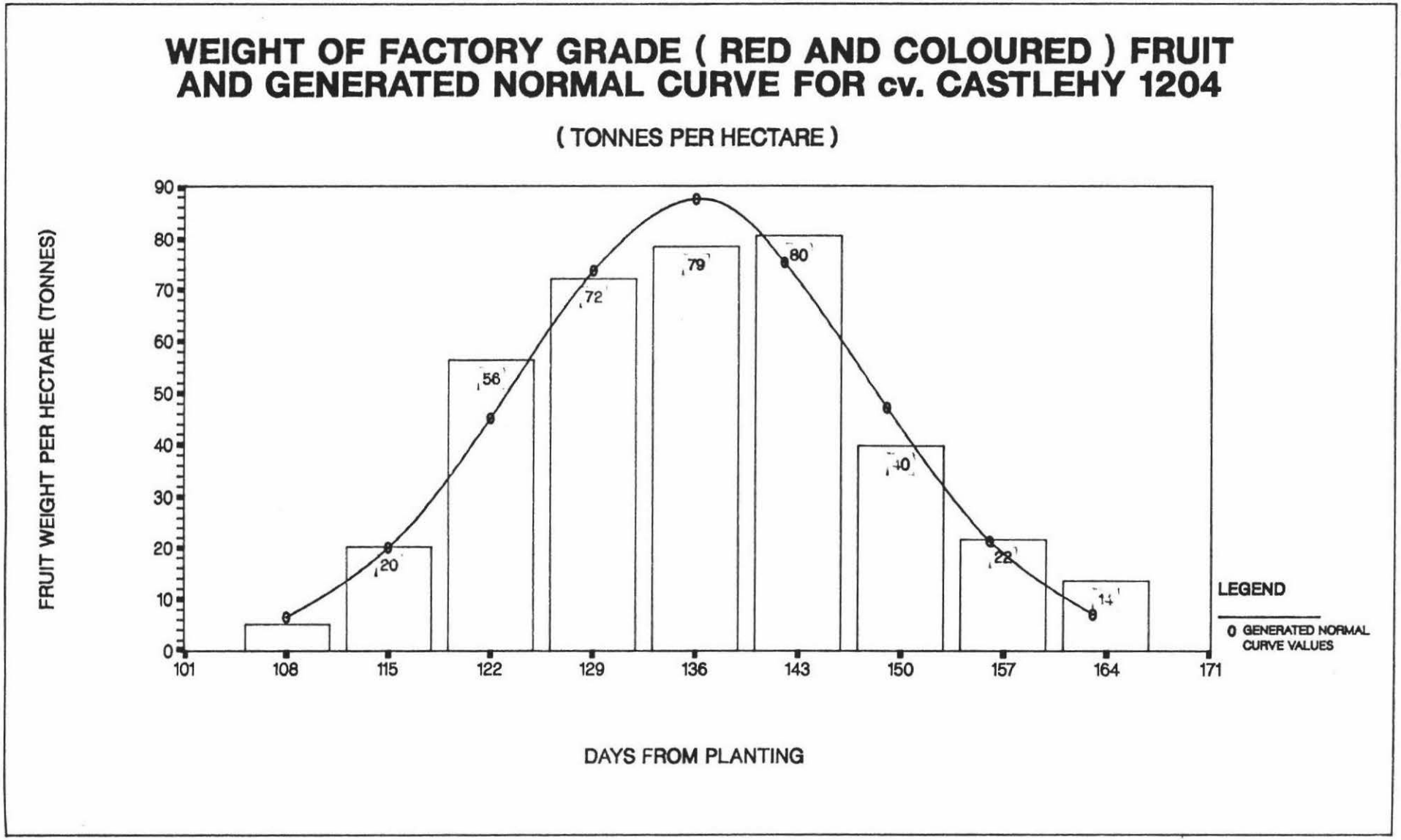

WEIGHT OF FACTORY GRADE (RED AND COLOURED) FRUIT AND GENERATED NORMAL CURVE FOR cv. CASTLEHY 1204
(TONNES PER HECTARE)
FRUIT WEIGHT PER HECTARE (TONNES)
90
80
70
60
50
40
30
20
10
0
20
56
72
79
80
40
22
14
101
108
115
122
129
136
143
150
157
164
171
LEGEND
0 GENERATED NORMAL CURVE VALUES
DAYS FROM PLANTING

FIGURE XV.

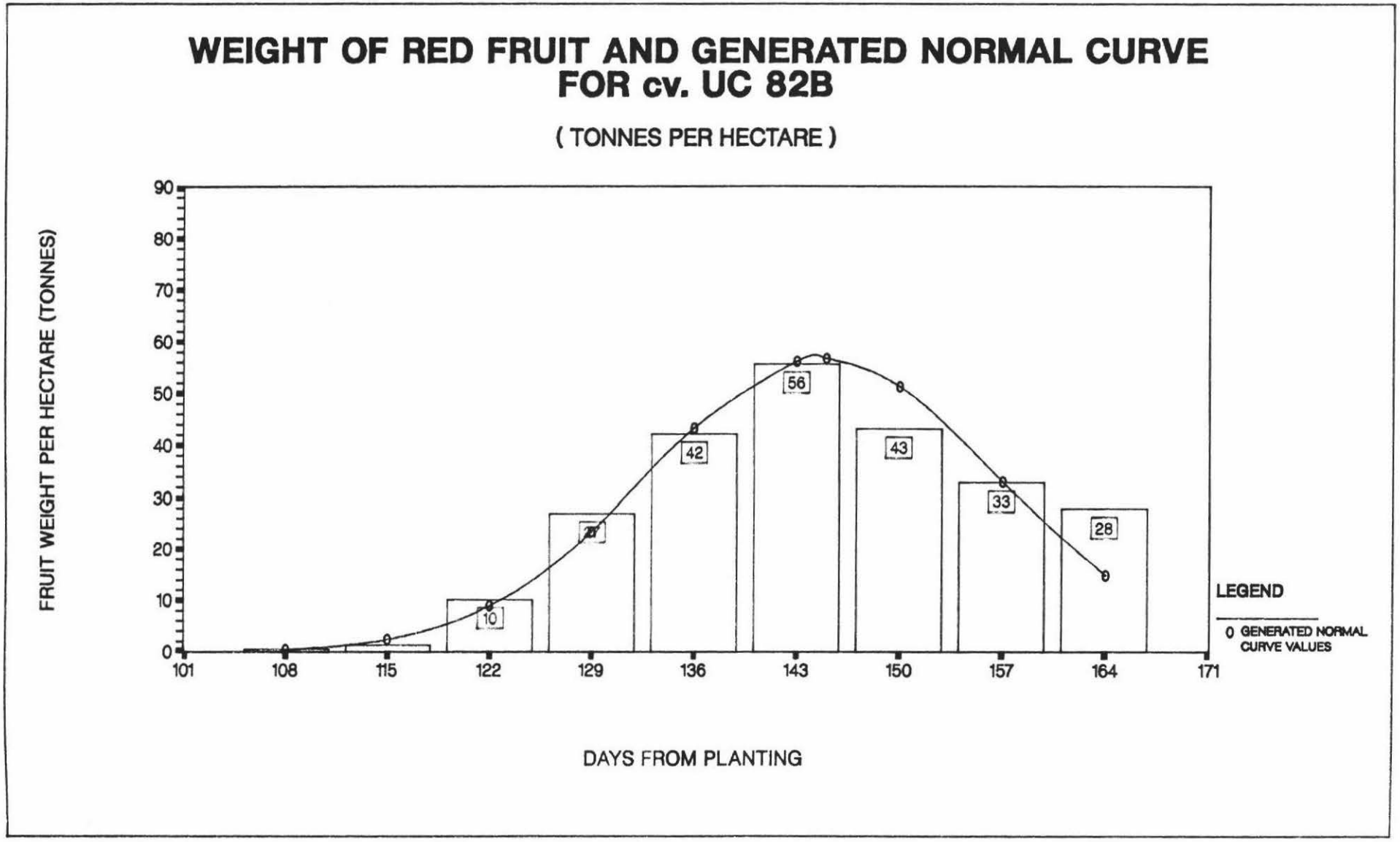

WEIGHT OF RED FRUIT AND GENERATED NORMAL CURVE FOR cv. UC 82B
(TONNES PER HECTARE)
FRUIT WEIGHT PER HECTARE (TONNES)
90
80
70
60
50
40
30
20
10
0
10
42
56
43
33
28
101
108
115
122
129
136
143
150
157
164
171
DAYS FROM PLANTING
LEGEND
0 GENERATED NORMAL CURVE VALUES

FIGURE XVI.

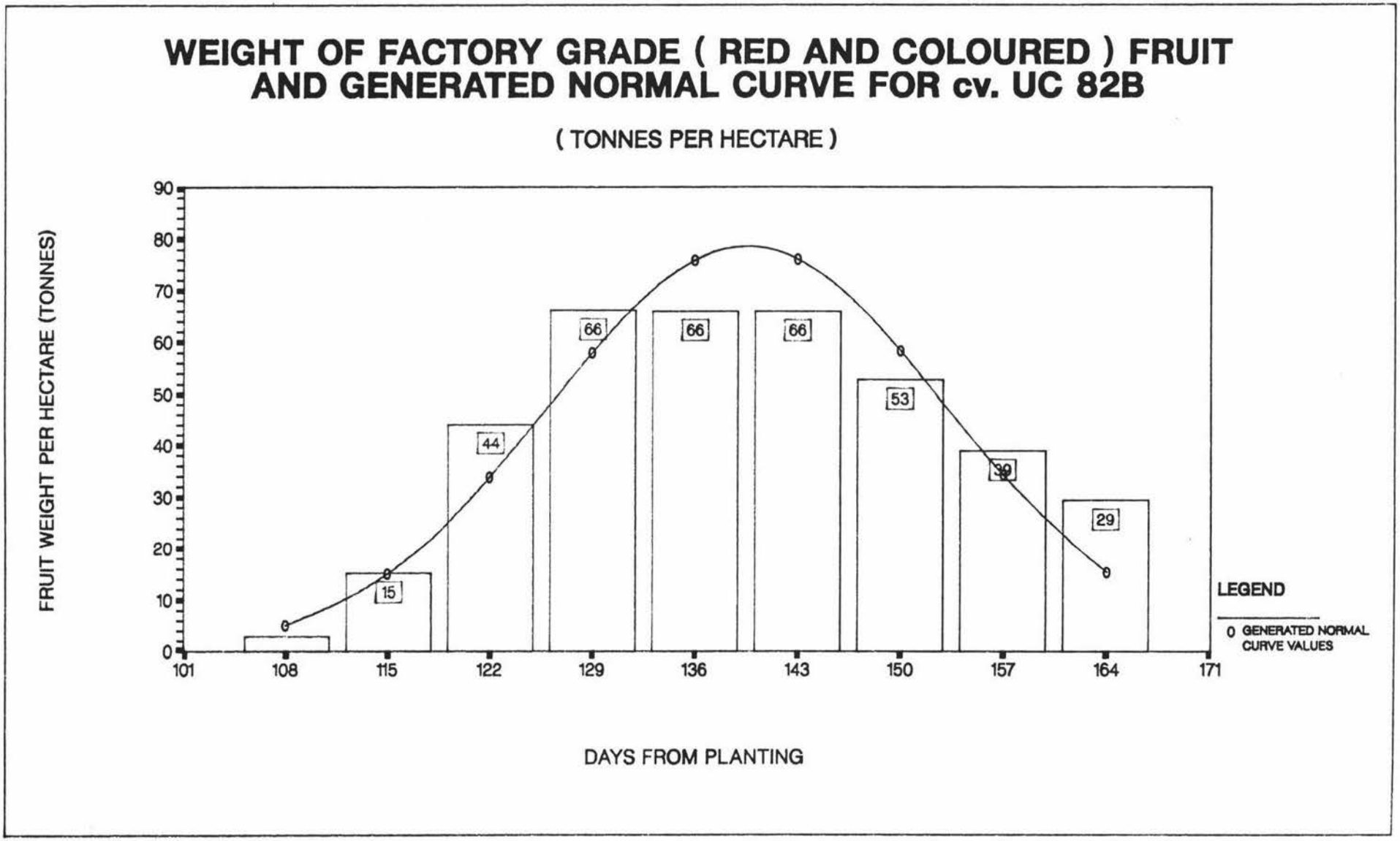

WEIGHT OF FACTORY GRADE (RED AND COLOURED) FRUIT AND GENERATED NORMAL CURVE FOR cv. UC 82B
(TONNES PER HECTARE)
FRUIT WEIGHT PER HECTARE (TONNES)
90
80
70
60
50
40
30
20
10
0
66
66
66
53
44
39
29
15
101
108
115
122
129
136
143
150
157
164
171
DAYS FROM PLANTING
LEGEND
0 GENERATED NORMAL CURVE VALUES

FIGURE XVII.

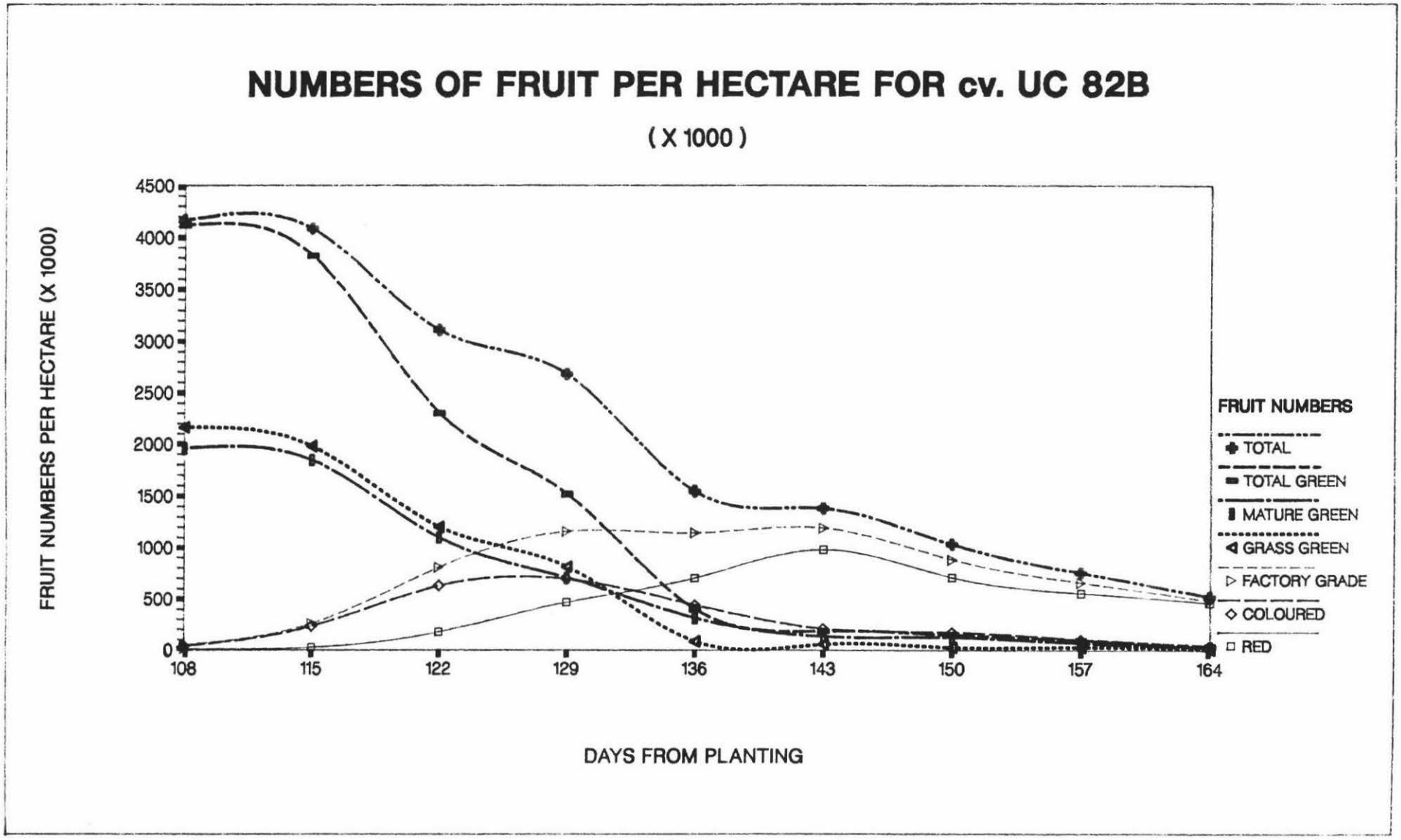


FIGURE XVIII.

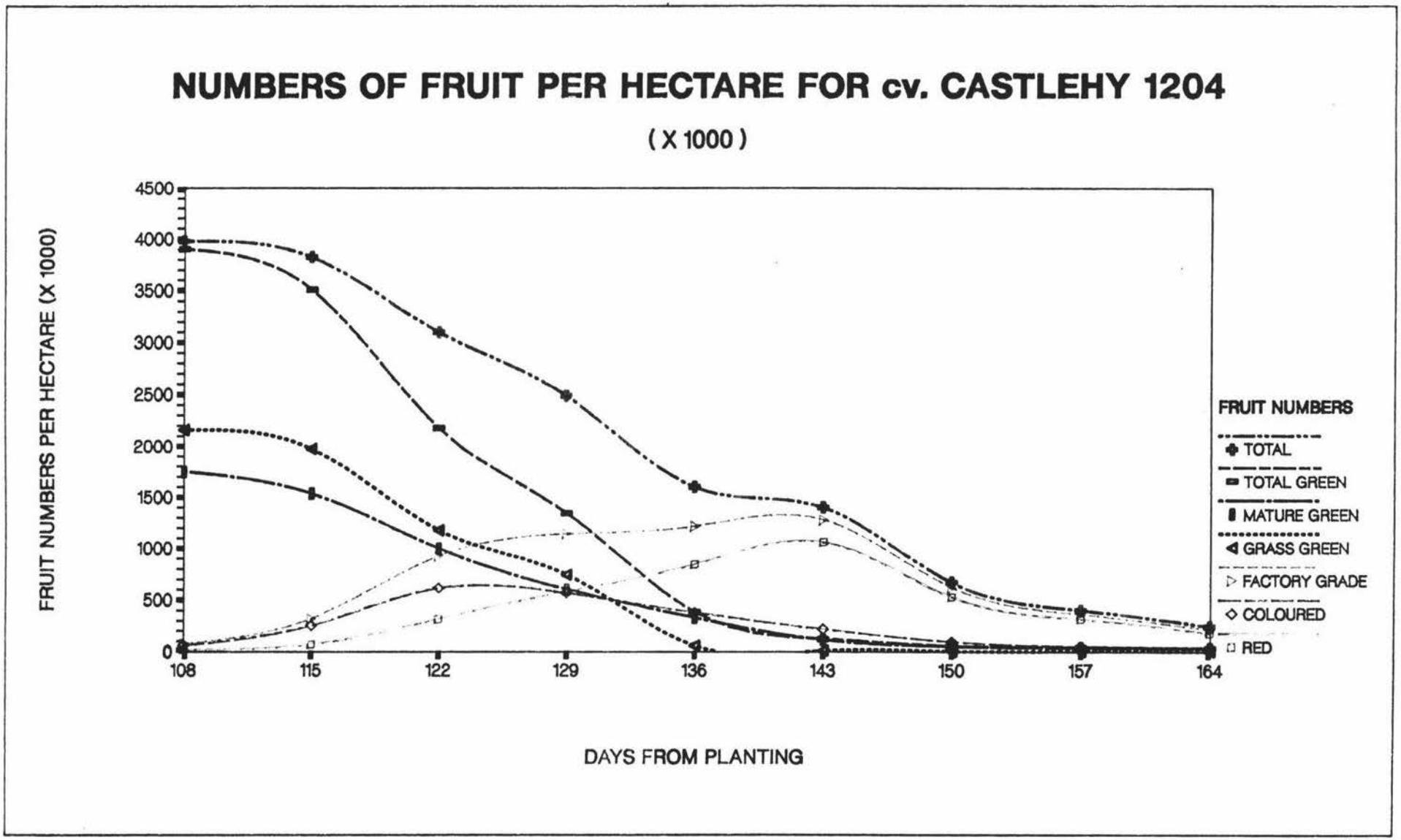

NUMBERS OF FRUIT PER HECTARE FOR cv. CASTLEHY 1204
(X 1000)
FRUIT NUMBERS PER HECTARE (X 1000)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
108
115
122
129
136
143
150
157
164
DAYS FROM PLANTING
FRUIT NUMBERS
TOTAL
TOTAL GREEN
MATURE GREEN
GRASS GREEN
FACTORY GRADE
COLOURED
RED

FIGURE XIX.

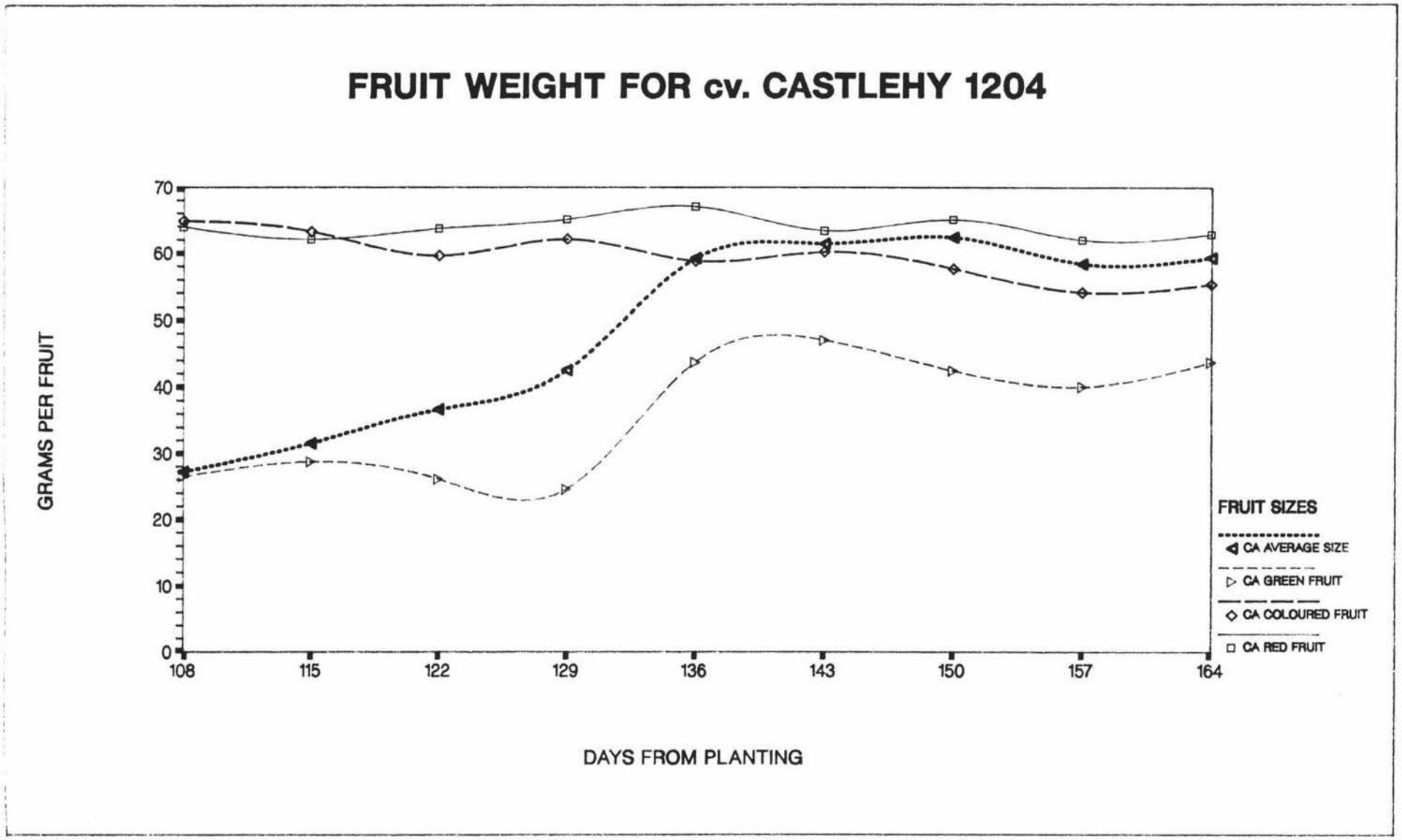

FRUIT WEIGHT FOR cv. CASTLEHY 1204
GRAMS PER FRUIT
70
60
50
40
30
20
10
0
108
115
122
129
136
143
150
157
164
DAYS FROM PLANTING
FRUIT SIZES
CA AVERAGE SIZE
CA GREEN FRUIT
CA COLOURED FRUIT
CA RED FRUIT

FIGURE XX.

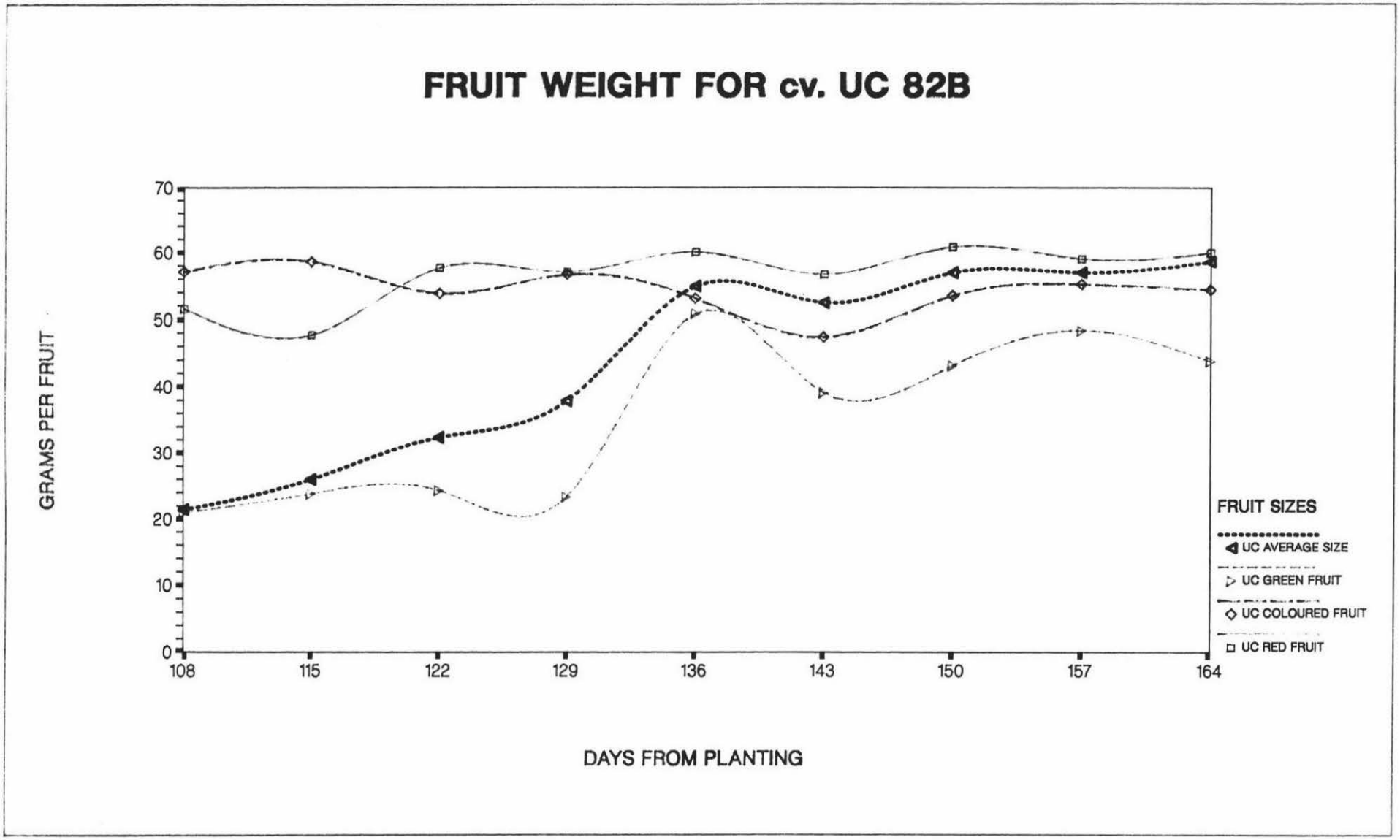

FRUIT WEIGHT FOR cv. UC 82B
GRAMS PER FRUIT
70
60
50
40
30
20
10
0
108
115
122
129
136
143
150
157
164
DAYS FROM PLANTING
FRUIT SIZES
UC AVERAGE SIZE
UC GREEN FRUIT
UC COLOURED FRUIT
UC RED FRUIT

FIGURE XXI.

WEEKLY RAINFALL AND COMBINED SOLUBLE SOLID MEANS FOR cvs. CASTLEHY 1204 AND UC 82B

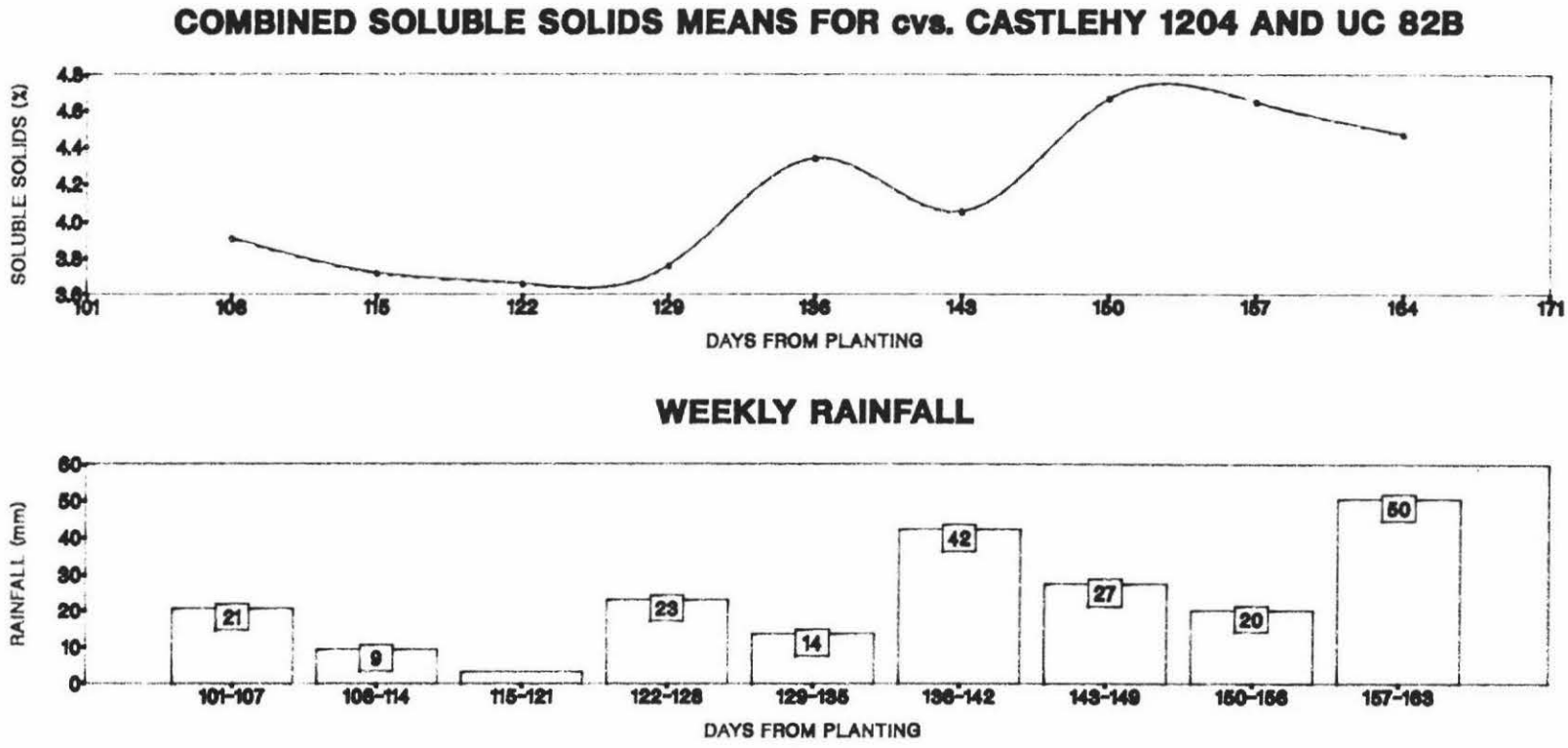


FIGURE XXII.

Figure XXIII- Diagrammatic Representation of a Typical Process Tomato Plant

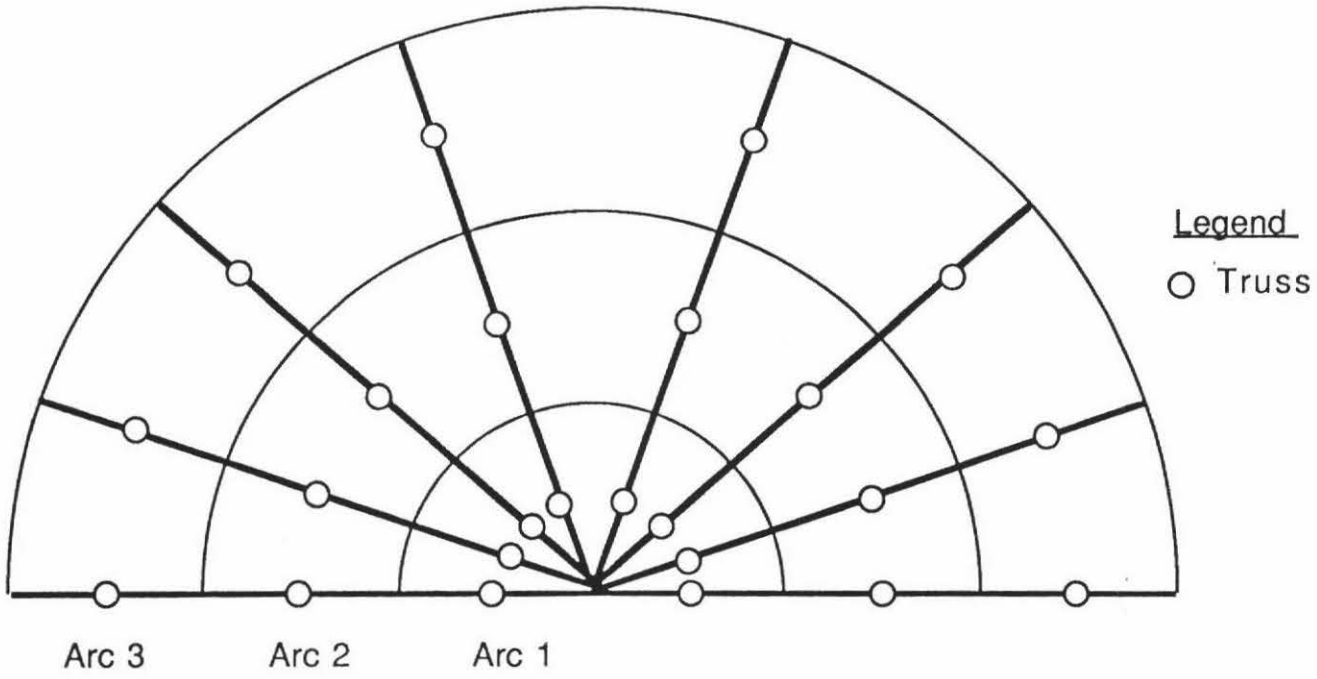


Figure XXIII

APPENDICES

APPENDIX I. CELL TRANSPLANT MEDIA

Ingredient	Amount / M^3
Sphagnum Peat Moss (sieved)	950 l.
Coarse River Sand	50 l.
Potassium Nitrate	1.00 kg.
Superphospate	2.25 kg.
Micromax (trace elements)	0.60 kg.
Lime	2.25 kg.
Dolomite	2.25 kg.

(Hiron and Symonds, 1985)

APPENDIX II. SPRAY PROGRAMME

i) SEEDLING STAGE (PRE TRANSPLANT)

Pesticide	Kg./100L
Streptomycin^{R} (Agrimycin)	0.03
Copper Oxychloride	0.10

Wetting agent (Citowette^{R}) was used it conjunction with the Agrimycin at a rate of 0.025 L./100L. One separate application of each of these sprays was applied while the seedlings were in the greenhouse.

ii)POST TRANSPLANT

Spray Period	Pesticide	Rate/Ha
Immediately post-transplant	Metasystox^{R}	1.10L.
	Copper Oxychloride	3.00Kg.
14 days later	Metasystox^{R}	1.10L.
	Copper Oxychloride	3.00Kg.
14 days later	Benlate^{R}	2.00Kg.
	Copper Oxychloride	3.00Kg.
14 days later	Copper Oxychloride	3.00Kg.
	Lannate^{R}	1.50L.
14 days later	Benlate^{R}	2.00Kg.
	Mancozeb^{R}	2.00Kg.
14 days later	Mancozeb^{R}	2.00Kg.
	Lannate^{R}	1.50L.
14 days later	Benlate^{R}	2.00Kg.
	Copper Oxychloride	3.00Kg.
14 days later	Mancozeb^{R}	2.00Kg.
	Lannate^{R}	1.50L.
Every 14 days	Mancozeb^{R}	2.00Kg.
between harvests	Lannate^{R}	1.50L.

(Anon, 1977)

APPENDIX III. SEEDLING LIQUID FEED

Fertiliser	Kg./100L.	PPM.	
Potassium sulphate	0.440		200 K_2O
Urea	0.217		100 N

(Hiron and Symonds, 1985)

APPENDIX IV. EXPERIMENTAL AREA SOIL TEST VALUES

Ministry of Agriculture and Fisheries Soil Test Results

pH	P	K	Mg	Na	Ca
6.3	60	16	23	9	12

Target Values (Tokomaru Silt Loam)

pH	P	K	Mg	Na	Ca
5.3-6.7	35-45	15	10-12	U.A.	>10

(Clarke et al, 1986)

APPENDIX V. FREQUENCY OF FLOWER OPENING - COMBINED DATA FOR BOTH CULTIVARS

DAYS FROM FIRST FLOWER OPENING	COMBINED TOTAL OF NUMBER OF FLOWERS OPENING (24 PLANTS)	MEAN NUMBER OF FLOWERS OPENING PER DAY PER PLANT.
0 -3.9	9	0.13
4 -7.9	29	0.40
8-11.9	66	0.92
12-15.9	205	2.85
16-19.9	360	5.00
20-23.9	662	9.19
24-27.9	895	12.43
28-31.9	876	12.17
32-35.9	850	11.81
36-39.9	642	8.92
40-43.2	249	3.46
44-47.9	35	0.49
48-51.9	3	0.04

APPENDIX VI. FREQUENCY OF FLOWER OPENINGS WHICH PRODUCE FRUIT - COMBINED DATA BOTH CULTIVARS.

DAYS FROM FIRST FLOWER OPENING	COMBINED TOTAL OF NUMBER OF FLOWERS OPEN (24 PLANTS)	MEAN NUMBER OF FLOWERS PER DAY PER PLANT
0 -3.9	6	0.08
4 -7.9	24	0.33
8 -11.9	51	0.71
12-15.9	141	4.14
16-19.9	298	5.94
20-23.9	428	5.14
24-27.9	370	1.58
28-31.9	114	0.44
32-35.9	32	0.11
36-39.9	8	0.01
40-43.9	1	0.01
44-47.9	2	0.02
48-51.9	0	0

APPENDIX VII. NORMAL DISTRIBUTION CURVE STATISTICS (EXPERIMENT ONE)

(Nichols, 1965)

Mean	Var.	Skew.	Kurt.	g1	g2	s.e. g1	s.e.g2
Frequency of flower openings							
28.5	2.47	-1.95E-04	2.94	-0.46	-5.12	1.22E-03	4.91E-03
Frequency of flower openings which result in fruit							
21.6	1.48	-2.05E-04	3.58	-0.297	0.594	4.06E-03	1.62E-02

Where;

Var. = VARIANCE

Skew. = SKEWNESS

Kurt. = KURTOSIS

NOTES

i Generated normal curve from the combined results of both cultivars.

ii For a Normal Distribution Curve Skewness =0 and Kurtosis =3

iii For a Normal Distribution Curve statistic g1 and g2 should be both equal to 0

iv s.e. g1 = Standard Error of G1 s.e. g2 = Standard Error of G2

APPENDIX VIII. EFFICIENCY OF TRUSSES IN PRODUCING FRUIT

	CASTLEHY 1204 IMP.			UC 82B		
TN.	EFF. R	EFF. R+C	EFF. R,C G	EFF. R	EFF. R+C	EFF. R,C,G
1	0.55	0.62	0.64	0.50	0.56	0.56
2	0.54	0.56	0.65	0.54	0.58	0.67
3	0.43	0.46	0.46	0.57	0.62	0.67
4	0.44	0.51	0.51	0.41	0.51	0.51
5	0.65	0.69	0.75	0.46	0.51	0.53
6	0.45	0.49	0.59	0.43	0.43	0.61
7	0.32	0.42	0.46	0.34	0.45	0.48
8	0.32	0.38	0.42	0.46	0.49	0.50
9	0.32	0.43	0.44	0.50	0.46	0.47
10	0.32	0.32	0.60	0.23	0.39	0.46
11	0.28	0.32	0.35	0.21	0.33	0.38
12	0.29	0.31	0.34	0.27	0.41	0.53
13	0.20	0.28	0.33	0.17	0.36	0.48
14	0.15	0.31	0.33	0.15	0.27	0.37
15	0.20	0.22	0.25	0.15	0.23	0.30
16	0.14	0.25	0.29	0.22	0.26	0.29
17	0.17	0.22	0.28	0.12	0.23	0.27
18	0.10	0.16	0.18	0.13	0.22	0.28
19	0.09	0.16	0.23	0.15	0.26	0.30
20	0.07	0.15	0.21	0.05	0.11	0.17
21	0.05	0.07	0.16	0.09	0.11	0.17
22	0.06	0.06	0.08	0.14	0.23	0.26
23	0.10	0.10	0.13	0.03	0.09	0.16
24	0.01	0.13	0.09	0.04	0.08	0.13
25	0	0.05	0.09	0.13	0.16	0.25
26	0.04	0.04	0.07	0	0.07	0.12
27	0.03	0.05	0.09	0.06	0.09	0.15
28	0	0	0	0	0.02	0.04
29	0	0.02	0.07	0.02	0.05	0.09
30	0.02	0.02	0.03	0	0.05	0.04
31	0	0.02	0.05	0	0	0
32	0	0	0	0	0.02	0.02
33	0	0	0.04	0	0.02	0.05
34	0	0.02	0.09	0	0.02	0.09
35	0	0.04	0.04	0	0	0
36	0	0	0	0.06	0	0.18
37	0	0	0	0	0.11	0.11

Where;

TN. = Truss Number

EFF. = Number of fruit per truss divided by the number of flowers per truss

EFF. R = Efficiency of the truss in producing red fruit

EFF. R+C = Efficiency of the truss in producing red and coloured fruit

EFF. R,C,G = Efficiency of the truss in producing red, coloured and green fruit.

APPENDIX IX. CUMULATIVE PERCENTAGE OF THE NUMBERS FRUIT PER TRUSS

	CASTLEHY 1204 IMP.			UC 82B		
TN	CU% R	CU% R+C	CU% R,C,G	CU% R	CU% R+C	CU% R,C,G
1	9.44	8.71	7.87	8.99	7.38	6.31
2	19.10	16.93	16.19	17.41	14.07	12.87
3	26.35	23.18	21.72	26.40	21.19	19.43
4	33.98	30.41	28.12	33.09	27.29	24.65
5	43.42	38.63	36.00	40.57	33.49	30.12
6	50.86	45.37	43.00	46.89	39.17	35.70
7	55.89	51.46	48.10	52.43	44.58	40.55
8	60.91	56.40	52.91	59.52	50.12	45.4
9	66.35	62.33	58.30	65.84	55.96	50.5
10	70.96	66.10	64.43	69.38	60.09	54.62
11	75.38	70.21	68.36	72.90	64.64	58.99
12	80.41	74.66	72.58	76.72	69.04	63.84
13	83.01	77.62	75.65	78.81	72.46	67.72
14	85.21	81.24	78.99	81.11	75.44	71.23
15	88.42	84.20	81.89	83.60	78.28	74.38
16	90.62	87.32	84.96	86.66	80.97	76.93
17	92.82	89.62	87.43	88.38	83.53	79.48
18	94.03	91.26	89.02	90.29	85.96	82.15
19	95.43	93.24	91.35	92.77	89.08	85.30
20	96.23	94.54	92.94	93.72	90.65	87.35
21	96.83	95.19	94.25	94.87	91.63	88.67
22	97.60	95.84	94.97	96.59	93.77	90.72
23	98.80	96.83	96.12	96.96	94.62	91.93
24	99.03	98.06	96.84	97.53	95.47	93.02
25	99.38	98.55	97.56	98.37	96.75	94.71
26	99.42	98.87	98.00	98.87	97.32	95.55
27	99.80	99.36	98.72	99.44	98.03	96.51
28	99.80	99.36	98.72	99.63	98.17	96.74
29	99.80	99.52	99.29	99.63	98.60	97.33
30	100.00	99.67	99.43	99.63	98.89	97.56
31		99.82	99.71	99.63	98.89	97.56
32		99.82	99.71	99.63	99.02	97.67
33		99.82	99.85	99.63	99.16	97.90
34		99.82	99.85	99.63	99.30	98.26
35		100.00	99.85	99.63	99.30	98.26
36			99.85	100.00	99.72	98.98
37			100.00		99.86	99.34
38					99.86	99.34
39					99.86	99.34
40					99.86	99.34
41					99.86	99.34
42					99.86	99.34
43					99.86	99.45
44					100.00	99.60
45						99.60
46						99.60
47						100.00

Where:

TN = Truss Number

CU% R = Cumulative percentage of the number of red fruit

CU% R+C = Cumulative percentage of the number of red and coloured fruit

CU% R,C,G= Cumulative percentage of the number of red, coloured and green fruit

APPENDIX X. FRUIT WEIGHT DATA

CASTLEHY 1204 IMP.

(Tonnes per hectare)

BLOCK 1

DAYS	RED	COL	FACT	GGR	MGR	TGR	SML	RROT	GROT	TROT	TWP	TWP(NRS)
108	0.64	3.51	4.15	84.27	12.48	96.75	7.72	0.00	1.23	1.23	109.86	100.90
115	3.27	13.18	16.45	73.52	21.48	95.00	8.68	0.27	3.51	3.78	123.92	111.45
122	19.33	37.33	56.66	23.07	32.10	55.17	6.66	1.67	7.33	9.00	127.50	111.83
129	28.67	39.83	68.50	13.10	32.73	45.83	4.54	4.32	4.50	8.82	127.70	114.33
136	55.83	22.50	78.33	0.75	15.17	15.92	3.54	20.67	7.67	28.33	126.12	94.25
143	70.00	13.00	83.00	1.00	5.56	6.55	1.16	35.33	2.00	37.33	128.04	89.55
150	29.00	7.95	36.95	0.00	2.57	2.57	1.60	64.17	0.77	64.94	106.06	39.52
157	20.00	4.13	24.13	0.51	1.40	1.91	1.35	74.50	2.40	76.90	104.29	26.04
164	5.33	1.26	6.59	0.23	1.09	1.33	0.43	58.67	0.65	59.31	67.66	7.92

BLOCK 2

DAYS	RED	COL	FACT	GGR	MGR	TGR	SML	RROT	GROT	TROT	TWP	TWP(NRS)
108	1.83	5.60	7.43	96.21	13.95	110.17	8.93	0.00	0.41	0.41	126.94	117.60
115	4.56	16.88	21.44	66.74	24.42	91.17	7.45	0.36	1.69	2.06	122.12	112.61
122	22.50	35.00	57.50	19.99	26.67	46.67	5.00	1.83	6.33	8.17	117.33	104.17
129	34.50	28.50	63.00	5.44	19.23	24.67	2.09	6.83	6.33	13.17	102.92	87.67
136	60.83	20.33	81.16	3.56	7.88	11.44	4.27	11.67	3.33	15.00	111.88	92.61
143	79.83	11.83	91.66	0.15	8.08	8.23	5.06	37.17	3.70	40.87	145.82	99.90
150	52.83	2.37	54.70	0.22	1.20	1.42	1.28	64.50	3.09	67.59	125.00	56.13
157	24.83	2.60	27.43	0.00	0.42	0.42	1.26	74.33	0.96	75.29	104.41	27.86
164	7.37	0.76	7.83	0.05	0.41	0.46	0.53	64.00	0.76	64.76	73.57	8.28

BLOCK 3

DAYS	RED	COL	FACT	GGR	MGR	TGR	SML	RROT	GROT	TROT	TWF	TWF(NRS)
108	1.95	3.57	5.52	86.59	13.58	100.17	13.80	0.00	0.71	0.71	120.19	105.68
115	1.81	17.20	19.01	81.94	27.22	109.17	8.03	0.31	3.47	3.78	140.00	128.18
122	20.17	34.50	54.67	23.05	33.29	56.33	9.83	4.33	6.67	11.00	131.83	111.00
129	50.33	31.33	81.66	3.53	18.80	22.33	4.80	7.83	8.33	16.17	124.96	104.00
136	47.17	23.17	70.34	5.28	21.33	26.61	4.08	13.33	8.83	22.17	123.19	96.94
143	63.17	16.50	79.67	0.25	4.30	4.55	4.95	32.33	3.91	36.25	125.42	84.21
150	26.83	6.08	32.91	0.15	2.38	2.53	0.56	56.50	0.78	57.28	93.28	35.43
157	8.17	0.99	9.16	0.16	1.43	1.59	0.39	68.50	0.26	68.76	79.89	10.75
164	19.37	4.72	24.09	0.00	1.91	1.91	1.00	68.33	3.04	71.37	98.37	26.00

BLOCK 4

DAYS	RED	COL	FACT	GGR	MGR	TGR	SML	RROT	GROT	TROT	TWF	TWF(NRS)
108	0.42	2.86	3.28	84.28	20.05	104.33	7.62	0.00	1.97	1.97	117.20	107.61
115	7.29	16.67	23.96	86.67	21.49	108.17	14.70	0.59	9.37	9.96	156.78	132.12
122	17.67	39.00	56.67	41.68	25.99	67.67	11.17	2.17	7.50	9.67	145.17	124.33
129	34.67	40.83	75.50	6.57	33.27	39.83	3.64	8.08	14.17	22.25	141.22	115.33
136	61.67	22.67	84.34	1.33	9.34	10.67	2.66	17.17	17.83	35.00	132.67	95.01
143	56.00	11.50	67.50	0.05	3.67	3.72	1.99	26.83	5.34	32.18	105.39	71.22
150	28.33	6.08	34.41	0.11	2.02	2.13	1.44	63.00	1.01	64.01	102.00	36.55
157	23.17	3.34	26.51	0.17	2.16	2.33	1.20	81.17	2.10	83.27	113.32	28.85
164	14.32	1.26	15.58	0.04	1.72	1.74	1.35	64.17	0.56	64.73	83.41	17.33

MEANS OF BLOCKS

DAYS	RED	COL	FACT	GGR	MGR	TGR	SML	RROT	GROT	TROT	TWP	TWP(NRS)
108	1.21	3.89	5.10	87.84	15.02	102.85	9.52	0	1.08	1.08	118.55	107.95
115	4.23	15.98	20.21	77.22	23.65	100.88	9.72	0.38	4.51	5.39	135.70	121.09
122	19.92	36.46	56.38	26.95	29.51	56.46	8.17	2.50	6.96	9.46	130.46	112.83
129	37.04	35.12	72.16	7.16	26.01	33.17	3.77	6.77	8.33	15.10	124.20	105.33
136	56.37	22.17	78.54	2.73	13.43	16.16	3.64	15.71	9.42	25.13	123.46	94.70
143	67.25	13.21	80.46	0.36	5.40	5.76	3.29	32.92	3.74	37.66	126.17	86.22
150	34.12	5.62	39.74	0.12	2.04	2.16	1.22	62.04	1.41	63.45	106.58	41.91
157	19.04	2.77	21.81	0.21	1.35	1.56	1.05	74.62	1.43	76.05	100.48	23.37
164	11.52	2.00	13.52	0.08	1.28	1.36	0.83	63.79	1.25	65.04	80.75	14.88

UC 82B

(Tonnes per hectare)

BLOCK 1

DAYS	RED	COL	FACT	GGR	MGR	TGR	SML	RROT	GROT	TROT	TWF	TWF(NRS)
108	0.20	1.04	1.24	79.99	12.01	92.00	11.20	0.00	0.16	0.16	104.60	93.24
115	1.53	13.33	14.86	69.03	16.30	85.33	6.18	0.09	0.37	0.46	106.85	100.20
122	4.43	28.33	32.76	58.99	18.01	77.00	7.83	4.00	4.83	8.83	126.43	109.77
129	30.83	39.00	69.83	7.83	26.33	34.17	4.29	2.74	6.50	9.23	117.53	104.00
136	42.83	23.00	65.83	4.53	13.33	17.86	1.60	12.33	10.00	22.33	107.63	83.70
143	64.83	13.67	78.50	3.99	6.92	10.90	2.94	18.67	3.24	21.91	114.26	89.40
150	36.83	13.47	50.30	1.67	8.70	10.36	1.97	45.83	7.85	53.68	116.32	60.67
157	34.50	6.29	40.79	0.13	1.80	1.93	0.52	68.33	2.43	70.76	114.00	42.72
164	29.83	2.74	32.57	0.58	1.65	2.23	0.81	47.67	3.73	51.39	87.01	34.81

BLOCK 2

DAYS	RED	COL	FACT	GGR	MGR	TGR	SML	RROT	GROT	TROT	TWF	TWF(NRS)
108	0.15	1.20	1.35	68.60	11.98	80.58	10.12	0.00	0.28	0.28	92.32	81.93
115	0.85	13.73	14.58	68.30	17.53	85.83	12.13	0.00	2.91	2.91	115.45	100.41
122	7.08	32.00	39.08	37.99	24.51	62.50	8.50	1.33	10.67	12.00	122.08	101.58
129	19.17	43.33	62.50	10.10	26.40	36.50	5.43	8.00	19.33	27.33	131.76	99.00
136	45.83	24.67	70.50	4.16	10.25	14.41	2.85	11.00	7.50	18.50	106.26	84.91
143	41.50	9.00	50.50	0.46	5.71	6.17	4.21	28.33	7.53	35.86	96.74	56.67
150	51.67	5.26	56.93	0.45	1.51	1.96	4.52	38.67	3.12	41.78	105.19	58.89
157	37.00	3.41	40.41	0.34	1.94	2.28	1.46	67.17	1.66	68.82	112.97	42.69
164	26.17	1.12	27.29	0.17	0.11	0.28	1.54	61.50	1.23	62.73	91.84	27.57

BLOCK 3

DAYS	RED	COL	FACT	GGR	MGR	TGR	SML	RROT	GROT	TROT	TWF	TWF(NRS)
108	0.64	4.95	5.59	71.46	14.70	86.17	10.38	0.00	2.50	2.50	104.64	91.76
115	1.89	18.33	20.22	79.86	11.48	91.33	12.02	0.13	4.70	4.83	128.41	111.56
122	15.50	34.00	49.50	10.57	28.26	38.83	9.67	1.83	4.50	6.33	104.33	88.33
129	25.67	38.17	63.84	16.49	16.51	33.00	5.69	5.67	13.17	18.83	121.36	96.83
136	42.00	33.17	75.17	2.19	27.50	29.69	3.38	8.83	9.67	18.50	126.73	104.86
143	75.67	9.67	85.34	0.71	5.15	5.86	8.13	19.00	3.92	22.92	122.24	91.19
150	44.17	10.40	54.57	0.91	7.30	8.21	1.47	47.83	3.73	51.56	115.82	62.79
157	30.00	4.89	34.89	2.63	2.85	5.49	1.56	55.83	2.86	58.69	100.64	40.38
164	27.66	0.71	28.37	0.56	1.54	2.11	1.42	64.50	0.56	65.06	96.97	30.49

BLOCK 4

DAYS	RED	COL	FACT	GGR	MGR	TGR	SML	RROT	GROT	TROT	TWF	TWF(NRS)
108	0.88	2.46	3.34	73.88	9.28	83.17	12.44	0.05	0.31	0.36	99.31	86.51
115	0.83	10.28	11.11	92.87	7.45	100.33	10.67	0.20	4.61	4.81	126.92	111.44
122	13.33	41.50	54.83	23.86	24.98	48.83	9.50	2.33	9.76	12.00	125.17	103.67
129	32.00	36.33	68.33	19.67	18.16	37.83	8.03	7.83	13.33	21.17	135.36	106.17
136	37.83	14.50	52.33	2.94	11.59	14.53	3.57	21.33	11.67	33.00	103.43	66.86
143	40.67	8.67	49.34	1.91	3.88	5.79	4.90	29.33	5.75	35.08	95.10	55.12
150	39.67	9.52	49.19	1.50	4.61	6.11	2.11	41.00	5.34	46.34	103.76	55.60
157	29.83	9.22	39.05	2.38	6.52	8.89	1.84	56.50	4.62	61.12	110.91	47.95
164	27.50	1.25	28.75	0.67	1.89	2.56	2.48	65.17	1.50	66.67	100.46	31.30

MEANS OF BLOCKS

DAYS	RED	COL	FACT	GGR	MGR	TGR	SML	RROT	GROT	TROT	TWF	TWF(NRS)
108	0.47	2.41	2.88	73.48	12.00	85.48	11.03	0.01	0.81	0.82	100.22	88.36
115	1.27	13.92	15.19	77.51	13.19	90.71	10.25	0.11	3.15	3.26	119.41	105.90
122	10.09	33.96	44.05	32.85	23.94	56.79	8.88	2.37	7.42	9.79	119.50	100.84
129	26.92	39.21	66.13	13.52	21.85	35.37	5.86	6.06	13.08	19.14	126.50	101.50
136	42.12	23.83	65.95	3.46	15.67	19.12	2.85	13.37	9.71	23.08	111.01	85.08
143	55.67	10.25	65.92	1.77	5.41	7.18	5.04	23.83	5.11	28.94	107.08	73.10
150	43.08	9.66	52.74	1.13	5.53	6.66	2.52	43.33	5.01	48.34	110.27	59.41
157	32.83	5.95	38.78	1.37	3.28	4.65	1.35	61.96	2.89	64.85	109.63	43.43
163	27.29	1.46	29.25	0.05	1.30	1.79	1.56	59.71	1.75	61.46	94.07	31.04

Where :

DAYS = Days from planting

RED = Red grade fruit

COL = Coloured grade fruit

FACT = Factory grade fruit

GGR = Grass green fruit

MGR = Mature green fruit

TGR = Total green fruit

SML = Small fruit

RROT = Red rotten fruit

GROT = Green rotten fruit

TROT = Total rotten fruit

TWF = Total weight fruit including small and rotten fruit

TW(NRS) = Total weight fruit excluding small and rotten fruit

APPENDIX XI. FRUIT NUMBER DATA

CASTLEHYE 1204 IMP.

(x 1000 / hectare)

BLOCK 1

DAYS	RED	COL	FACT	GGR	MGR	TGR	TNF(NRS)
108	10.00	53.33	63.33	2047.07	1676.05	3723.12	3786.45
115	50.00	210.00	260.00	1891.81	1294.80	3186.60	3446.60
122	301.67	613.33	915.00	1142.91	891.68	2034.59	2949.59
129	413.33	648.33	1061.66	928.54	759.34	1687.87	2749.54
136	907.94	375.00	1282.94	18.33	291.67	310.00	1592.94
143	1022.94	208.33	1231.27	28.33	120.00	148.33	1379.61
150	418.33	130.00	548.33	0.00	55.00	2.57	603.33
157	318.33	70.00	388.33	16.67	41.67	58.33	446.67
164	96.67	21.67	118.34	6.67	28.33	35.00	153.33

BLOCK 2

DAYS	RED	COL	FACT	GGR	MGR	TGR	TNF(NRS)
108	28.33	91.67	120.00	2488.78	2101.08	4589.86	4709.86
115	78.33	270.00	348.33	1958.93	1390.58	3349.51	3697.85
122	330.00	556.67	886.67	939.02	746.56	1685.59	2572.25
129	550.00	483.33	1033.33	549.15	447.49	996.94	2030.27
136	914.46	348.33	1262.79	71.67	168.33	240.00	1502.79
143	1256.19	200.00	1456.19	6.67	130.00	136.67	1592.86
150	813.33	46.67	869.00	8.33	30.00	38.33	898.33
157	390.00	48.33	438.33	0.00	10.00	10.00	448.33
164	110.00	15.00	125.00	1.67	10.00	11.67	136.67

BLOCK 3

DAYS	RED	COL	FACT	GGR	MGR	TGR	TNF(NRS)
108	30.00	58.33	88.33	1962.53	1646.39	3608.00	3697.26
115	30.00	258.33	288.33	2154.60	1667.80	3822.40	4110.73
122	338.33	590.00	928.33	1236.49	1050.63	2287.12	3215.45
129	858.33	475.00	1333.33	516.24	432.40	516.24	2281.97
136	673.82	378.33	1052.15	105.00	578.33	683.33	1735.49
143	1074.16	275.00	1049.16	6.67	95.00	101.67	1450.83
150	421.67	96.67	518.34	3.33	50.00	53.33	571.67
157	126.67	20.00	146.67	3.33	35.00	38.33	185.00
164	271.67	80.00	351.67	0.00	40.00	40.00	391.67

BLOCK 4

DAYS	RED	COL	FACT	GGR	MGR	TGR	TNF(NRS)
108	6.67	40.00	46.67	2126.76	1540.96	3667.72	3714.38
115	113.33	271.67	385.00	1889.49	1765.61	3655.10	4040.10
122	280.00	690.00	970.00	1392.66	1287.30	2679.96	3649.96
129	496.67	655.00	1151.67	980.08	746.12	1726.20	2877.87
136	875.69	405.00	1280.67	33.33	253.33	286.67	1567.35
143	892.19	193.33	1085.52	1.67	93.33	95.00	1180.53
150	448.33	108.33	556.66	5.00	50.00	55.00	611.67
157	406.67	61.67	468.34	0.17	48.33	53.33	521.67
164	235.00	23.33	258.33	1.67	33.33	35.00	293.33

MEANS OF BLOCKS

DAYS	RED	COL	FACT	GGR	MGR	TGR	TNF(NRS)
108	18.75	60.83	79.58	2156.28	1741.12	3897.41	3976.99
115	67.91	252.50	320.11	1973.71	1529.70	3503.40	3823.82
122	312.50	612.50	925.00	1177.77	994.04	2171.81	3096.81
129	579.58	565.42	1145.00	743.50	596.41	1339.91	2484.91
136	842.98	376.67	1219.65	57.08	322.91	380.00	1599.64
143	1061.37	219.17	1280.54	10.83	109.58	120.42	1400.96
150	525.42	95.42	680.84	4.16	46.25	50.41	671.25
157	310.42	50.00	360.42	6.25	33.75	40.00	400.42
163	178.33	35.00	213.33	2.50	27.91	30.42	243.75

UC 82B

(x 1000 per hectare)

BLOCK 1

DAYS	RED	COL	FACT	GGR	MGR	TGR	TNF(NRS)
108	3.33	16.67	20.00	2480.07	2107.67	4587.74	4607.74
115	28.33	230.00	258.33	1838.70	1647.07	3485.77	3744.10
122	75.00	500.00	575.00	1340.94	1361.08	2702.02	3277.02
129	546.67	713.33	1260.00	776.13	642.42	1418.55	2678.55
136	746.77	416.67	1163.44	110.00	121.67	231.67	1395.10
143	1113.36	285.00	1398.36	138.33	173.33	311.67	1710.03
150	615.00	246.67	861.67	48.33	185.00	233.33	1095.00
157	560.00	106.67	666.67	3.33	38.33	41.67	708.33
164	455.00	45.00	500.00	15.00	35.00	50.00	550.00

BLOCK 2

DAYS	RED	COL	FACT	GGR	MGR	TGR	TNF(NRS)
108	3.33	21.67	25.00	1957.26	1760.86	3718.12	3743.12
115	20.00	228.33	248.33	1862.09	1588.87	3450.95	3699.28
122	126.67	575.00	701.67	1340.76	1278.61	2619.37	3321.03
129	360.00	828.33	1188.38	937.50	796.54	1734.04	2922.37
136	753.78	440.00	1193.78	103.33	230.00	333.33	1527.11
143	713.35	195.00	908.35	11.67	161.67	173.33	1081.68
150	873.33	96.67	970.00	10.00	36.67	46.67	1016.67
157	620.00	60.00	680.00	6.67	33.33	40.00	720.00
164	473.00	21.67	492.67	5.00	3.33	8.33	503.33

BLOCK 3

DAYS	RED	COL	FACT	GGR	MGR	TGR	TNF(NRS)
108	13.33	88.33	101.66	1986.93	1502.28	3489.21	3590.88
115	38.33	325.00	363.33	2024.05	1745.67	3769.72	4133.05
122	278.33	670.00	948.33	940.68	765.82	1706.50	2654.83
129	453.33	613.33	1066.66	704.12	667.43	1371.56	2438.22
136	692.64	646.67	1339.31	56.67	603.33	660.00	1999.31
143	1353.73	205.00	1558.73	20.00	105.00	125.00	1683.73
150	720.00	200.00	920.00	21.67	156.67	178.33	1098.33
157	530.00	96.67	626.67	63.33	56.67	120.00	746.67
164	475.00	15.00	490.00	15.00	35.00	50.00	540.00

BLOCK 4

DAYS	RED	COL	FACT	GGR	MGR	TGR	TNF(NRS)
108	16.67	45.00	61.67	2230.11	2452.87	4682.97	4744.64
115	18.33	171.67	190.00	2202.44	2391.48	4593.91	4783.91
122	230.00	790.00	1020.00	1203.36	985.20	2188.56	3208.56
129	515.00	630.00	1145.00	846.12	712.68	1558.80	2703.80
136	614.68	290.00	904.68	81.67	298.33	380.00	1284.68
143	745.49	180.00	925.49	66.67	81.67	148.33	1073.83
150	626.67	178.33	805.00	41.67	110.00	151.67	956.67
157	510.00	168.33	678.33	60.00	140.00	200.00	878.33
164	450.00	21.67	471.67	13.33	33.33	46.67	518.33

MEANS OF BLOCKS

DAYS	RED	COL	FACT	GGR	MGR	TGR	TNF(NRS)
108	9.16	42.92	52.08	2163.59	1955.92	4119.51	4171.59
115	26.25	238.75	264.10	1981.82	1843.27	3825.09	4090.08
122	177.50	633.75	811.25	1206.43	1097.68	2304.11	3115.36
129	486.75	696.25	1165.00	815.97	704.77	1520.74	2685.73
136	701.97	448.33	1150.30	87.92	313.33	401.25	1551.55
143	981.43	216.25	1197.68	59.17	130.42	189.58	1387.32
150	708.75	180.42	889.17	30.42	122.09	152.50	1041.67
157	555.00	107.92	662.92	33.33	67.08	100.42	763.33
163	463.33	25.83	489.16	12.08	26.66	38.75	527.92

Where ;

DAYS = Days from planting

RED = Red grade fruit

COL = Coloured grade fruit

FACT = Factory grade fruit

GGR = Grass green fruit

MGR = Mature green fruit

TGR = Total green fruit

TNF(NRS) = Total number of fruit excluding small and rotten fruit

APPENDIX XII. INDIVIDUAL FRUIT WEIGHT DATA (MEANS OF BLOCKS)

CASTLEHYE 1204 IMP.

(Grams per fruit)

DAYS	GREEN	RED	COL	AVERAGE
108	26.55	63.99	64.92	27.29
115	28.80	62.09	63.31	31.67
122	26.17	63.74	59.68	36.75
129	24.63	65.13	62.18	42.60
136	43.79	67.11	58.89	59.32
143	47.06	63.39	60.26	61.50
150	42.51	65.13	57.72	62.43
157	40.07	61.99	54.16	58.45
163	43.75	62.90	55.39	59.42

UC 82B

(Grams per fruit)

DAYS	GREEN	RED	COL	AVERAGE
108	21.05	51.55	57.11	21.48
115	23.86	47.71	58.61	26.05
122	24.36	57.71	53.90	32.42
129	23.37	57.10	56.72	37.92
136	50.89	60.09	53.14	55.02
143	39.12	56.71	47.35	52.54
150	43.19	60.92	53.61	57.07
157	48.37	59.10	55.29	57.07
163	43.84	60.05	54.47	58.73

Where ;

DAYS = Days from planting

GREEN = Overall green grade fruit

RED = Red grade fruit

COL = Coloured grade fruit

AVERAGE = Average of all weight per fruit excluding rotten or small fruit

APPENDIX XIII. NORMAL DISTRIBUTION CURVE STATISTICS (EXPERIMENT TWO)

(Nichols, 1965)

Cultivar	Mean		Var.	Skew.	Kurt.	g1	g2	s.e. g1	s.e.g2
RED FRUIT WEIGHT									
Castlehy	140	18	1.59E-03	2.79	3.13E-02	-0.19	2.36E-02	9.39E-02	
UC 82B	145	20	-5.76E-03	2.37	-0.101	-0.61	2.46E-02	9.78E-02	
FACTORY GRADE FRUIT WEIGHT									
Castlehy	136	22	6.32E-03	2.57	0.15	-0.42	1.53E-02	6.08E-02	
UC 82B	140	26	2.76E-03	2.21	6.55E-02	-0.79	1.56E-02	6.22E-02	
RED FRUIT NUMBERS									
Castlehy	140	18	8.61E-04	2.76	1.68E-02	-0.23	1.54-03	6.15E-03	
UC 82B	144	20	-5.79E-03	2.39	-0.1043	-0.601	1.46E-03	5.85E-03	
FACTORY GRADE FRUIT NUMBERS									
Castlehy	136	22	7.12E-03	2.56	0.16	-0.44	9.73-04	3.89-03	
UC 82B	139	26	4.39E-03	2.19	0.10	0.801	8.86E-04	3.54E-03	

Where;

Var. = VARIANCE

Skew. = SKEWNESS

Kurt. = KURTOSIS

NOTES

i Means variance for both cultivars were transformed to days from planting.

ii For a Normal Distribution Curve Skewness =0 and Kurtosis =3

iii For a Normal Distribution Curve statistic g1 and g2 should be both equal to 0

iv s.e. g1 = Standard Error of G1 s.e. g2 = Standard Error of G2

APPENDIX XIV. RED FRUIT SOLUBLE SOLIDS

DAYS FROM PLANTING	CASTLEHY 1204 IMP. SS (%)	UC 82B SS (%)
108	3.79	4.02
115	3.75	3.69
122	3.79	3.53
129	3.90	3.61
136	4.38	4.30
143	4.09	4.01
150	4.62	4.71
157	4.71	4.60
164	4.61	4.34

APPENDIX XV. RAINFALL IN SEVEN DAY INTERVALS OVER THE HARVEST PERIOD

PERIOD OF RAINFALL (Days from planting)	RAINFALL (mm.)
101 - 107	20.6
108 - 114	9.4
115 - 121	3.2
122 - 128	23.1
129 - 135	13.5
136 - 144	42.1
143 - 149	27.3
150 - 156	20.2
157 - 163	50.3

(Calculated from; Ministry of Transport - N.Z. Meterorological Service Daily Climatological Observations Grasslands Div. DSIR Palmerston North)

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