INFLUENCE OF CLUSTER NUMBER AND SPACING ON SET, GROWTH, YIELD AND QUALITY OF EARLY FRUIT OF THE 'WEST VIRGINIA '63' TOMATO

<u>LYCOPERSICON</u> <u>ESCULENTUM</u> (MILL.)

THESIS

SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL

OF

WEST VIRGINIA UNIVERSITY

IN

PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE

OF

MASTER OF SCIENCE

BY

NAMEUS ABEL MNZAVA
B.Sc. (Agric.) (Hons.)

MORGANTOWN, WEST VIRGINIA

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1974

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INTRODUCTION

Most commercial tomato lines exhibit a pronounced indeterminate growth habit on the main and lateral vegetative axes and weakly on the raceme. Due to this, their culture has been associated with high material and labor requirements, earliness is usually delayed and unharvested crop is high in regions with short growing seasons. Current emphasis for processing types is to attain a once-over destructive harvest made nearly efficient by determinate cultivars. Despite the large genetic reservoir available to breeders for such ideotypes suitable for mechanical harvesting, it may be a long time (Massey et al. (40)) before optimum combinations of physical characteristics of fruit and vine combined with high processing quality are found. Current indeterminate cultivars produce fruit of excellent horticultural quality. If we are to operate with these, their pattern of vine growth, therefore, requires physical alteration as a logical alternative.

Earliness, high yield concentration and high total yields are primary objectives in tomato production. Plant population density invariably affects them. In tomato, yield is related to cluster number and the fruits thereof. Holliday (25) working with various crops concluded that yield per acre is maximum when yield per plant is far below its genetic potential. Fery and Janick (18) found that, regardless of vine type, total yields of tomatoes, are the same at high density following the law of 'Constant Final Yields' of Shizonaki and Kira (53). Studies on the cropping behavior of tomato indicate that efficiency of cropping declines after a certain number of clusters have developed. It has been suggested by Lam *et al*. (32) that the continuation of fruit set after the usable crop has been set diverts the growth activities of the plant in an unproductive manner. This is suggestive of the level of efficiency where current techniques of production are operating. Whereas the present methods aim at maximizing yield per plant, high yield per acre may have been sacrificed. Efforts to keep the genetic potential of the plant low have taken various forms; namely increasing plant density coupled with severe pruning and chemically regulating the number of fruits that develop. These have resulted in high concentrated yields while fruit size decreased. However, tip removal and limiting cluster numbers that develop with subsequent readjustment of plant population to optimize yield per acre is another alternative that has received much less attention than it deserves.

Restricting vine growth to single fruit cluster has been suggested as a means of increasing efficiency of production in tomatoes (8, 9, 63, 68). Studies of Cooper (9) and others (17, 23, 26, 49) for the greenhouse crop were based on this technique. Single truss culture has been shown to be more beneficial than the conventional multicluster trellis type culture, yet investigations on the behavior of the first fruit cluster (which this technique advocates to retain) are few. The effects of decapitation on fruit set and growth of the first cluster fruits have not been reported especially when coupled with population pressure effects. Knowledge of the trends of some quality attributes in the first cluster fruits at high density is necessary since it will be indicative of the suitability of this type of culture. It is imperative therefore, to determine the level of inter- and intra-plant competition for optimum cropping, testing as it were, of the 'West Virginia '63' tomato cultivar.

It is the objective of this investigation to examine how cluster numbers per plant and plant spacing affect the set, growth and yield of early fruits of an indeterminate cultivar and the influence of high density on their quality.

LITERATURE REVIEW

I. FRUIT SET

The number of fruits set on the first cluster determines early yield of a tomato crop. Growers in cool climates frequently experience difficulty in obtaining satisfactory set of fruit on the first infloresence and have therefore planted early varieties which have greater capacity to set early fruits. The basic greenhouse studies of Kraus and Kraybill (30) on the influence of the C/N ratio on fruiting of tomato and Murneek (45) on growth correlations in tomato clearly define certain fundamental relationships between the carbohydrate and nitrogen content of tomato plant tissue and the vegetative and fruiting behavior. Went and Cosper (64) reported the influence of the environmental factors specifically the mean nightly minimal temperatures on the set of fruits in the first flower cluster as dependent on variety. However, Wittwer et al. (67) using auxin could offset the deleterious effect of low temperature and cloudy weather in fruit set on the first cluster. Since then, a number of factors, namely cultural and nutritional, have been reported to affect fruit set. Reeve et al. (51) advocated that late planting, N and wider spacing favor more fruit set but dense planting and late planting resulted in lower fruit set in tomato. Cooper (5) studied in detail the behavior of the plant in the glasshouse and revealed that fruit set increased with plant height and declined as age and season progressed. Leaf numbers and lengths exhibited a similar pattern (6). The first cluster on indeterminate plants had the least number of fruit. Dullforce (17) modified vine growth patterns and her work with single and double truss plants indicated that the presence of the second truss did not reduce the number of fruits in the first truss at 6,800 plants/ha.

II. FRUIT GROWTH

Successful manipulation of the tomato plant requires a thorough understanding of the fruiting pattern. By virtue of the growth habit, maturation of fruits proceeds from the first cluster to the top and from the proximal to the distal fruit within an infloresence. Fruit size decreases in the same manner. Davis *et al*. (13) reported that there is a scattering of maturation dates within a cluster conditioned by differing growth rates. The presence of the second, third and fourth trusses lengthened the overall maturation of the crop up to the seventh truss whose maturation period was similar to the first truss (5). Fruit dry matter decreased with plant height (37) and fruit size did not increase proportionately with leaf area (21).

Khan and Sagar (29) established that the efficiency of plants with regards to fruit production was greatest when leaf area was small and emphasized that the first truss was a major sink for all leaves. 'Half period' values (5) declined with increasing cluster number and increased again in the seventh cluster. This indicated that growth rate of fruit was higher in the first half of the maturation period prior to the fourth cluster and this explained the delay in the maturation of fruit as a function of cluster number left on the plant. Thus earliness could decline with number of trusses as suggested by Thompson (57).

III. TOMATO YIELD AND QUALITY

(1) SPACING

The literature is replete with studies on plant population and tomato yields. The most noteworthy effect of increasing plant density is the increase of total yield, reduction in fruit size and in yield per plant (3, 7, 39, 47, 50, 51, 58, 61, 69). Earliness is also enhanced (18, 44, 51). The most important single factor affecting total yield, earliness and yield concentration was spacing (10, 18, 66). Where yield in a single harvest is an objective, the closest spacing is a prerequisite (56) but Hayslip (24) cautioned that for optimum yields and fruit size, this compromise is achieved at smaller populations. Further, high density planting has been associated with a higher incidence of diseases than low density.

(2) CLUSTER NUMBER

In most areas, tomato production is based on the cropping of indeterminate multicluster plants. Several researches have been conducted to find whether higher efficiency in tomato production could be achieved by fewer cluster cropping. Dullforce (17) first attempted to find whether a double truss crop was a better proposition. She reported that the second truss reduced the total weight of fruit in the first truss. However, total yield was greater, as was expected, than from single truss plants at 6,885 plants/ha. A marked effect on earliness and higher returns with fewer truss plants was reported by Petrescu and Andrei (49) at spacing of 4.6 dm by 15.2 cm than wider spacings of 9.1 dm by 22.8 cm. Canham (4) and Honma et al. (26) established that single truss plants increased earliness. Hartman (23) noticed that under close spacing, two crops of two trusses could be grown in one season producing higher total yield than an eight truss crop. Plants with fewer trusses are suited to closer spacings (18) but Honma et al. (26) stressed the necessity of adaptable cultivars. When growth is restricted to one cluster per plant, yield concentration is increased and at high density a once-over destructive harvest can be achieved, hence lowering harvesting and/or growing costs (68). Petrescu (48) reported that reducing number of trusses per plant lowered costs, increased early and total yields and land was made available at an earlier date. An observation of this production system led Cooper (8) to suggest that yields in excess of 224 millier/ha in greenhouse could be obtained. Restricting indeterminatism to single or double clusters would stabilize labor requirements and facilitate year round production by employing simplified cultural operations on densely planted crops of short duration.

IV. EFFECTS OF HIGH DENSITY AND CLUSTER NUMBER ON QUALITY OF FIRST TRUSS FRUITS

Studies on quality are of importance for fresh market and processing due to the consumer's awareness of quality. In the tomato market, quality is a function of size, firmness, color, sugar/acid ratio and texture. These vary considerably with environmental factors, year, season, variety, fertility regime and cultural practices (62). According to Lee and Sayre (33), acidity is highest in the first cluster and decreases with subsequent clusters. There is a definite relationship between fruit size and chemical composition (59). A comparison between small and big fruits revealed that small fruits have higher dry matter and more sugars in all plant types than big fruits (41) and were of higher firmness (60). Early harvested fruits had a higher percentage soluble solids (42), but Hanna (22) reported that the per cent soluble solids decreased with increasing numbers of fruits per plant. The effects of varying spacing and cluster number on firmness, pH, per cent soluble solids and titratable acidity of the first cluster fruits have not been elucidated.

V. THE 'WEST VIRGINIA '63' ('W.VA. '63') TOMATO CULTIVAR

Gallegly (20) in 1964 described the cultivar as having excellent horticultural characteristics. "It is of large, indeterminate and leafy vine which strains well and may be staked. Its medium to large fruits averaging 18.14 gm are meaty, smooth, oblate to globe, red, have fine flavor, ripen uniformly and resist cracking. It is a late maturing variety requiring 80 days after transplanting for earliest ripening." Further, the cultivar carries the Ve gene for resistance against Verticillium wilt incited by <u>Verticillium albo-atrum</u> (Reinke and Berthold), and the multigenic type resistance to Fusarium wilt incited by <u>Fusarium</u> <u>oxysporum</u> f. <u>lycopersici</u> (Sacc.) Snyder and Hansen and also both monogenic and multigenic resistance to late Blight caused by Phytophthora infestans (Mont.) de Bary.

Zahara (70) mentioned several criteria for an ideal cultivar suitable for mechanical handling of fruit. The cultivar must set all fruit in a short period, retain firm fruits for a long time on the vine and should be resistant to common fungal wilts. The 'W.Va. '63' syn. 'Centennial' fails to satisfy two criteria since it is of an indeterminate growth habit, rapidly becomes soft and deteriorates[1].

It's adaptability to a wide range of climate has attracted even the farmers in equatorial regions[2]. Smith[3] working with 'W.Va. '63' reported that reducing spacing from 1.5 m by 4 dm to 1.5 m by 3 dm did not reduce yield or fruit size significantly. Since this cultivar has desirable characteristics, its suitability for a single cluster high density type culture was tested.

---

[1]Lampe, C. H. 1968. Studies of fruit quality of several cultivars of Lycopersicon esculentum. M.S. Thesis. West Virginia University. 30p
Sobotka, F. E. 1970. Physical and biochemical studies of the softening process of several cultivars of Lycopersicon esculentum (Mill). M.S. Thesis. West Virginia University. 33p

[2]Wurster, R. T. 1973. Personal Communication.

[3]Smith, S. P. 1964. The effect of variety and spacing on yield of mature green tomatoes. M.S. Problem report. West Virginia University. 19p

MATERIALS AND METHODS

A. THE EXPERIMENT

A 2 by 3 factorial field experiment of two levels of plant population and three levels of cluster number; single cluster, double cluster and indeterminate plants was carried out between June and September at the West Virginia University Horticulture Farm. Seeds of the 'West Virginia '63' tomato cultivar were sown in flats in the greenhouse in a peat-vermiculite medium in April. After eight days, seedlings were pricked-off into 10 cm by 10 cm by 7.5 cm plastic pots and transplanted to field plots on June 18th, 1973.

Plots 3.7 m by 3.3 m and 3.7 m by 2.3 m for plant populations of 5,200 plants/ha and 11,600 plants/ha, respectively were arranged in a randomized complete block design and replicated six times with a 1.5 m space between blocks. Randomization of treatments within replicates was obtained by using a Table of Random Digits (54). Each plot had five rows of 15 plants. Two side rows of each plot were guard rows planted to the cv 'Manapal'. All plants were trained to a single stem trellis.

Plant densities were designated at planting by varying the spacing within the row viz. 0.9 m by 25.4 cm and 0.9 m by 15.2 cm the latter in double rows allowing, therefore, 0.8 sq dm/plant and 0.6 sq dm/plant respectively. Cluster number treatments were superimposed at various stages of plant development. Single cluster plants were obtained by the removal of the top, two leaves above the first cluster when the second infloresence flowers were visibly open. Plants bearing two clusters were obtained by removing the top two leaves above the second cluster when the third cluster flowers started to open. Ten days elapsed before the second cluster treatment was started. The third treatment consisted of undecapitated indeterminate plants.

B. PREPLANTING AND POST-ESTABLISHMENT OPERATIONS

The experiment was carried out in a 'Wharton clay loam' soil previously planted to strawberries (Fragaria vesca L.). After plowing, 224 millier/ha manure and 2240 kg/ha of 10-20-20 were applied. After plowing and harrowing, preemergent weed control for the tomato crop followed the recommendations of Schubert[4]. Pebulate (S-propylbutylethylthiocarbanute) plus trifluralin (a, a, a,-trifluoro-2, 6-dinitro-N-N-dipropyl-a-toluidine) ec at 6.7 kg/ha and 1.1 kg/ha, respectively were incorporated immediately by disking in two different directions. Sheets of black polyethylene and trickle irrigation plastic tubes[5] were laid on premarked rows. At transplanting, a starter solution of 0-45-15 at the rate of 67.2 kg/ha in 185 litres of water was applied. The few plants which failed to establish were replaced the week after transplanting. Following establishment a monthly broadcast of 22.4 kg/ha of urea (45-0-0) to the crop was made. An inch of irrigation water was supplied weekly from the trickle irrigation system. Diseases were not a problem throughout the growing

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[4]Schubert, O. E. 1973. Single herbicide program recommended for field tomatoes. Private Communication.

[5]Twin-Wall Hose (1.9 cm) manufactured by Chapin Watermatics Inc., Box 298, Watertown, New York 13601.

period but a weekly spray of Carbaryl (1-naphthyl-N-methylcarbamate) 0.45 kg 50 per cent W. P. in 370 litres of water per ha after fruit set gave a good control of aphids and fruit worms. Lateral growth was discouraged for all treatments throughout the experimental period by removing the suckers as soon as it was practicable. Weeds that escaped the preplanting treatment were hand pulled.

C. FRUIT SET AND FRUIT GROWTH STUDIES

Fifteen tomato plants per plot for all treatments were randomly tagged after establishment. A count of the number of fruits set on the first cluster was made on the pre-tagged plants for all treatment combinations four days after the second cluster treatment when fruits were visible on the first cluster.

Fruit growth in the first cluster was determined on the first proximal fruit. Growth was determined on three dates, ca fortnightly, 26th July, 10th August and 28th August by the method described by Cooper (5) with modifications: ie, the diameters were determined by measuring fruits equatorially once using a Fruit Diameter Measuring device[6]. When the proximal fruit was obviously distorted, another plant was chosen and fruits of uniform comformation belonging to the pretagged plants were used. Later, the diameter readings were converted to volume by cubing the radii. Because fruits were flattened spheres, there was too much variation in using volume as an index of growth as apposed to diameter. Although the two parameters

[6] Manufactured by Cranston Machinery Company, Oak Grove, Oregon

behaved similarly, diameter as an index of growth was chosen for this reason. The last growth study was conducted at the first harvest. The relation of growth and maturation period was established following Cooper's 'Half-period' value (5) whereby the cube of the radius in the middle of the maturation period was expressed as per cent of the final cube of the fruit's radius.

D. HARVESTING AND QUALITY ANALYSES

Four harvests were made when a large proportion of the fruits were between the pink and red stages. All fruits from breaker to red stages were harvested. The number and weights of fruit for each plot were recorded and the fruit was then graded to size using a tomato size grader[7]. The number and weight of United States Grade 1 (herein comprising of Grade 1 and 2 together) and culls were determined following the USDA grading system[8].

Studies on the raw product quality of the first cluster fruits were carried out to compare the effects of high density on single cluster and indeterminate plants. Fifteen proximal fruits of the pretagged plants were harvested at full pink stage of maturation after replacing those which were obviously distorted, cracked or diseased. They were quickly transported to the laboratory where they were put in perforated plastic bags and held in constant temperature chambers

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[7] "Market Maker" Manufactured by Fruit and Vegetable Machines, TEW Manufacturing Corporation, Fairport, New York 14450.

[8] USDA Standards for Food and Farm Products. 1968. Ag. Handbook 341, (USDA Standards for Grades of Fresh Tomatoes, 1961)

at 20° C for two weeks. Then they were analysed for firmness, pH, titratable acidity and per cent soluble solids. Firmness was determined using the Pressure - Load Meter (0.95 cm radius tip and 220 gram weight) as described by Diener *et al*. (16). The individual fruits were minced in a Blender for two min. One hundred fifty ml of each sample were centrifuged for 10 minutes at 5000 x g, filtered through two layers of cheesecloth into beakers and the juice was then transferred to bottles and frozen until analysis. The juice was thawed at room temperature. Percentage soluble solids were determined using the Abbe'-Lomb refractometer at 20° C. In the pH and titratable acidity determination, 10 ml of juice was diluted with 40 ml of distilled water; pH was determined with a Coleman pH meter and acidity by titration with 0.1 N NaOH to pH 8.1. Acidity was then expressed as per cent citric acid.

The statistical significance of the differences among treatments was determined using the Analysis of Variance and the means were compared at the 5 and 1 per cent levels of probability as described in Snedecor and Cochran's 'Statistical Methods' (54).

RESULTS

I. FRUITSET ON THE FIRST TRUSS AS AFFECTED BY TRUSS NUMBER AND PLANT POPULATION DENSITY

The mean number of fruits per plant set on the first truss as influenced by cluster number and plant population pressure is shown in Figure 1. The analysis of variance indicated that the effect of cluster number on fruit set was significant at the 1 per cent level of probability. Although the effect of spacing was non-significant, there was a significant cluster number by spacing interaction at the 5 per cent level. There were approximately 12 per cent more fruits set on single cluster plants than on either double cluster or indeterminate plants, although the differences in the number of fruits set on the first trusses of the latter were not significant. The significant cluster by spacing interaction shows that single cluster plants had more fruits set at high plant populations whereas indeterminate plants had more set on their first cluster at low plant populations. However, fruit set on the first truss of double cluster plants was independent of plant population density.

II. EFFECT OF TRUSS NUMBER AND PLANT DENSITY ON THE GROWTH AND MATURATION OF FIRST TRUSS FRUITS

The growth curves of the first proximal fruits of the first cluster as affected by plant density and number of trusses left on the plant are shown in Figure 2. The effects of cluster number and plant density were significant at the 1 per cent level. Fruit growth as estimated by diameter measurements was higher for single cluster

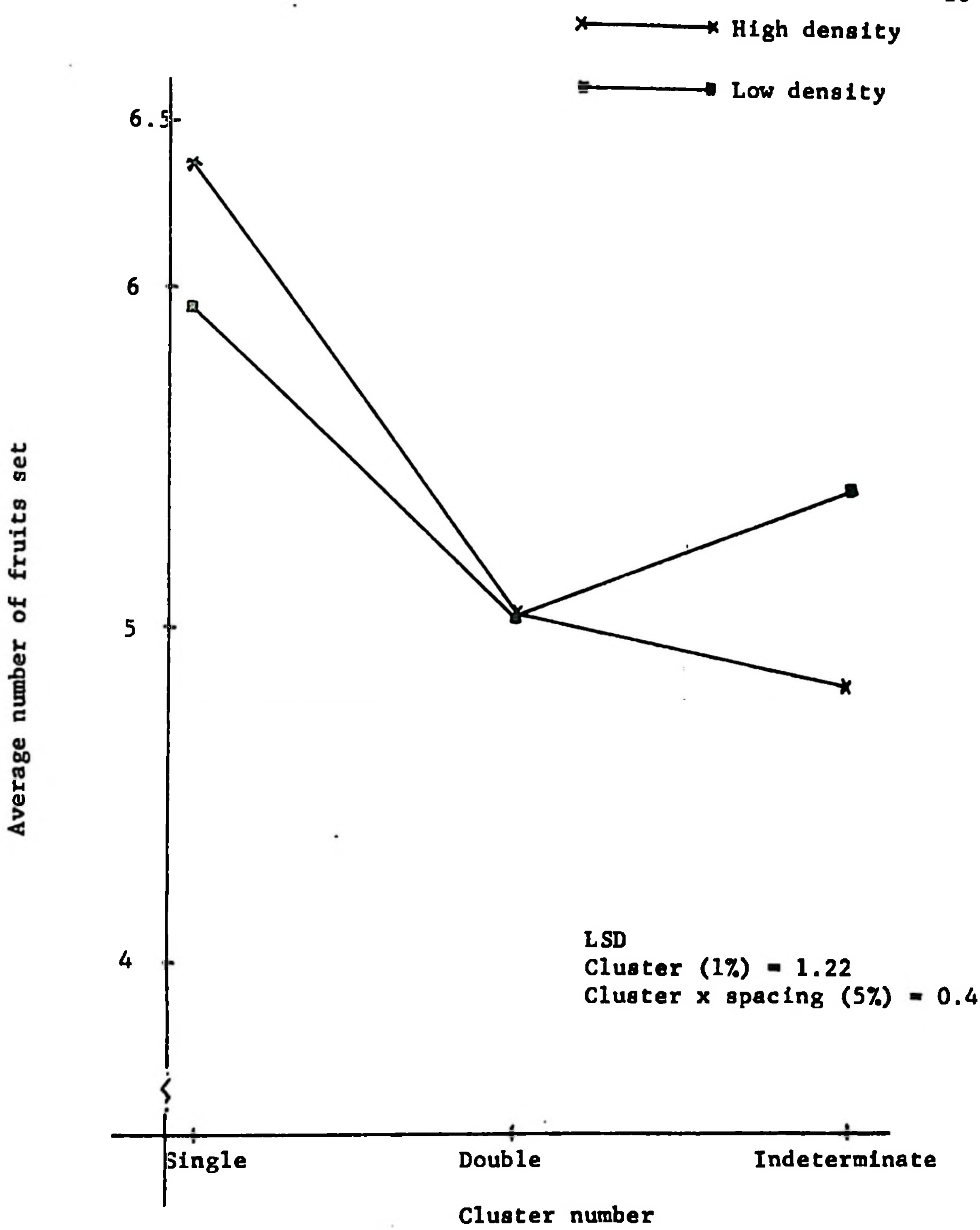


Figure 1. Fruit set on the first truss of 'W.VA. '63' tomato as affected by truss number and plant population density.

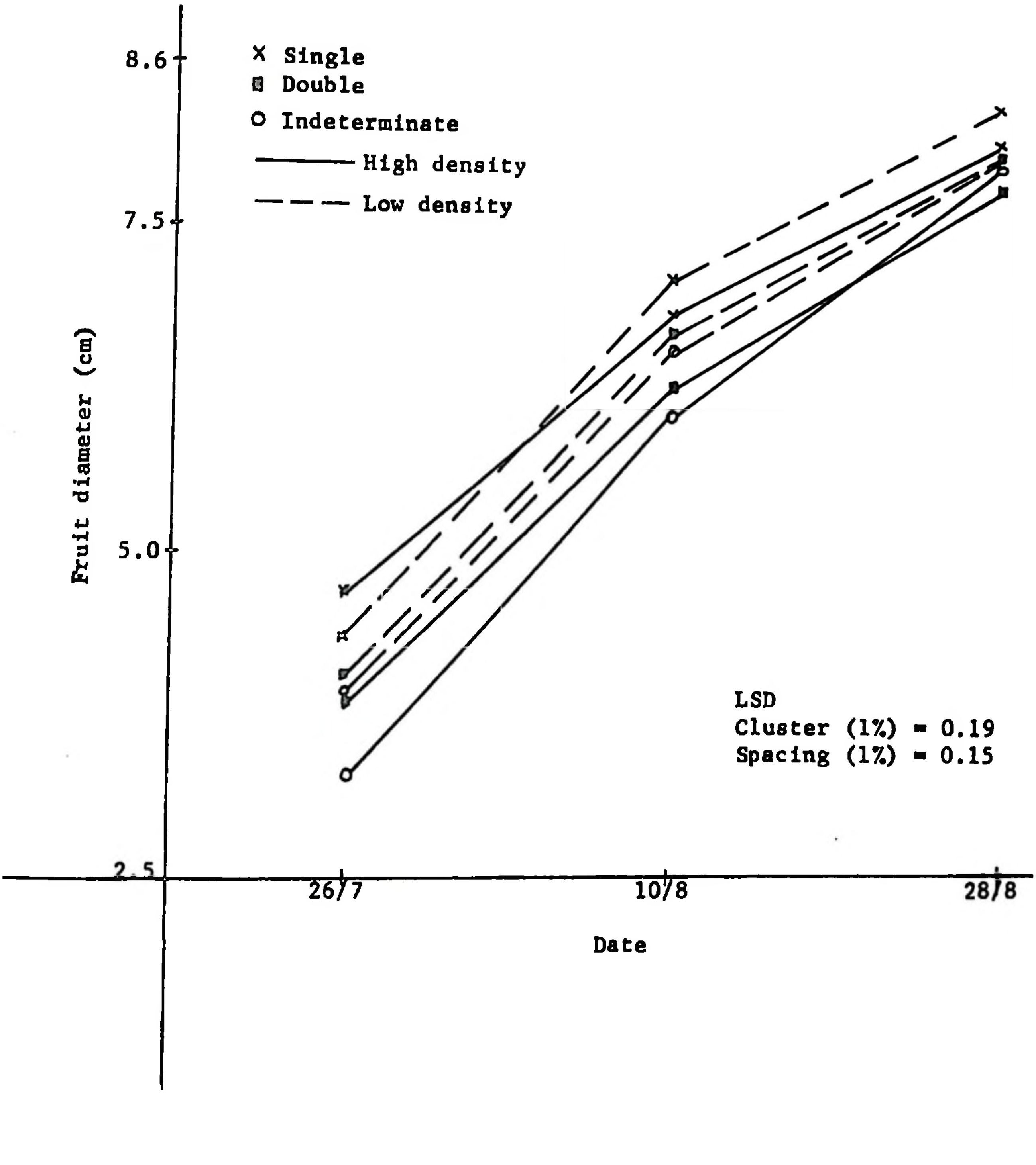


Figure 2. First proximal fruit growth on the first truss of 'W.Va. '63' tomato as influenced by truss number and plant population density.

plants for both plant densities than the rest. The first proximal fruits on the first cluster of indeterminate plants had the least growth rate at both plant densities and it was markedly lower at high plant density. There was no appreciable difference between growth rates of fruits of double cluster and indeterminate plants, but, high density had the effect of reducing growth. This altered the form of the double-cluster-fruit growth curve in comparison to that of the low-plant-density fruits. There was no significant cluster by spacing interaction.

The per cent growth in the first half of the maturation period i.e. Half-period values, are given in Figure 3. Relating the form of the growth curve to maturation, the greater the cluster load on the plant, the smaller was the per cent growth made in the first half of the maturation period. This was affected mostly at a high plant population. Plant density and cluster effects were significant at the 5 per cent level. Thus at high density, fruit growth was most rapid in the second half of the maturation period whereas at a low population rapid growth was made in the first half. Whereas fruits of single cluster plants made faster growth in the first half of the maturation period irrespective of plant density, fruit growth tended to shift to the second half of the maturation period as cluster number increased, the effect being accentuated by high density planting.

III. EFFECT OF TRUSS NUMBER AND PLANT DENSITY ON CROPPING PATTERN

Figure 4 illustrates the yield of fruit for the four harvests

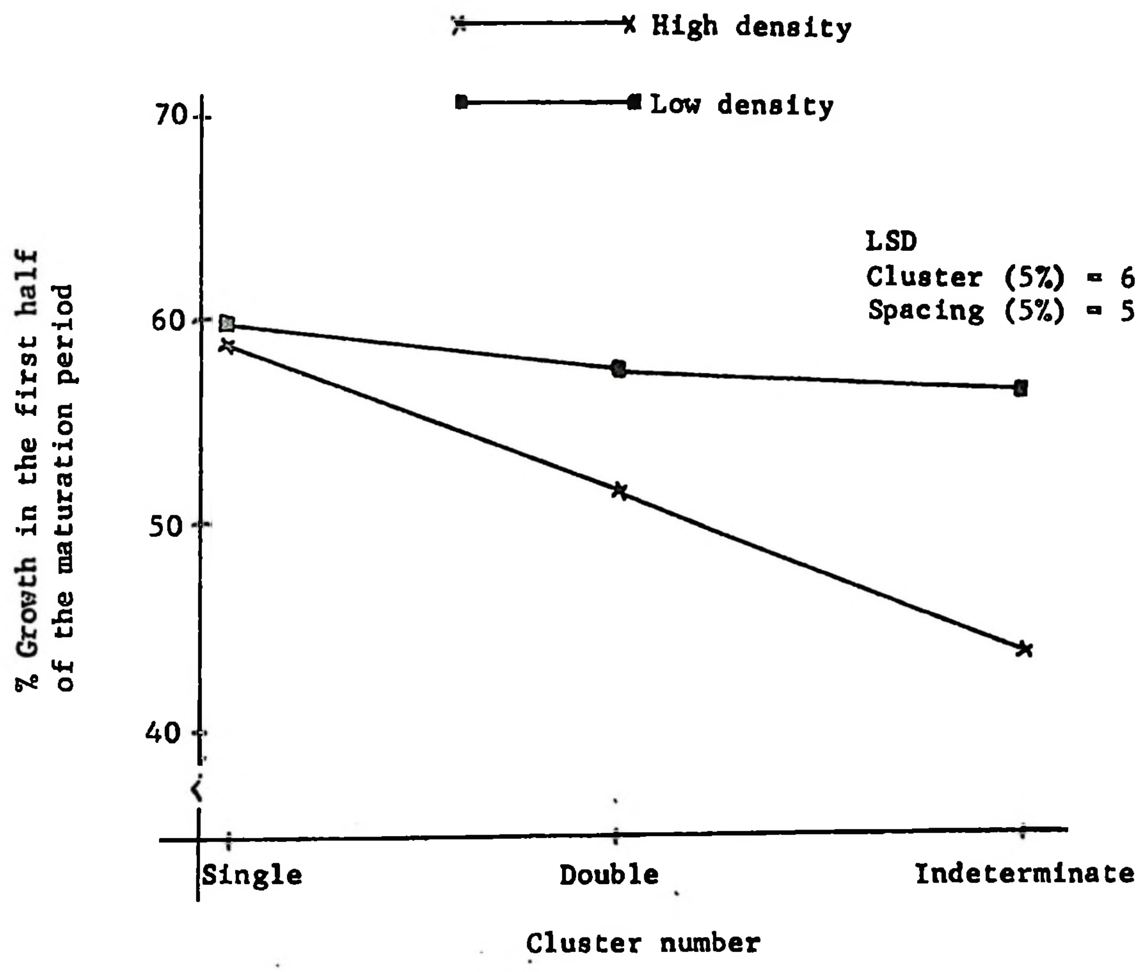


Figure 3. Per cent growth in the first half of the maturation period (Half-period values) of the first proximal fruit of 'W.VA. '63' tomato as affected by truss number and plant population.

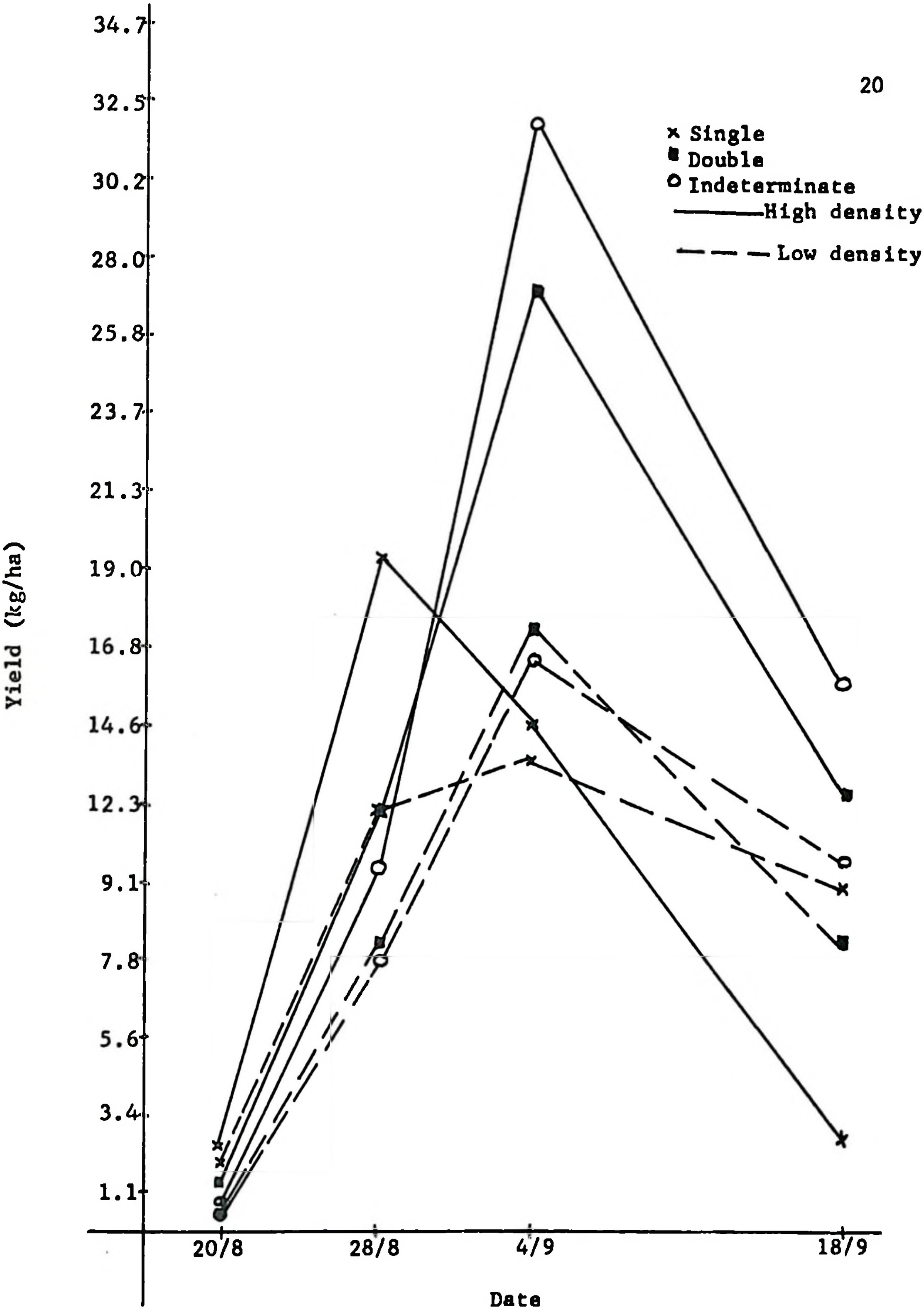


Figure 4. Cropping pattern as influenced by truss number and plant population density.

made. For both plant densities, single cluster plants yielded more than the rest in the second harvest; and those at high density yielded more than those at low. However, single cluster plants had significantly lower yields in the third and fourth harvests than double or indeterminate plants. For both plant populations, yield of double cluster and indeterminate plants were not significantly different at the 5 per cent level. The effect on yield increase by high density planting was demonstrated and this was more striking for double and indeterminate plants than those at low density.

The effect on total fruit yield is shown in Figure 5. At high density, there was significantly more yield than at low density for all levels of cluster number. Total fruit yield also increased with number of clusters left on the plant although the increase was more pronounced at high density for the four recorded harvests. Single cluster plants logically yielded lowest at both plant densities than the multicluster plants.

Figure 6 shows the effects on yield concentration. Although the differences between treatments on yield concentration were not statistically significant at the 5 per cent level, single cluster plants at high density had a tendency of increasing the proportion of total marketable fruit.

Earliness estimated as per cent marketable fruit at the first two harvests decreased as number of trusses remaining on the plant increased (Figure 7). Single cluster plants produced significantly more early fruit than multicluster plants whereupon at high density

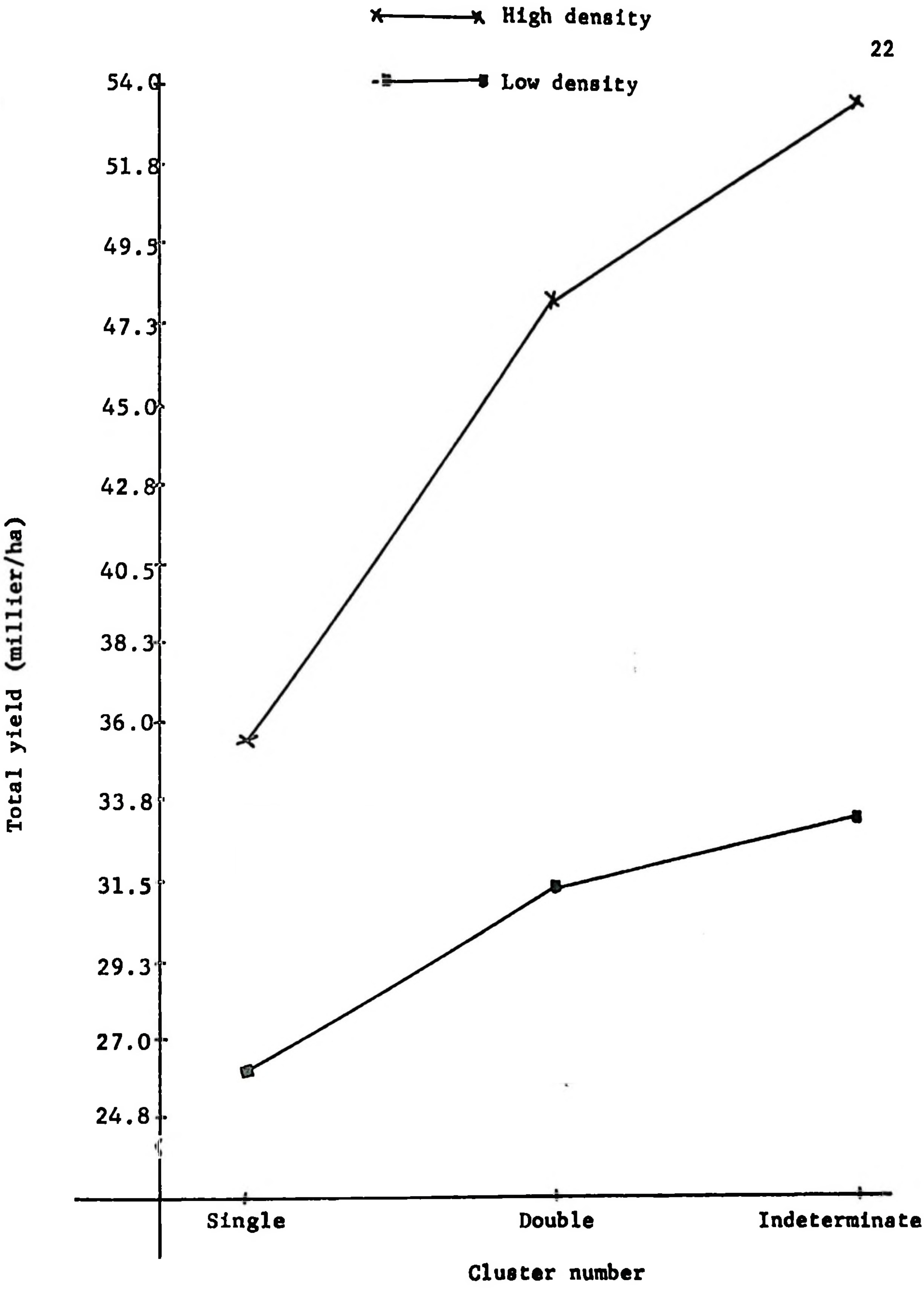


Figure 5. Effect of truss number and plant population on total fruit yield.

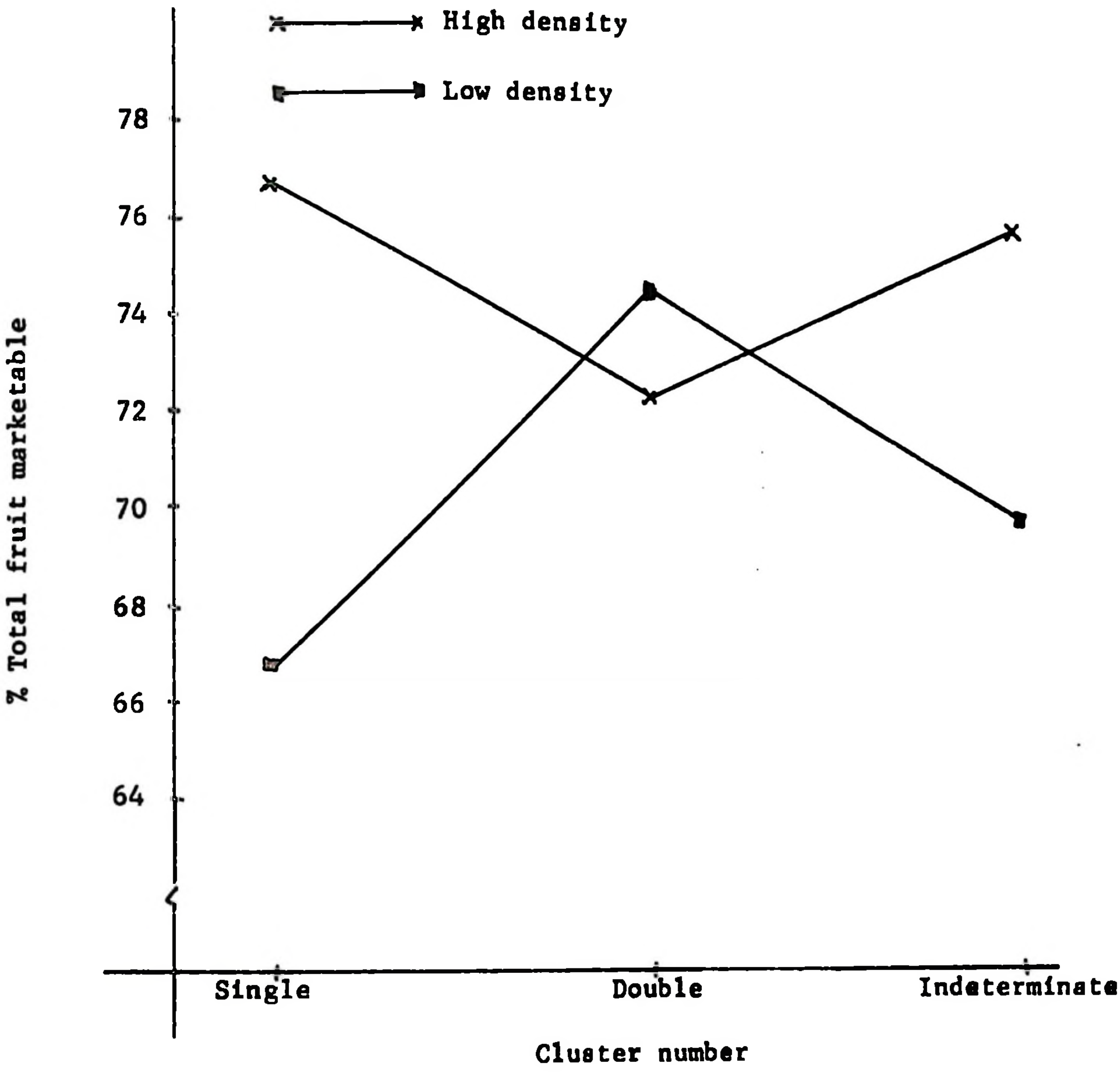


Figure 6. Effect of truss number and plant density on yield concentration.

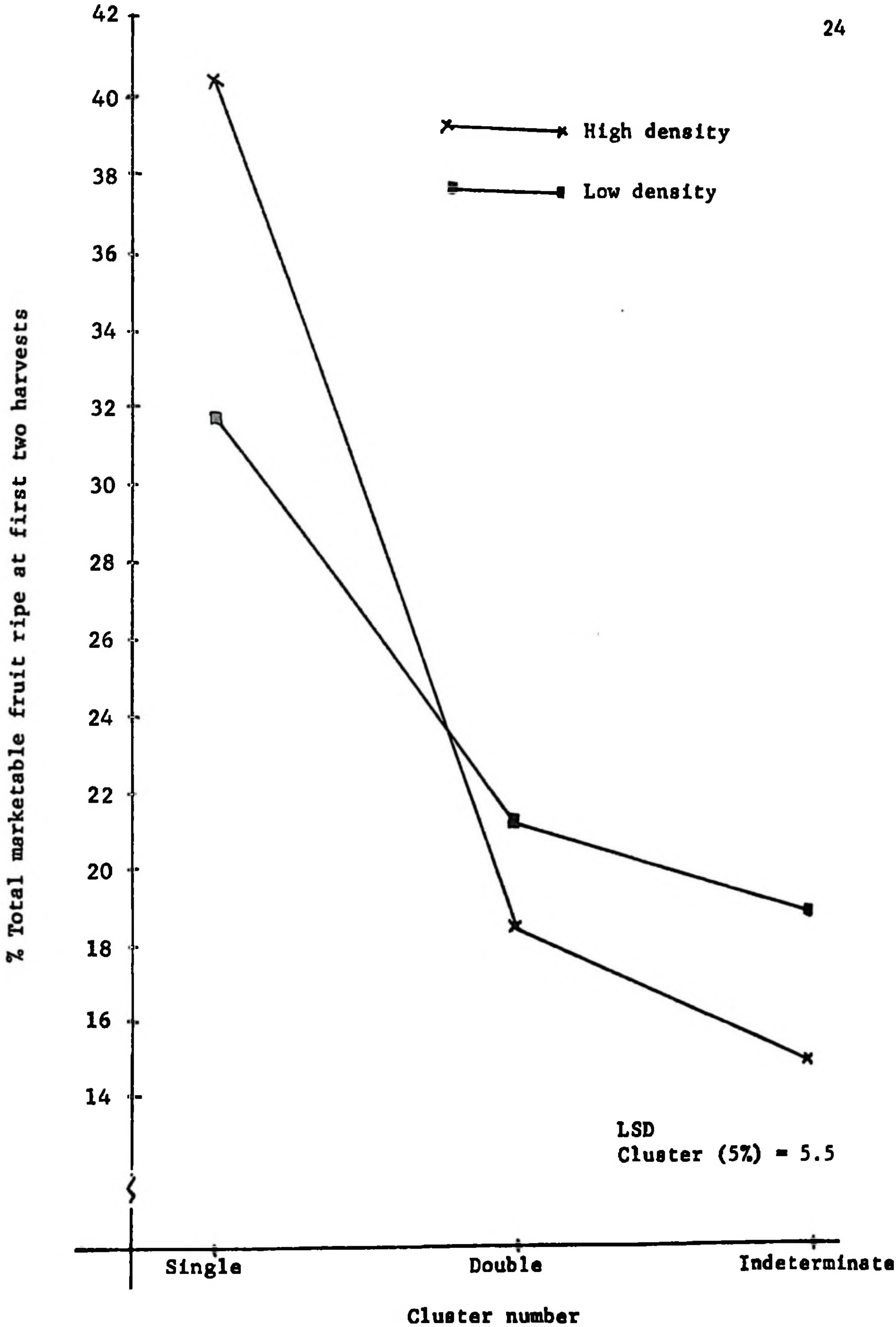


Figure 7. Effect of truss number and plant density on earliness.

about 10 per cent early yields over single cluster plants were realized. Indeterminate plants had considerably higher earlier yield at low plant population than at high density. The effect due to spacing on earliness on double cluster plants was nonsignificant.

Single cluster plants at high density produced significantly less cull fruit than at low density; the latter had ca 20 per cent more culls (Figure 8). The proportion of cull fruit on double or indeterminate plants did not differ appreciably at both populations and neither was the cluster number by spacing interaction significant at the 5 per cent level.

IV. QUALITY ATTRIBUTES OF THE FIRST TRUSS FRUITS OF 'W.VA. '63' AS AFFECTED BY RESTRICTED INDETERMINATISM AT A HIGH PLANT POPULATION DENSITY (average of 15 first proximal fruits)

(TABLE)

TRUSS NUMBER	AVERAGE FRUIT SIZE (lb)	pH	SOLUBLE SOLIDS %	CITRIC ACID %	SOLUBLE SOLIDS / ACID	P-L FIRMNESS ($Kx10^{-2}$GM/IN)
SINGLE	0.482	4.34	4.23	0.459	0.95	38.25
INDETERMINATE	0.475	4.43	4.32	0.445	0.96	25.45
LSD 5%	NS	NS	NS	NS	NS	2.36
1%	-----	----	----	-----	----	3.03

Decapitation of plants to a single cluster at a high plant population density had no effect on some of the raw product quality attributes analysed as shown in the table. Fruit firmness was significantly higher for fruits of single cluster plants than of

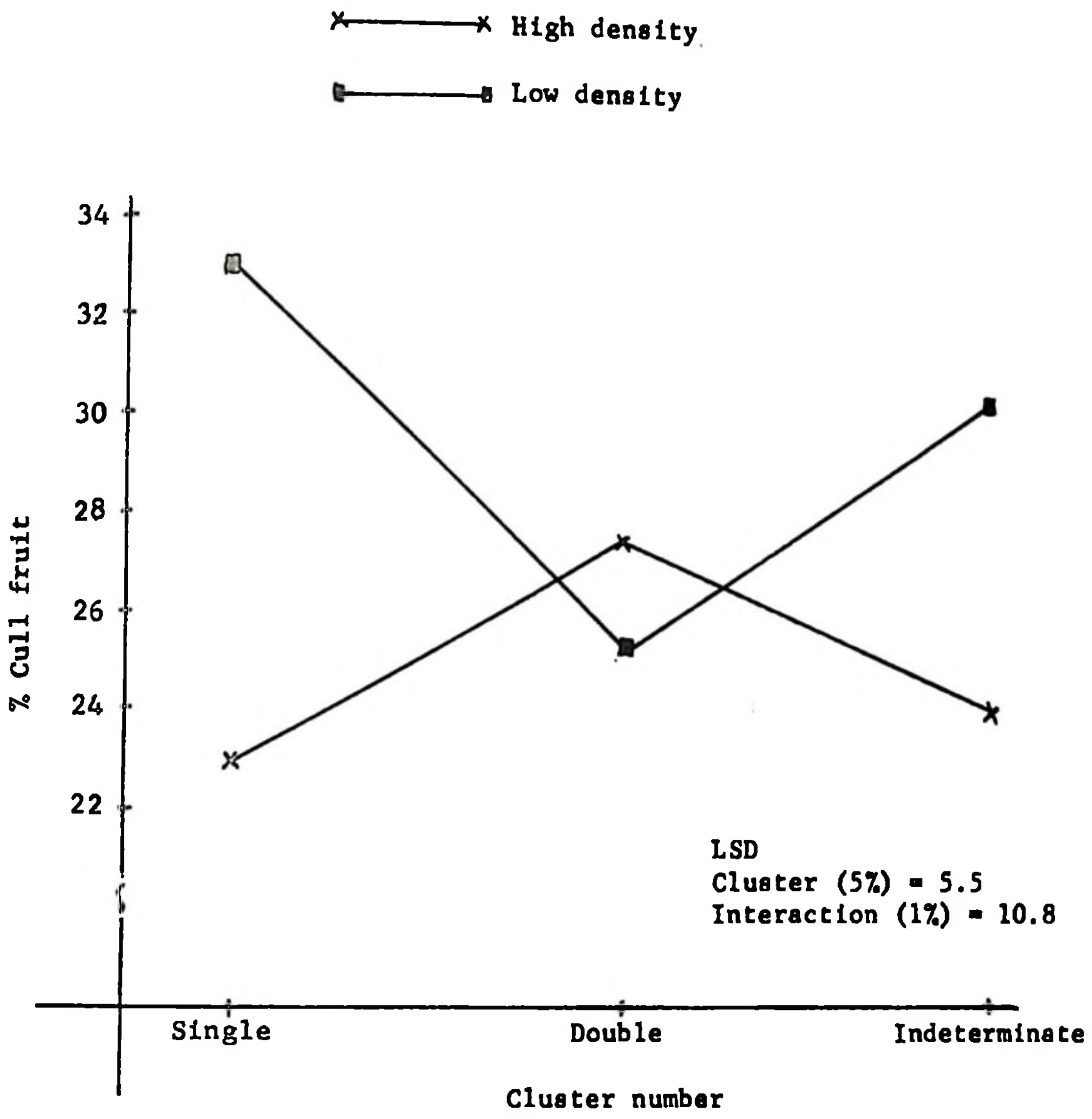


Figure 8. Influence of truss number and plant population on per cent cull fruit.

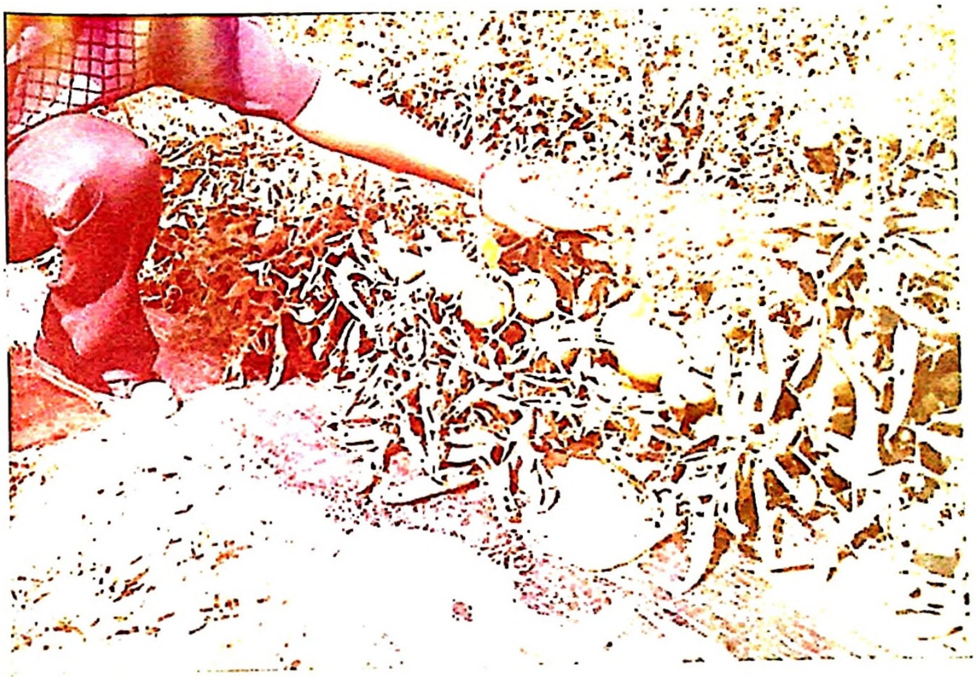
[illegible] plants. The pH, per cent soluble solids, per cent [illegible] acid and soluble solids/acid ratio were not significantly different at the 5 per cent level. Average fruit size also was not affected significantly by all treatment combinations in general.

[illegible]

[illegible]

PLATE

CROP RESPONSE TO EARLY DECAPITATION. EFFECTS ON LEAFLET POSTURE.



DISCUSSION AND CONCLUSIONS

The critical factor insofar as fruit setting in tomato is concerned is night temperature (64, 67) the optimum range being 15 - 20° C (Figure 9). There were fluctuations below the optimum during the critical period of fruit set in the first cluster in July and this might have in part accounted for the observed flower drop. The ambient night temperature was in general in the favorable range during this investigation. The presence of the second truss reduced fruit set on the first cluster which is in disagreement with the findings of Dullforce (17) who reported to the contrary. The results also show that at a low plant population, fruit set on the first cluster of indeterminate plants is higher than at high density, agreeing with published results (18, 51, 65). Decapitation to a single cluster had an effect of increasing fruit set especially at a high plant density. When plants are pruned, size, shape or flowering and fruiting responses are regulated and the underlying principle implicit in the practice is that a relationship between vegetative growth and reproduction exists (2). Adopting the concept of sink size-assimilate balance could aid explaining the results. The removal of apical and lateral vegetative growth hence reducing sink number made available more assimilates for fruit setting. It is generally acknowledged that the theory of C/N ratio (30) has been used successfully in many instances for the interpretation of results from physiological studies of growth and performance of horticultural plants. Inasmuch as there is a descending gradient of total N within the plant from top to bottom

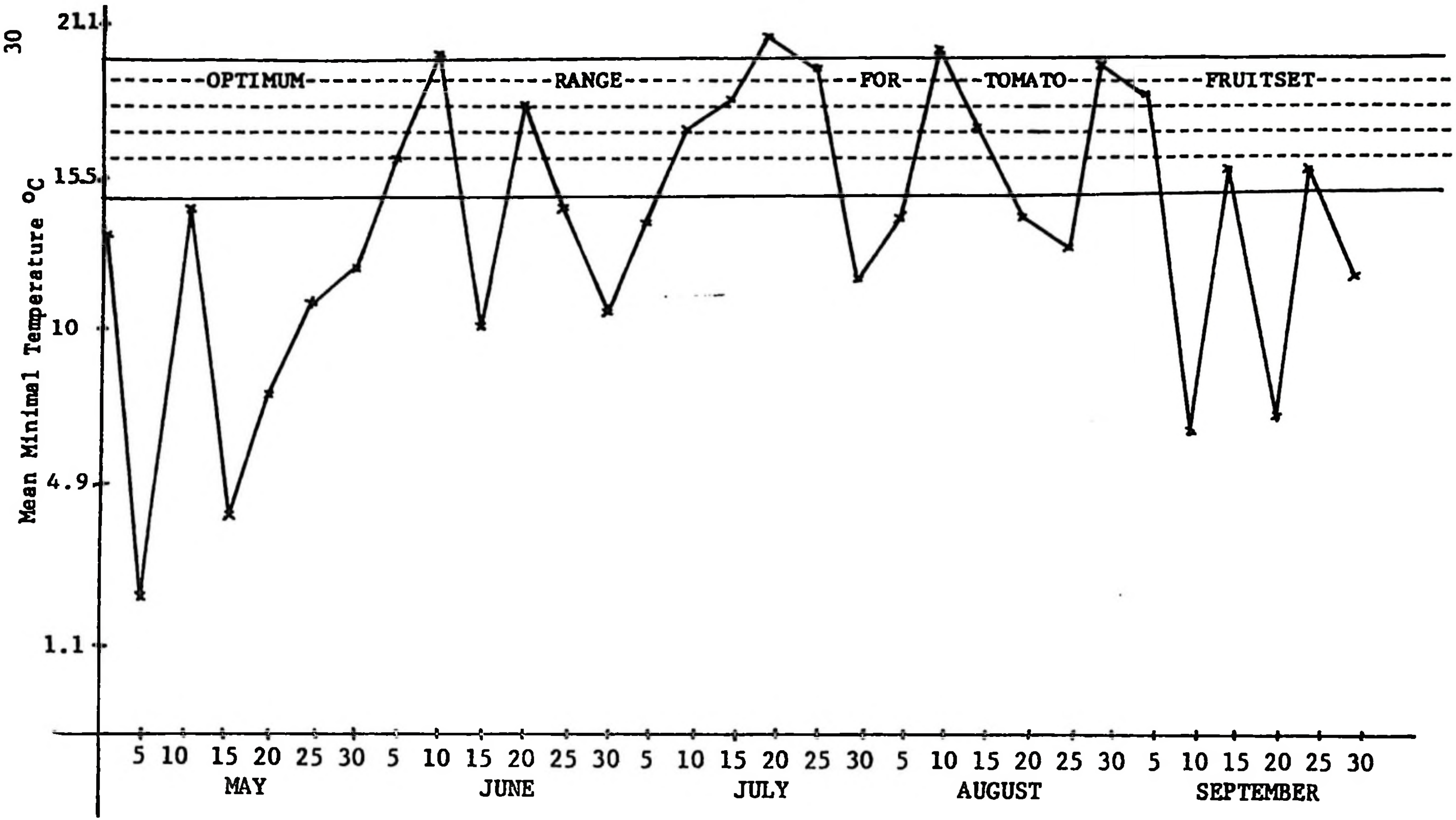


Figure 9. Mean minimal night temperatures in relation to the optimum range for tomato fruit set throughout the growing season - (May - September 1973) at the West Virginia University Horticulture Farm.

and an ascending gradient in carbohydrate (46) the results obtained with single cluster plants could be explained by adopting the C/N concept. The effect of N in increasing fruit set on first truss has been shown (1, 35). Pruning controls the C producing apparatus and thus affects the ratio and thence fruitfulness. There exists intra- and inter-plant competition in the case of tomatoes so that single cluster plants experience minimum intra-plant competition as opposed to indeterminate (multicluster) plants. Whereas the plant density factor governs the availability of exogenous resources for plant growth, the cluster factor determines the partition of endogenous growth metabolites. Indeterminate plants at a high density manifest a higher degree of bilateral antagonism so that fruit set on the first cluster is reduced. Single cluster plants, however, attained a good balance of assimilates by virtue of the physical modification of the growth habit which led to higher fruit set.

Although there is an increasing argument that it is not simply the carbohydrate, nitrogen or moisture levels concerned in fruitfulness as suggested by earlier workers, the C/N concept is perhaps basic. Aung and Kelly (2) proposed that inter- and intra-relationships of vegetative and reproductive organs should be examined in order to fully understand aspects of crop development. They found that after defoliation, the remaining leaves grew larger thus plants could maintain equilibrium after disturbance. Hussey (27) working on defoliation in tomato disclosed that various parts of young plants competed with one another for products of carbon assimilation and concluded that young leaves at first use more assimilates than they produce so that the removal of a young vegetative shoot above the first cluster made more assimilates available for floral growth. A similar conclusion was arrived at by Lake (31) when he observed that floral development was arrested in plants grown on a single stem of indeterminate length. Leopold and Scott (34) noted that the ability of tomatoes to set fruit was dependent on the presence of older leaves with supplied the necessary metobolites essential for fruit setting. Other workers (15, 35, 55) described an inhibiting effect of young leaves of fruit set so that when they were removed, flowering was promoted. A release from an inhibitory effect was apparent and this could be responsible for earliness in tomato (34) and can help explain the increased early flowering and earlier yields as those obtained by early decapitation by other workers (52, 65). Results from this investigation thus agree with some of the known physiological mechanisms affecting tomato fruit set.

The results obtained from the fruit growth studies could be explained similarly with a notion that the reduction of competitive sink allowed fruits on single cluster plants to make higher growth rate. This could be regarded as a converse of the studies on growth correlations in tomato (45) whereby fruit removal enhanced vegetative growth and the noted promotion of faster growth when plants are at low density is logical due to the reduction of inter-plant competition. Despite the final fruit size being unaffected by the treatment combinations, fruit growth made in the first half of the maturation period was invariably affected. The presence of the second or third cluster reduced the half-period value which agreed with the report of Cooper (5). Thus high density and indeterminatism had the effect of causing the initial lag in growth with subsequent lengthening of the maturation period. It could be concluded that the photosynthetic machinery was adequate for the development of fruits on single cluster plants and the effects of inter-plant competition were masked by the reduced cluster number. Further, results agree with the findings that fruit size did not increase proportionately with leaf area due to the fact that each fruit is in itself a photoshythesizing unit (21). The reduction of early growth (Figure 3) could be a measure of the magnitude of competition. The effect of cluster number when inter-plant competition was low (low density) shows smaller reduction of the "half-period' value but at a high density there was a greater reduction of growth in the first half of the maturation period. A conclusion is reached that population pressure is much more of a detrimental competitive factor than the developing fruit load with regards to fruit growth.

It is demonstrated here that owing to the fruiting habit of the test cultivar, like other commercial indeterminately grown cultivars, several harvests of fruit have to be made to obtain adequate yields as described in a time-frequency distribution (Figure 4). This tendency however, was reduced by single cluster cropping especially at a high density whose main effect was to shift the yield of fruit to an earlier period in the growing season rather than to increase the yielding capacity of the plants. The increase of total yields due to high density and multicluster cropping parallels many published results mainly due to the increase of cluster per unit area (18, 70). The effect of single cluster culture at a high plant population in increasing earliness is consistent with preceeding reports (4, 9, 26). Knowledge of marketable proportions is prerequisite to the estimation of potential yield obtainable in a single destructive harvest (13). Treatment effects did not show differences with regards to yield concentration, however high density had a tendency of increasing yield concentration for single and indeterminate plants. Fery and Janick (18) reported that at high density yields of indeterminate plants are concentrated because the fruit on each plant is restricted to the early cluster. Results from this investigation do not seem to agree probably because of type of test cultivar or length of growing season. The increase of early yields at high plant population of indeterminate plants was because of increased number of early clusters per unit area (18, 51, 70). The increase of earliness by single cluster cropping could be explained by the increased fruit set observed. Single cluster plants are of limited reproduction and vegetative growth in *sensu strictu* and maturation dispersion is due solely to within truss variation whereas for multicluster plants another maturation variable component, truss position, operates. Davis *et al*. (11, 12) observed that the dispersion of fruit set in a plant results in a scattering of maturation dates causing harvests to vary considerably but faster rates of maturation for successfully initiated fruits will concentrate the harvest pattern. Results reported herein abide with these findings. Concentrating fruit setting, achieved by decapitation to a single cluster and adjusting the plant population to enhance more set and fruit growth, had an effect of limiting maturation dispersion caused in part by the distribution of initiation over time. However, it is worth noting that the 'West Virginia '63', a late and vigorous cultivar, barely reached fourth cluster fruit maturation prior to termination of the investigation, which does imply that these results are of a cultivar inherently different from those used by previous investigators. Cultivars respond differently to population pressure (18) and their differences in adaptability to single cluster and dense planting has been stressed by Honma et al. (26).

Neither did spacing nor cluster number treatment significantly reduced the size of fruits on the first cluster perhaps because population pressures were not great enough whereas moisture, nutrients and other factors may have been adequate. Consequently the raw product analysis of these fruits did not differ appreciably. Decapitation to single cluster had the tendency to lower the pH, per cent soluble solids and the per cent soluble solids/acid ratio, the latter being due to the slight increase in acidity. As individual fruits mature, organic acids tend to decrease while sugars tend to increase thus the soluble solids/acid ratio should be higher in mature fruits than the immature ones. Fruit of indeterminate plants had slightly higher pH and lower acidity indicating that they were slightly more mature initiated fruits will concentrate the harvest pattern. Results reported herein abide with these findings. Concentrating fruit setting, achieved by decapitation to a single cluster and adjusting the plant population to enhance more set and fruit growth, had an effect of limiting maturation dispersion caused in part by the distribution of initiation over time. However, it is worth noting that the 'West Virginia '63', a late and vigorous cultivar, barely reached fourth cluster fruit maturation prior to termination of the investigation, which does imply that these results are of a cultivar inherently different from those used by previous investigators. Cultivars respond differently to population pressure (18) and their differences in adaptability to single cluster and dense planting has been stressed by Honma _et al_. (26).

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The observed change in foliage orientation and characteristics when rapid fruit growth became eminent is puzzling but could be explained by adopting the findings of Murneek (46) that there exists antagonism between vegetative and reproductive growth. He found that the per cent of N in fruit is higher than in any other part of the same plant the fruit being able to divert and monopolize in some manner almost all the available nitrogen, accounting in part at least for marked carbohydrate accumulation in vegetative structures. The sink size-assimilate imbalance created results in partial starvation of leaves. However the hyponastic response was not accompanied by any adverse effects on the performance of the plants and indeed the change of leaf orientation should mean a higher level of photosynthetic efficiency as advocated by Loomis and Williams (38). Such crop responses have obvious advantages in tomato culture. Decapitation to single cluster afforded the fruits a better exposure to light and pesticidal cover and made the desuckering operation easier and minimal. The costly operations of trellising could be alimated as suggested (26). The plants were able to complete their developmental cycle early which implies the possibilities of intensive multiple cropping as previous researchers have suggested (8, 23, 26, 63, 68). And as Cooper (7) remarked, "Factors which limit yield as density of planting is increased are apparently not related to inter-plant competition but rather with ease of management."

SUMMARY

A field experiment to investigate the influence of cluster (truss) number and plant population on the set, growth and yield of early fruit of the 'West Virginia '63' tomato cultivar and the effect of decapitation to single cluster on fruit quality at a high plant population was conducted.

Transplants were raised for ten weeks in the greenhouse prior to field set. Liberal inorganic and organic fertilization, preemergent chemical weed control and laying of plastic mulch and trickle irrigation tubes constituted some of the pre-establishment practices while weekly irrigation, sucker removal and insect control were thereafter routine operations. Single or double cluster plants were obtained by the removal of the plant top two leaves above the cluster when the respective top infloresence was in full bloom whereas multicluster treatment comprised of indeterminate single stem plants. Spacing between plants were varied from 0.9 m by 25 cm to 0.9 m by 15 cm to obtain plant populations of 5,200 plants/ha and 11,600 plants/ha respectively. On fifteen pre-tagged plants per plot, the number of fruits set on the first cluster was counted when fruits were visible. Growth studies of the first proximal fruits on the first cluster were carried out approximately fortnightly on three dates; a week after set, middle of the maturation period and at harvest. The per cent growth in the first half of the maturation period - 'Half-period' values were estimated from the cube of radii in the middle of the maturation period expressed as per cent of the final.

Harvesting followed grower practice (i.e. when a larger proportion of fruits were ripe) thereafter fruits were graded into U.S. No. 1 (= U.S. No. 1 plus U.S. No. 2), culls and their number and weights were recorded. From the cumulative yields, earliness and yield concentration were estimated as per cent marketable fruit obtained in the first two harvests and per cent total marketable fruits respectively.

Under the night temperatures which prevailed in the course of the investigation, decapitation of plants to a single cluster markedly increased fruit set over those on double or multicluster plants though differences in set were nonsignificant. The influence of plant population was such as to increase fruit set of single cluster plants at high density and that of indeterminate plants at a low density. Fruits on single cluster plants attained a higher growth rate at both spacings than those on other cluster number treatments while high density planting had a tendency to reduce rate of fruit growth for double and indeterminate plants over those at a low density. The differences in growth rates are reflected in the estimations of 'Half-period' values which clearly show that single cluster cropping at both spacings promoted faster fruit growth in the first half of the maturation period and this declined as cluster number and population pressure increased. Inter-plant competition was a more important factor affecting fruit growth than intra-plant competition.

Total yields increased with plant population and cluster number but single cluster cropping promoted high earliness and had least percentage of cull fruits at a high density although yield concentration was not significantly increased. The differences between double and multicluster cropping of this cultivar with regard to earliness and per cent cull fruit were nonsignificant except that low plant population had a tendency to increase earliness which paralleled the increased fruit set on the first cluster. In lieu of the alteration of growth pattern, single cluster plants had the effect of shifting cropping to an earlier period in the growing season. Neither final fruit size nor attributes of fruit quality i.e. pH, per cent soluble solids, per cent citric acid and soluble solids/acid ratio were significantly affected by limiting plant growth to a single cluster at a high population (11,600 plants/ha). However, the pressure-load fruit firmness of single cluster plants was strikingly higher than that of corresponding fruits on multicluster plants under similar population pressure. The need to analyse for calcium intake as a possible explanation for the high firmness is suggested. Hyponasty manifested by leaflets in response to early decapitation did not seem to impair plant performance. Sucker removal was minimal, trellising was rendered unnecessary and pesticidal sprays attained better coverage on fruits.

In light of this investigation, 'West Virginia '63' cultivar is adapted to single cluster cropping at a high plant population for more efficient but intensive cropping.

LITERATURE CITED

1. Adams, P. G., G. W. Winsor, and J. D. Donald. 1973. The effect of nitrogen, potassium and sub-irrigation on the yield, quality and composition of single truss tomatoes. J. Hort. Sci. 48: 123-33.

2. Aung, L. H., and W. C. Kelly. 1966. Influence of defoliation on vegetative, floral and fruit development in tomatoes (Lycopersicon esculentum Mill). Proc. Amer. Soc. Hort. Sci. 89:563-70.

3. Butters, R. E. 1961. A tomato spacing trial under Gurnsey conditions. Grower. 56:208-9.

4. Canham, A. E. 1967. Single truss tomatoes in a growing room. Shinfield Prog. 11:8-12.

5. Cooper, A. J. 1959. Observations on the growth of the fruit on glasshouse tomato plants between March and September. J. Hort. Sci. 34:96-103.

6. ____________. 1959. Observations on the growth of leaves of glasshouse tomato plants between March and August. J. Hort. Sci. 34:104-110.

7. ____________. 1960. The effect of plant form and plant density on glasshouse tomato cropping. J. Hort. Sci. 35:103-9.

8. ____________. 1965. Single truss tomato production. Rep. Glasshouse Crops Res. Inst. 115-125.

9. ____________. 1966. Single truss tomatoes mean plant, pinch, pick and pull up. Grower 65:143-4.

10. Crowder, R. A. 1970. High density tomatoes for processing. N.Z.J. Agr. 121:70-5.

11. Davis, R. M., P. G. Smith, V. H. Schweers, and R. W. Scheuerman. 1965. Relationships between fruit set and developing fruit load in tomato. Proc. Amer. Soc. Hort. Sci. 86:557-64.

12. ____________, ____________, ____________, ____________, and A. H. Millett. 1969. Components of variation in tomato harvest patterns. J. Amer. Soc. Hort. Sci. 94:538-41.

13. ____________, R. Fildes, G. A. Baker, M. Zahara, D. M. May, and K. B. Tyler. 1970. A method of estimating the potential yield of a vegetable crop obtainable in a single harvest. J. Amer. Soc. Hort. Sci. 95:475-80.

14. Dennison, R. A. 1955. Tomato ripening. A discussion of the factors that influence color, flavor and firmness in tomato fruits. Market Growers' J. 84:6.

15. deZeeuw, D. 1956. Leaf induced inhibition of flowering in tomato. Proc. Koninkl. Ned. Acad. Wetenschappen Amsterdam 59: 535-450. (Cited by Leopold, A. C., and S. L. Lam. (35))

16. Diener, R. G., F. E. Sobotka, and A. E. Watada. 1970. An accurate low cost firmness measuring instrument. ASAE Paper No. 70-391.

17. Dullforce, W. M. 1965. Is a two truss crop a better proposition? Grower 64:565-69.

18. Fery, R. L., and J. Janick. 1970. Response of the tomato to population pressure. J. Amer. Soc. Hort. Sci. 95:614-24.

19. Fisher, K. J. 1969. Effect of nitrogen supply during propagation on flowering and fruiting of glasshouse tomatoes. J. Hort. Sci. 44:407-11.

20. Gallegly, M. E. 1964. 'West Virginia '63'. A new home garden tomato resistant to late blight. W.Va. Agric. Exp. Sta. Sci. Bull. 490 3pp.

21. Gustafson, E. G., and T. E. Stoldt. 1936. Some relations between leaf area and fruit size in tomatoes. Plant Physiol. 11:445-51.

22. Hanna, G. C. 1960. Progress report on studies of ripening tomatoes on the vine. Veg. Crop Ser., University of Calif., Davis 102:7.

23. Hartmann, H. D., F. W. Frenz, and W. Zischka. 1968. Cultivating stopped tomatoes. Gemuse 3:149-52 (Hort. Abstr. 38:752)

24. Hayslip, N. C. 1966. Spacing vegetable crop plants. A.R. Fla. Agric. Exp. Stat. 1963-63 p 286

25. Holliday, R. 1960. Plant population and crop yield. Nature 186:22-24

26. Honma, S., J. D. Vriesenga, and R. C. Herner. 1970. High density tomato production. Amer. Veg. Grower 34-6pp.

27. Hussey, G. 1963. Growth and development in young tomato. II. The effect of defoliation on the development of the shoot apex. J. Exp. Bot. 14:326-33.

28. Kattan, A. A., F. C. Stark, and A. Kramer. 1957. Effect of certain pre-harvest factors on yield and quality of raw and processed tomatoes. Proc. Amer. Soc. Hort. Sci. 69:327-342.

29. Khan, A. A., and A. R. Sagar. 1967. Translocation in tomato. The distribution of products of photosynthesis of leaves of a tomato plant during the phase of fruit production. Hort Res. 7:60-9.

30. Kraus, E. J., and H. R. Kraybill. 1918. Vegetation and reproduction with special reference to the tomato. Oreg. Agr. Exp. Bull. 149.

31. Lake, J. V. 1967. The temperature response of single truss tomatoes. J. Hort. Sci. 42:1-12.

32. Lam, S. L., A. C. Leopold, and K. W. Johnson. 1962. A chemical treatment to concentrate tomato ripening for mechanical harvest. Proc. Amer. Soc. Hort. Sci. 80:530-34.

33. Lee, F. A., and C. B. Sayre. 1946. Factors affecting the acid and total solids content of tomato. N.Y. Agr. Exp. Sta. Bull. 297.

34. Leopold, A. C., and F. I. Scott. 1952. Physiological factors in tomato fruit set. Amer. J. Bot. 39:310-17.

35. ____________, and S. L. Lam. 1960. A leaf factor influencing tomato earliness. Proc. Amer. Soc. Hort. Sci. 76:543-54.

36. ____________. 1964. Plant growth and development. McGraw-Hill Book Co., New York.

37. Litynski, M., and Z. Stankiewicz. 1955. Observation on the flowering and fruiting of some varieties of glasshouse tomatoes. Tesc. Nauk. Wyz. Szkory Rol. Wroclaw. Rolnictwo 1:113-34. (Hort. Abstr. 27:80).

38. Loomis, R. S., and W. A. Williams. 1969. Productivity and the morphology of crop stands: Pattern with leaves. 27-46p In Eastin, J. D., F. A. Haskins, C. Y. Sullivan, and C. H. M. van Bavel (Ed). Physiological Aspects of Crop Yield. Amer. Soc. Agron. Crop Sci. Soc. of Amer., Madison, Wisconsin.

39. Loughton, A. 1968. Effect of plant density on yield of field tomatoes. Rep. Hort. Res. Inst. Ont. 35-7.

40. Massey, L. M., W. B. Robinson, N. H. Peck, and G. A. Marks. 1962.

Yield and raw product quality of processing tomatoes resulting from once-over harvest. Proc. Amer. Soc. Hort. Sci. 80:544-49.

41. McCollum, J. P. 1956. Sampling tomato fruits for composition studies. Proc. Amer. Soc. Hort. Sci. 68:587-95.

42. McGillivray, J. H., and I. L. Clemente. 1956. Effect of tomato fruit size on solids content. Proc. Amer. Soc. Hort. Sci. 68: 466-69.

43. Millikan, C. R., E. N. Bjarnason, R. K. Osborn, and B. C. Hanger. 1971. Calcium concentration in tomato fruits in relation to incidence of Blossom End Rot. J. Exp. Agr. Anim. Husb. 11: 570-75.

44. Moore, J. N., A. A. Kattan, and J. W. Fleming. 1958. Effect of supplemental irrigation, spacing and fertility on yield and quality of processing tomatoes. Proc. Amer. Soc. Hort. Sci. 71:356-368.

45. Murneek, A. E. 1926. Effect of correlation between vegetative and reproductive functions in tomato. (Lycopersicon esculentum Mill). Plant Phys. 1:3-56.

46. ____________. 1927. Effect of pruning of the Carbohydrate-Nitrogen ratio in the tomato. Proc. Amer. Soc. Hort. Sci. 180-184.

47. Nicklow, C. W., and J. D. Downes. 1971. Influence of nitrogen and potassium and plant population on the maturity of field seeded tomatoes for once-over harvest. J. Amer. Soc. Hort. Sci. 96:46-9.

48. Petresu, C. 1966. A new method of growing early tomatoes for higher yields. Grad. via Liv (Bucharest) 15:11-15. (Hort. Abstr. 36:791)

49. ____________, and P. Andrei. 1944. The influence of plant density and number of infloresences on early tomato yields. Res. Hort. Vitic. 20:40-6.

50. Reeve, E., and W. A. Schmidt. 1952. Influence of plant spacing on canning tomato yields. Proc. Amer. Soc. Hort. Sci. 59:384-88.

51. ____________, W. A. Robbins, W. S. Taylor, and J. F. Kelly. 1962. Cultural and nitrogen fertilization practices in relation to tomato fruit set and yield. Campbell Soup Company, Camden, New Jersey 129-147

52. Sayre, C. B. 1948. Early and total yields of tomatoes as affected by the time of seeding, topping the plants and spacing in the flats. Proc. Amer. Soc. Hort. Sci. 51:367-70.

53. Shizonaki, V., and T. Kira. 1956. Interspecific competition among higher plants. VII. Logistics theory on C-D effect. J. Inst. Polytech, Osaka City, Univ. Ser. D. 7:35-72.

54. Snedecor, G. W., and W. G. Cochran. 1967. 'Statistical Methods' 6th Ed. Iowa Sta. Univ. Press, Ames, Iowa.

55. Snow, R. 1929. The young leaves as an inhibiting organ. New Phytol. 28:345-58.

56. Sumerghy, J. B. 1965. High yields in one pick from close spacings of tomatoes. Agric. Gax. N. S. W. 76:497.

57. Thompson, A. E. 1962. Characterization of tomato varieties and strains for constituents of fruit quality. Univ. Ill. Agr. Sta. Bull. 685.

58. Thompson, H. C., and W. C. Kelly. 1957. Vegetable Crops. 5th Ed. McGraw Hill Book Co., New York.

59. Videki, L. 1969. The relationship between chemical composition and fruit size in tomatoes. Duna-Tisza Kozi Mezogazd Kiserl. Inst. Bull. 4:65-71. (Hort. Abstr. 41:193)

60. _____________, and L. Vukovits. 1969. Studies on factors affecting firmness in tomatoes. Zoldsegtermesztes 3:3-19. (Hort. Abstr. 40:1044)

61. Vitum, M. T., and W. T. Tapley. 1954. Spacing and fertility level with a determinate type tomato. Proc. Amer. Soc. Hort. Sci. 61:339-42.

62. _____________, W. B. Robinson, and G. A. Marx. 1962. Raw product quality of vine-ripened processing tomatoes as influenced by irrigation, fertility level and variety. Proc. Amer. Soc. Hort. Sci. 80:535-43.

63. Walls, I. G. 1972. Tomato Growing Today. David and Charles Newton Abbot 134-5pp.

64. Went, F. W., and G. E. Cosper. 1945. Plant growth under controlled conditions. VI. Comparison between field and air conditioned greenhouse culture of tomatoes. Amer. J. Bot. 32:643-54.

65. Westover, K. C. 1942. Further studies on the effect of topping young tomato plants on fruit set and yield. Proc. Amer. Soc.

Hort. Sci. 41:285-88.

66. Wilcox, G. E. 1970. Influence of row spacing and plant density on single harvest tomato yields. J. Amer. Soc. Hort. Sci. 95: 435-37.

67. Witwer, S. H., H. Stallworth, and M. J. Howell. 1948. The value of a 'Hormone' spray for overcoming delayed fruit set and increasing yields of outdoor tomatoes. Proc. Amer. Soc. Hort. Sci. 51:371-80.

68. ____________, and S. Honma. 1969. Greenhouse Tomatoes Guidelines for Successful Production. E. Lansing M.S.U. Press.

69. Woods, J. J. 1940. Spacing staked tomatoes. Sci. Agr. 20: 313-16.

70. Zahara, M. 1970. Influence of plant density on yield of process tomatoes for mechanical harvest. J. Amer. Soc. Hort. Sci. 95: 510-12.

Table 2. (Appendix)

Harvest Data

DATE	TREATMENTS		TOTAL FRUIT NUMBER	TOTAL WEIGHT (kg)	US#1 WEIGHT (kg)	CULLS WEIGHT (kg)	AV. FRUIT SIZE (gm)
	DENSITY	CLUSTER					
8/20/73	High	Single	9.8	1.9	0.7	1.2	181.4
	High	Double	5.5	0.9	0.2	0.7	158.8
	High	Ind.	4.0	0.7	0.3	0.4	172.4
	Low	Single	13.2	2.7	1.2	1.5	195.0
	Low	Double	4.2	0.8	0.2	0.6	181.4
	Low	Ind.	4.2	0.8	0.3	0.5	204.1
8/28/73	High	Single	64.2	14.3	10.9	3.5	222.2
	High	Double	41.5	8.9	7.0	1.9	213.1
	High	Ind.	37.8	7.7	6.2	1.5	199.6
	Low	Single	76.8	16.1	10.8	5.3	204.1
	Low	Double	52.0	10.9	8.9	2.0	208.6
	Low	Ind.	42.5	10.4	8.4	2.0	249.4
9/4/73	High	Single	47.7	10.7	9.6	1.1	222.2
	High	Double	94.3	19.9	14.8	5.1	208.6
	High	Ind.	108.3	23.5	17.9	5.6	313.1
	Low	Single	81.7	17.8	12.6	5.2	217.7
	Low	Double	108.8	22.7	17.3	5.4	208.6
	Low	Ind.	97.8	21.6	13.4	8.2	217.7
9/18/73	High	Single	10.5	1.9	0.9	1.0	181.4
	High	Double	40.8	9.3	6.3	3.0	222.2
	High	Ind.	49.3	11.2	8.4	2.8	231.3
	Low	Single	6.7	1.3	0.7	0.6	195.0
	Low	Double	48.2	10.9	7.3	3.6	222.2
	Low	Ind.	60.7	13.8	10.4	3.4	222.5

ABSTRACT

In a field experiment with the 'West Virginia '63' tomato cultivar to identify the influence of truss number and plant population density on the set, growth and yield of early fruits and the effect of single cluster cropping on their quality at a high density, it was revealed that there was a dependence of set and growth of first cluster fruits on number of clusters left to develop and plant population. Decapitation of greenhouse raised and field set transplants two leaves above the first cluster when the second cluster was in full bloom increased fruit set remarkably in a dense planting of 11,600 plants/ha whereas when conventionally grown (trellis indeterminate and single stem) fruit set was improved at plant density of 5,200 plants/ha. Single cluster cropping favored more rapid fruit growth. The effect of high density and multicluster cropping was such as to defer fruit growth to the second half of the maturation period as opposed to either high density single cluster cropping or low density planting. Inter-plant competition became a more important factor governing early fruit growth as cluster number increased.

Limiting plants to a single cluster at a high density planting did not increase yield concentration but promoted earliness with least per cent cull fruit. Influence of plant population variation on double cluster plants was in all cases minimal and nonsignificant while there was a tendency for multicluster single stem plants at low density to promote earliness primarily because of the increased fruit set on the first truss.

Owing to the alteration of the fruiting habit single cluster plants at a high density had an effect of shifting cropping to an earlier period in the season with the effect of increasing fruit firmness without adversely affecting fruit size or quality attributes. Some aspects of crop management i.e. sucker removal, trellising and pest control were made easier and efficient due to, in part, the early termination of the cropping cycle. 'West Virginia '63' a late maturing, vigorous and indeterminate cultivar has shown promise to be adaptable to high density single cluster culture at field level.

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