EVALUATION FOR PROCESSING CHARACTERISTICS AND THEIR EXPRESSION IN A BACTERIAL WILT RESISTANT GENETIC BACKGROUND IN TOMATO

BY

ALICE KURIAN

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Introduction

INTRODUCTION

Tomato is the most versatile vegetable grown throughout the world. The crop is well suited for processing and ranks first among processed vegetables.

The main tomato producing countries in the world are USA, USSR, China, Italy, Egypt and Japan. World production of tomato estimated by FAO is 64 million tonnes during 1988. USA is the principal producer (8.3 million tonnes) and consumer of tomato and tomato products (0.4 million tonnes). India, with an estimated area of 83,000 ha and annual production of 0.79 million tonnes of tomato, does not figure in the processing map of the world. During 1985, India produced 8.8 tonnes of tomato products of which ketchup was the predominant item.

The future of processing tomato in India is bright due to rapidly increasing domestic consumption and export potential. Now-a-days processed tomatoes are incorporated in many traditional foods. Lack of ideal processing variety with requisite quality standards is a major constraint of processing industry in India. Varieties like Pusa Ruby is widely used by the industry, in spite of its poor processing attributes due to non-availability of better types.

In India, tomato breeding is mainly oriented on production problems of growers and consequently improvement of productivity and disease resistance took precedence over quality. In the west, tomato is fine tuned into several varieties, better able to meet the needs of growers and rapidly expanding processing industry. Ultimately, this resulted in the development of cultivars suited to specific products. Processing tomatoes are distinct from fresh market types for high total solids and insoluble solids, fairly high acidity, uniform intense red colour, resistance to cracking and elongated fruits with high yield potential. Plants should also be adapted for mechanical harvesting with determinate habit, concentrated fruit set for once over harvest and jointless pedicel of fruit.

Utilization for processing is low in India compared to developed countries where 30 to 40% of the production is processed. Lack of ideal processing varieties and inexhaustive data on the processing genotypes, its physicochemical characteristics under different agroclimatic zones are some of the reasons for this situation. This prompted the need to evaluate known processing tomatoes so as to identify genotypes and characters which contribute to high case yield and quality.

It is well known that artificial colours are injurious to health and there is a ban on its use in tomato products. It has become imperative to identify tomatoes which retain natural colour in processed products for a reasonable period of storage.

Cultivation of processing tomatoes in the warm humid tropics of Kerala is possible only in association with bacterial wilt resistance as these varieties are highly susceptible to the disease. Transfer of processing characteristics to a wilt resistant genetic background becomes relevant here. The bacterial wilt resistant 'Sakthi' found resistant in many parts of the country is not completely free from negative horticultural characters like cracking, green shoulder and softness. A programme to combine yield, quality and disease resistance is necessitated. Heterosis breeding appears to be an efficacious attempt in this direction.

The present study was mainly aimed at

(i) Evaluation of tomato genotypes for processing characteristics

(ii) Identification of tomatoes for ketchup and paste

(iii) Evaluation of tomatoes for long shelf life of ketchup

(iv) Transfer of processing characteristics to a bacterial wilt resistant genetic background.

Review of Literature

REVIEW OF LITERATURE

Literature pertaining to evaluation for processing characteristics in tomato and their expression in a bacterial wilt resistant genetic background are briefly dealt in this chapter.

A. Evaluation of tomato genotypes for processing characteristics

Physico-chemical characteristics of fresh tomato dictate largely the ultimate quality of tomato products (Stoner and Thompson, 1966a; Saimbhi, 1970; Roy and Choudhary, 1972; Kaur et al., 1975). According to Goose and Binstead (1973), the desirable attributes of a processing tomato, are high solids, intense red colour, good flavour, fairly low acidity and reasonably consistent pulp. Tigchelaar (1980) also considered solids, viscosity, fruit colour and freedom from defects as indices of processing quality.

Tomato solids

High solids are desirable because production of concentrates of a specified solids level with high 'solids tomatoes', provides greater product yield, demanding less water removal and low evaporation costs. However, high solids varieties should also contain high levels of insoluble solids to maintain consistency of manufactured products. Consistency or viscosity becomes important since it is one of the grade criteria for processed products, especially ketchup (Opena, 1983).

Williams and Bevenue (1954) analysed tomato fruits and found 81% of tomato solids to be soluble in 80% alcohol. The soluble part was constituted mainly by sugars, ash, organic acids and other minor constituents. The alcohol insoluble fraction contained mainly protein, cellulose, pectin and polysaccharides. Lower and Thompson (1966) found that soluble and total solids which were highly correlated with sugar content in tomato fruits were important in the yield of concentrated tomato products. An increase of 0.2% in soluble solids of the raw produce was of economic significance, in tomato processing. ISI (1967a) prescribed a minimum of 5% by weight of total solids in tomato for preparing paste and ketchup. Significant varietal differences were reported for soluble and total solids (Kattan et al., 1957; Hanna, 1961; Thompson et al., 1962; Lambeth et al., 1964; Rick, 1974).

Variations in solids content in different portions of fruit were reported and it was higher in the pericarp than in the locular tissue (Davies and Kempton, 1975; Zhou and Xu, 1984). The pericarp portion contained more reducing sugars than the locular area (Stevens et al., 1977). A few varieties contain more soluble solids in the locules than in the pericarp (Brecht et al., 1976).

Emery and Munger (1970) reported a [illegible] negative relationship between determinate growth habit and TSS of [illegible]. Fruit size and TSS were negatively correlated (Kalloo et al., [illegible]; Pandey et al., 1978; Rattan et al., 1978; Tikoo et al., [illegible]; Mittal and Singh, 1979). A close association between cracking and high soluble solids was also reported (Rick, 1974). According to Stevens et al. (1977) major progress in breeding for high solids was limited, due to an association of high solids with small fruit size, indeterminate growth habit and poor fruit set.

Goose and Binstead (1973) found certain tomato varieties to be more pulpy than others and had more insoluble solids which resulted in variation in the body of the product. A ratio not exceeding 8:1 of total solids to insoluble solids gave a product of satisfactory consistency. In fresh pulp, the insoluble solids usually constituted 12.5% of the total solids content. Stevens et al. (1977) found that the total solids of the firm fruited cultivars are not lower than that of softer varieties. But since more dry matter was partitioned into cell wall components, there was reduction in soluble solids content.

Colour

Carotenoid pigments, lycopene and carotene are the basic components of colour. Lycopene is the most important colour constituent of tomato which contributes to the overall colour and appearance of tomato products. High lycopene varieties, having uniform intense red colour are preferred for processing. Similarly, uniform ripening which eliminates the dark green shoulder of ripe fruit, forms another desirable character (Goose and Binstead, 1973).

Of the many genes which affect carotene synthesis in tomato fruit, two genes which intensify the desirable red colour are of practical interest in applied breeding programmes. The high pigment (hp) gene increases fruit chlorophyll and carotenoid levels and enhances viscosity and ascorbic acid content. The crimson (og^c) gene conditions an increase in the ratio of lycopene to carotene resulting in brighter red fruit colour. Total carotenoids are not enhanced and the observed colour differences result from reductions in carotene and corresponding increases in lycopene content. The lowered nutritional value of crimson cultivars resulting from reduction in fruit carotene content limits the use of this gene to situations where the nutritional impact of lowered pro-vitamin A would be negligible. Exceptional fruit colour and improved nutritional value are possible by combining high pigment (hp) and old gold crimson (og^c) genes. The 'hp' in combination with 'og^c' restores the carotene levels and elevates acid content thus effecting both improved fruit colour and nutritional status. Undesirable characters like slow germination and growth, poor fruit set and general lateness associated with 'hp' limited the practical use of this gene (Sayama and Tigchelaar, 1985). Rubyvee (Kerr and Cook, 1983a) and Ohio 832 (Berry and Gould, 1986) posses og^c gene.

Consistency

Raw fruit viscosity was largely attributed to a heterogenous group of alcohol insoluble constituents of which the polygalacturonides appear the most important. Firm fruited cultivars have a high alcohol insoluble solids resulting in high viscosity and more case yield (Stevens and Paulson, 1976).

Marsh et al. (1979) reported that consistency and serum separations are unrelated quality attributes. It was found that with the same consistency level, serum separation varied from none to considerable. Consistency depended directly upon the fraction of water insoluble solids of the total solids of the tomato pulp used. Serum separation depended upon the break system employed. Concentration resulted in change of cell shapes and the irreversible alteration of cells might contribute to change in precipitate weight ratio during concentration. But, Marsh et al. (1980) observed good relationship between water insoluble solids and total solids of processed juice sample and Bostwick consistency of diluted paste from the same raw material. Nagy and Sardi (1980) found that the original apparent viscosity of tomato juice did not depend on the rheological properties of the fruit (firmness, elasticity and tissue resistance) but on type of fruit. They observed that both Hungarian and foreign varieties were suitable for mechanical harvesting but the apparent viscosity (pectin content) was significantly lower in foreign varieties making the Hungarian varieties more suitable for canning purpose. Yanovchick et al. (1980) reported that the correlation between dynamic viscosity of tomato puree and ratio of soluble to insoluble substance was high.

Takada and Nelson (1983) indicated a good relationship between precipitate weight of a centrifuged sample and the Bostwick consistency of that sample. Luh et al. (1984) found that tomato varieties containing high molecular weight pectic fractions yielded thicker consistency paste.

Mohr (1987) analysed tomato fruit properties affecting consistency of concentrated tomato products. The fruit properties which determine the flow characteristics of the concentrated product were associated mainly with water insoluble solids content and serum viscosity and levels of total solids (mostly soluble) had a much less effect on product flow ability.

Total solids and insoluble solids fluctuated widely between seasons, increasing during periods of low rainfall whereas water insoluble solids appeared to be mostly cultivar dependent. Cultivars differed significantly in the levels of solid fractions and serum viscosity and their apparent loss during concentration. Setty et al. (1987) observed that higher the pulp in tomato, higher would be the viscosity.

Flavour

Sugars and acids contribute not only to sweetness and sourness of tomato fruit, but also to overall flavour intensity (De Bruyn et al., 1971; Kader et al., 1977; Stevens et al., 1979; Jones and Scott, 1984).

Tomatoes with high sugar acid ratio were inferior in taste and had a tendency to be flat whereas those with low values were sharp and acidic in taste. Thus, a low sugar acid ratio of fresh tomato is a desirable characteristic for processing (Stoner and Thompson, 1966a; Sandhu, 1970; Sethi and Anand, 1986). Contrary to the above, a high sugar acid ratio was reported desirable for processing (Tarutani, 1954; Stevens et al., 1979; Bajaj et al., 1988).

Based on regression analysis, Stevens (1979) established that sweetness was determined largely by reducing sugar content while sourness was related to titratable acidity and pH. Among the sugars, fructose made the greatest contribution to sweetness and citric acid made the greatest contribution to sourness. Overall flavour intensity was determined largely by an interaction between sugars and acids. The flavour quality in firm fruited cultivars was low because, more of the dry matter was partitioned into insoluble solids in fruit at the expense of reducing sugars. Andryushchenko et al. (1982) found that irrespective of the content of dry matter, good quality paste was obtained when sugar content of fruit was more than 49% and the acid content less than 10%. However, higher the dry matter content, more likely were sugar and acid contents to be favourable.

Organic acids provide flavour and play an important role in keeping quality of processed tomato products by inhibiting germination of spores of thermophilic organisms. High acidity reduced processing time and improved colour, flavour, texture and vitamin C retention in the final product (Leonard et al., 1959).

The most important acid in tomato is citric acid. Other organic acids are malic, formic and acetic acids (Hobson and Davies, 1971). Tomato fruits contained a large number of buffers mainly citrate, glutamate, phosphate and malate. Consequent to an increase in organic acids, titratable acidity increased and the pH decreased. When the phosphate concentration was increased, there was sudden increase in pH but the titratable acidity was unaffected. The phosphorus content in 25 accessions ranged from 3.1 to 6.7 m moles/l (Paulson and Stevens, 1974). The locular tissues of fruit were more acidic than other parts (Brecht et al., 1976; Stevens et al., 1977). The firm fruited varieties had a low locular area and consequent to this, acid content was reduced.

Tarutani (1954) and Sherkat and Luh (1976) reported that tomatoes ideal for processing should have an acid content of 0.35% as citric acid. Low acidity and resultant high pH (>4.5) in certain varieties of tomatoes were weak points in processing. Wolcott et al. (1987) also found a low pH to be desirable since acidic products such as tomato with pH below 4.6 receive less severe heat treatment during thermal processing.

Freedom from defects

The greatest challenge facing tomato breeders is the development of cultivars, free from defects which detract from processed fruit quality. In humid areas, where rainfall occurs during the harvest season, freedom from defects entailed high degree of resistance to fruit cracking, fruit rots and foliar diseases. Firm fruit with good 'vine storability' is essential to maintain freedom from defects during harvesting and handling process. One of the most significant achievements in processing tomato cultivars was the development of machine harvest types with very firm fruits which are crack resistant (Veepro, Veeroma, Ohio 7814, Rubyvee, Ohio 832, Processor 40, UC 28, UC 82). The outstanding characteristics of the firm fruited cultivars resulted from greater amounts of cell walls in fruits (Stevens and Paulson, 1976; Ramadan, 1982). Lukyanenko and Lukyanenko (1981) observed 20 to 30% higher content of water insoluble compounds like cellulose, pectin and protopectin but a 28% lower content of titratable acids and lower content of ascorbic acid, when tomato fruits differing in firmness were compared. Ramadan (1982) reported that the long vine storage characteristic was due to greater firmness of cultivars at onset of ripening. He found that rate of fruit ripening was not different from softer cultivars but since the initial firmness was much greater they remained in a usable condition for a much longer time. The firm fruited cultivars also had a high level of crack resistance. This was related to skin toughness and firmness of these cultivars as there is a positive relationship between skin puncture resistance and crack resistance. For the processor, the chief advantages of firm fruited cultivars were less broken fruits and lower losses during handling. They also gave greatly increased case yields of products which were sold on the basis of consistency level.

In addition to these quality factors, following morphological characters are also important.

Fruit shape

Pear shaped fruits have more significance in processing. In tomatoes, locule number usually ranges from 2 to 30/fruit (Ahuja, 1968), although Zeilinski (1948) counted upto 215 locules in an exceptional case. Along with variability in locule number, fruit size varies from a few grams to several hundred grams and shape varies from oblate to elongate. In general, large size is accompanied by an oblate shape and a high locule number and small size by round or elongate shape and low locule number (Yeager, 1937; Zeilinski, 1948; Dennett and Sarson, 1953; Bergh, 1956).

El-Sayed et al. (1966a) and Roy et al. (1970) reported that oval to pear shaped varieties had high flesh thickness, less locule number and firm fruits. Roy and Choudhary (1972) also had similar observations where oval shaped varieties with shape index >1.0, had high flesh thickness, less locule number and firm fruits unlike fruits of spherical or flat shape with shape index < 1.0, which were soft, have high locule number and less flesh thickness. Oval shaped varieties also had high viscosity and total solids than spherical ones. Rao and Choudhary (1981) attributed higher percentage of drained weight and intact tomatoes in canning to the oblong shape of fruits and their high flesh thickness and firmness.

Jointless pedicel of fruit

Retention of pedicels on fruit is an undesirable attribute for processing tomatoes. Pedicels damage fruits and adversely affect flavour of processed products. For this, jointless (j2) gene was used, since this reduced stalk retention because fruit is detached directly from the stalk instead of the stalk being separated from the fruit cluster (Reynard, 1961). Although this gene has some yield disadvantage, it is being used in several new varieties because of its potential in reducing shattering and fruit damage (Ohio 7814, Veeking, Rubyvee, Processor 40, Ohio 832).

Plant habit

Processing types are designed for once over machine harvest or a maximum of two or three hand picks. Critical attributes of the machine harvest types are determinate vine governed by gene 'sp' with modifiers conditioning small vine size, dependable concentrated fruit set and uniform ripening.

I Variability, heritability and genetic advance

a. Fruit yield and its components

Baronrelli et al. (1972) reported high heritability for fruit weight (0.70) while plant height had the lowest heritability. On the contrary, Dudi et al. (1983) reported high heritability for plant height (0.70). Similar observations were made by Kumar et al. (1980) and Alvarez (1984). Nandpuri et al. (1973) observed the highest gcv (90.32) and pcv (96.77) for early yield/plant followed by fruits/plant (gcv - 57.62; pcv - 60.53). The lowest gcv was observed for total yield/plant (24.33). The heritability estimates for fruit weight (0.93), fruits/plant (0.91), early yield/plant (0.89) and total yield/plant (0.80) were very high. A wide range (40.00 to 177.42%) was observed for the expected genetic advance as % of mean. Early yield/plant recorded the highest genetic advance as % of mean (177.42%) followed by fruits/plant (113.19%) and fruit weight (82.39%). Srivastava and Sachan (1973) reported the highest heritability for fruit weight ([illegible]) coupled with high genetic advance as % of mean (43.35%). Dudi et al. (1983) observed high values of gcv (37.55 and 38.56, respectively) and pcv (47.58 and 45.08, respectively) for early yield and fruit weight. Gibrel (1983) reported heritability of 0.15 for yield and 0.10 for fruit size. Khalaf-Allah et al. (1985) found that heritability estimate was the highest for fruit weight (0.66) followed by fruits/plant (0.60).

b. Fruit characteristics

Mochizuki et al. (1986) reported high heritability for fruit shape index (0.82) and fruit firmness (0.74). Padda et al. (1971) observed high heritability (0.65) along with high genetic advance for locules/fruit (0.87). Choudhary and Khanna (1972a) reported broad sense heritability of 0.33 to 0.72 for locules/fruit. High heritability along with high genetic advance for locules/fruit were also reported by Singh et al. (1974), Mital and Singh (1977), Singh and Singh (1980) and Bhutani (1981). Arora et al. (1982) reported high heritability (0.81) and genetic advance as % of mean (41.63%) for locules/fruit. Dudi et al. (1983) observed only the lowest pcv (21.84), gcv (16.88) and genetic advance as % of mean (26.91%) for pericarp thickness. Heritability estimates for cracking, from crosses between varieties resistant and susceptible to cracking varied from 0.42 to 0.63

(Alvarez, 1984). The very same estimate of heritability for cracking (0.42 to 0.63) was also made by Lancaster and Morelock (1984).

c. Fruit juice characteristics

Lower (1963) reported heritability estimates in the range of 0.75 to 0.91 for soluble solids and 0.80 to 0.92 for total solids. Lower and Thompson (1966) also observed a relatively high heritability for soluble solids (0.75). Agble (1977) in contrast, reported a very low heritability for solids based on regression of offsprings on parents. High heritability estimate for total soluble solids (0.88) was reported by Srivastava and Sachan (1973). Monma and Kamimura (1982) observed heritability estimates in the F_2 for soluble solids to be 0.65. Bhutani et al. (1983) observed the highest heritability for total solids (0.98). Zhou and Xu (1984) studied inheritance of soluble solids in tomato fruits and reported narrow and broad sense heritability to be 0.56 and 0.81 respectively. Stevens (1976) found high heritability for alcohol insoluble solids (0.68) and viscosity (0.75).

Arora et al. (1982) reported high pcv (25.54), gcv (23.65), the highest heritability (0.86) along with high genetic advance as % of mean (45.01%) for acidity. Monma and Kamimura (1982) while studying inheritance of sugar content and acidity in processing tomatoes, reported heritability estimates in the F_2 to be 0.65 for acidity and 0.78 for pH. Bhutani et al. (1983) observed the highest pcv (31.55) and gcv (31.02) for ascorbic acid followed by reducing sugar (pcv - 29.57; gcv - 28.77). High heritability was observed for acidity (0.97). Abani and Uzo (1984) also observed high heritability (0.88). Lukyanenko and Lukyanenko (1986) reported heritability estimate for acidity to be 0.42 to 0.63.

Agble (1977) found the fruit colour intensity to be moderately heritable (0.50). Bhutani and Kalloo (1983) while studying genetic components of carotenoids and lycopene also reported moderate narrow sense heritability for both compounds (0.44 and 0.34 respectively).

Table 1. Variability in fruit and juice characteristics

Characters	Variability (Range)	Reported by
Fruit shape index	0.70 (Pusa Ruby) to 1.43 (Italian Red Pear)	Roy and Choudhary (1972)
	0.70 (Pusa Ruby) to 1.42 (Chiku Grande)	Rao and Choudhary (1981)
Pericarp thickness (cm)	0.40 cm (Pusa Early Dwarf) to 0.62 cm (Chiku Grande)	Roy <u>et</u> <u>al</u>. (1970)
	0.33 cm (No.695) to 0.63 cm (No.114)	Roy and Choudhary (1972)
	0.37 cm (Pusa Ruby) to 0.47 cm (Roma)	Rao and Choudhary (1981)
	0.22 cm (Sabour Prabha) to 0.59 cm (Traveller)	Dudi <u>et</u> <u>al</u>. (1983)
	0.45 cm (Pusa Ruby) to 0.70 cm (HHR 674 SB)	Tikoo (1987)
Juice yield (%)	38.20% (Princezincka Borghese) to 65.80% (Kasparex)	Swamy <u>et</u> <u>al</u>. (1963)
	62.30% (Chiku Grande) to 71.00% (SL 120)	Roy <u>et</u> <u>al</u>. (1970)
	64.00% (Italian Red Pear) to 73.30% (SL 120)	Roy and Choudhary (1972)
	70.00% to 77.00%	Kaur <u>et</u> <u>al</u>. (1975)
	70.00% (SL 120) to 77.00% (Punjab Tropic)	Pruthi <u>et</u> <u>al</u>. (1980)
	66.00% (S-1-0) to 71.00% (Angurlatha)	Sethi and Anand (1982)
	68.60% (V. 687) to 87.70% (EC 130046)	Madaiah <u>et</u> <u>al</u>. (1986)

Characters	Variability (Range)	Reported by
	73.33% (Indoprocess I to 93.33% (Vaishali)	Sethi and Anand (1986)
	70.55% (HS 101) to 85.71% (Punjab Kesari)	Bhatnagar et al. (1987)
	83.90% (Selection 4) to 91.00% (Prista)	Setty et al. (1987)
Total soluble solids (%)	4.50% (Pruhonicky Universal) to 8.00% (Rybizovc)	Swamy et al. (1963)
	4.50% to 5.00%	Roy and Choudhary (1972)
	5.40% (EC 54723) to 8.20% (Gola)	Rattan et al. (1978)
	3.50% (Punjab Kesari) to 5.00% (Pusa Ruby)	Pruthi et al. (1980)
	3.90% (Pusa Ruby) to 6.60% (Sel. 152)	Sethi and Anand (1982)
	3.20% (M 128) to 6.00% (Roma VF)	Fontes et al. (1984)
	3.20% (Dryzhba) to 6.20% (EC 154888)	Madaiah et al. (1986)
	3.80% (Shital) to 4.62% (Indoprocess II)	Sethi and Anand (1986)
	4.20% (Preslav) to 6.00% (Pusa Ruby)	Setty et al. (1987)
	4.00% to 5.50%	Tikoo (1987)
	3.83% (Punjab Chhuhara) to 5.90% (Sel. 152)	
Total solids (%)	5.40% (No.700) to 6.79% (Chiku Grande)	Roy and Choudhary (1972)
"	2.94% (Campbell) to 7.46% (Kalohi)	Bajaj and Mahajan (1982)
	3.13% (VL-11-1) to 10.95% (Roma)	Bhutani et al. (1983)

Characters	Variability (Range)	Reported by
	4.10% (Mangala) to 6.16% (Indoprocess II)	Sethi and Anand (1986)
Insoluble solids (%)	0.70% (Fresh market tomatoes) to 1.20% (Processing tomatoes)	Atherton and Rudich (1986)
Reducing sugar (%)	0.17% (Campbell) to 3.92% (F 455-DI)	Bajaj and Mahajan (1982)
	0.92% (Pusa Lal Meeruti) to 4.05% (B-17)	Bhutani *et al.* (1983)
Acidity (%)	0.29% (Immune) to 0.59% (Rybizove)	Swamy *et al.* (1963)
	0.33% (Chiku Grande) to 0.71% (Pusa Ruby)	Roy and Choudhary (1972)
	0.26% (Brech) to 0.68% (F 455-DI)	Bajaj and Mahajan (1982)
	0.35% (Angurlatha) to 0.63% (Sel. 152)	Sethi and Anand (1982)
	0.38% (Growthens Globe) to 1.61% (Cherry)	Bhutani *et al.* (1983)
	0.32% (V 687) to 0.58% (Selection 22)	Madaiah *et al.* (1986)
	0.33% (Shutal) to 0.48% (Varshali and Mangala)	Sethi and Anand (1986)
	0.50% (Punjab Kesari) to 0.68% (HS 101)	Bhatnagar *et al.* (1987)
	0.37% (Prista) to 0.70% (Pusa Ruby)	Setty *et al.* (1987)
	0.31% (IHR 858 x IHR 709) to 0.42% (82 PR 1)	Tikoo (1987)
	0.37% (Punjab Kesari) 0.62% (KS 1)	Bajaj *et al.* (1988)
	4.25% (Pusa Ruby) to 4.75% (Punjab Chhuhara)	Pruthi *et al.* (1980)

Characters	Variability (Range)	Reported by
	4.10 (Pusa Ruby) to 4.50 (S-1-0)	Sethi and Anand (1982)
	4.00 to 4.30	Madaiah _et_ _al._ (1986)
	3.90 (Pusa Ruby) to 4.40 (Druzbha)	Setty _et_ _al._ (1987)
Sugar acid ratio or TSS/acid ratio	5.60:1 (Punjab Kesari) to 13.00:1 (Punjab Chhuhara)-TSS/acid ratio	Pruthi _et_ _al._ (1980)
	0.44 (Campbell) to 7.26 (Ronita) - sugar/acid ratio	Bajaj and Mahajan (1982)
	5.14 (Indoprocess II) to 8.72 (Shutal) - Sugar/acid ratio	Sethi and Anand (1986)
	6.40% (KS 1) to 12.50 (Roma) - TSS/acid ratio	Bajaj _et_ _al._ (1988)
Pulp content (%)	44.00% in Chiku Grande	Fontes _et_ _al._ (1984)
	23.00% (EC 1157889/Ogasta) to 50.00% (EC 154890/Meston E 7116 LOVED)	Madaiah _et_ _al._ (1986)
	21.00% (Preslav and Hebros) to 30.40% (Pusa Ruby)	Setty _et_ _al._ (1987)
Juice viscosity	35.50 (No.700) to 47.00 S (Italian Red Pear)	Roy and Choudhary (1972)
	119.00 (Hebros) to 250.00 CPS (Prista)	Setty _et_ _al._ (1987)
Lycopene (mg/100 g)	0.045 mg (Sovetske Lahonde) to 6.94 mg/100 g (Kasparex)	Swamy _et_ _al._ (1963)
	1.05 mg (Patriot) to 3.60 mg/100 g (Kewalo)	Bajaj and Mahajan (1982)
	8.20 mg/100 g (Nuova Super Roma x Bai Liang Hong)	Yongjian _et_ _al._ (1982)
	1.97 mg (EC 154896/12307 F_1) to 5.12 mg/100 g (EC 1296604/73/122)	Madaiah _et_ _al._ (1986)

Characters	Variability (Range)	Reported by
	3.72 mg (Preslav) to 5.35 mg/100 g (Prista)	Setty et al. (1987)
	1.95 mg (Sel. 152) to 6.77 mg/100 g (Pusa Ruby)	Bajaj et al. (1988)
β carotene (μg/100 g)	52.04 μg (Zlata Kralovna) to 719.90 μg/100 g (Rybizove)	Swamy et al. (1963)
	12.20 μg (Patriot) to 46.80 μg/100 g (Brench)	Bajaj and Mahajan (1982)
	2000 μg (Shutal) to 6000 μg/100 g (Indoprocess II)	Sethi and Anand (1986)
Ascorbic acid (mg/100 g)	13.10 mg (Pruhonicky Universal) to 36.64 mg/100 g (Rybizove)	Swamy et al. (1963)
	9.50 mg (No.116) to 18.00 mg/100 g (Pusa Ruby and Roma)	Roy and Choudhary (1972)
	11.00 mg (Sel.120) to 24.60 mg/100 g (S 12)	Pruthi et al. (1980)
	6.51 mg (Healani) to 19.69 mg/100 g (F 455-DI)	Bajaj and Mahajan (1982)
	19.00 mg (Chiku Grande) to 26.20 mg/100 g (Sel. 152)	Sethi and Anand (1982)
	7.20 mg (EC 52062-1) to 26.27 mg/100 g (Pusa Red Plum)	Bhutani et al. (1983)
	20.00 mg to 30.00 mg/100 g	Georgijev et al. (1983)
	4.50 mg (Ogasta) to 28.9 mg/100 g (EC 135501)	Madaiah et al. (1986)
	13.50 mg (Indoprocess III) to 21.20 mg/100 g (Shutal)	Sethi and Anand (1986)
	15.20 mg (Preslav) to 27.5 mg/100 g (Pusa Ruby)	Setty et al. (1987)
	10.44 mg (Karnataka Hybrid) 22.10 mg/100 g (AC 238)	Bajaj et al. (1988)
	15.00 mg to 30 mg/100 g	Kalloo (1989)

2. **Somatic analyses for fruit shape index and quality characteristics**

The available information pertain mainly to association among yield and yield contributing characters. A high negative correlation was observed between dry matter content and fruit weight (Goldenberg and Pahlen, 1966). Fruit weight was negatively and significantly correlated with fruit number showing that with increase in fruit number there would be decrease in fruit weight (Nandpuri et al., 1973; Stefanova and Steva, 1979; Rattan et al., 1983). High yield was negatively correlated with high solids and alcohol insoluble solids (Janoria and Rhodes, 1974).

Early yield, fruit weight and fruits/plant had high direct effect on yield. Fruit weight, besides its strong direct effects, contributed towards yield through positive indirect effects via pericarp thickness and locule number (Dudi and Kalloo, 1982).

Fruit weight was negatively correlated with ascorbic acid content (Brown and Bohn, 1946; Poole, 1956; Currence et al., 1961; Rattan et al., 1983). Mesocarp thickness was positively correlated with fruit size and yield revealing that any increase in mesocarp thickness will result in increased yield and fruit size. Acidity and ascorbic acid content had positive correlation with fruits/plant, seed percentage and yield (Rattan et al., 1983). Yanovchick et al. (1980) reported correlation between viscosity and ratio of soluble to insoluble substances to be high. Abani and Uzo (1984) found that correlations were apparent between reducing sugars and total soluble solids. Gorbatenko and Gorbatenko (1987) conducted path analysis of fruit quality traits in tomato. They studied direct and indirect effects of sugars, total titrable acids, ascorbic acid, carotene and cellulose on dry matter content of fruit. The direct effect of total sugar on dry matter content was greater in parental forms than in their hybrids. Ascorbic acid, carotene and cellulose had lower or negative path coefficients.

3. Identification of processing type(s) based on selection index

Selection index is a linear function of different attributes having an appropriate weight. Conti et al. (1981) proposed a method for evaluating the processing tomato. The method involves ranking varieties on the basis of an index calaculated from the data on the most important agronomic and technological traits. The index is calculated according to the formula $I = \Sigma b_i c_i$ where b_i is the weighting coefficient of each trait and c_i is the value of each trait.

B. Evaluation of tomatoes for ketchup and paste

The essential characteristics of tomatoes for processing vary for different products. Indian work mainly deals with varietal suitability of tomatoes for canning and juice making. Varieties Chiku Grande, Roma and Italian Red Pear (Jain and Mukerjee, 1966; Roy et al., 1970), Ruth, Early Chatham, San Marzano and Red Top (Beerh and Rane, 1976) and HS 110 (Pathak and Mahajan, 1978) were suitable for processing into juice or for canning of whole peel tomatoes. Adsule et al. (1980) reported Roma, Sel 11, Punjab Chhuhara and Selection 4 as highly suitable for making juice. Rama et al. (1980) screened six oval fruited lines for canning of whole tomatoes. EC 55055 was the most superior ranking first in yield/ha, yield of canned product, colour, firmness and resistance to breakage in the can. Rao and Choudhary (1981) found that the F_1 Pusa Ruby x Chiku Grande which out yielded all others held promise as the best material for canning.

Swamy et al. (1963) found that of the eleven Czekoslovakian varieties, Kosparex and Rybizove produced ketchup of deep red colour, excellent consistency and good flavour. Pruthi et al. (1980) reported Punjab Chhuhara, Pusa Ruby and Selection 12 as the best three in the order of merit to manufacture tomato ketchup. Based on juice yield, paste yield, colour and appearance, acidity level and lycopene content, three varieties EC 129604 75/122, EC 129606/ARND and Selection 4 were the best for paste manufacture (Madaiah et al., 1986). Eight hybrid tomatoes were evaluated for physico-chemical characteristics and suitability for puree preparation. Indo-Process II was the top ranking followed by Indo-Process III and Rupali (Sethi and Anand, 1986). Bhatnagar et al. (1987) on the basis of organoleptic ratings suggested HS 101 and HS 110 for paste and ketchup. Setty et al. (1987) found Prista, a Bulgarian variety, to be the most suitable for making paste, ketchup and juice, taking into consideration yield of tomatoes, juice and paste and sensory quality.

Varietal evaluation and breeding programmes under All India Co-ordinated Vegetable Improvement Project (ICAR) resulted in the recommendation of some introductions/selections for exclusive use as processing tomatoes. Roma, 2466-27, Punjab Chhuhara and Sel. 152 were recommended for release on national level. In addition, two varieties were identified for processing from IIHR, Bangalore, IIHR 674 SB (UC 82 B) and Sel. 11.

In developed countries, there is a growing interest in fruit quality attributes which contributed to improved quality and case yield. Ultimately, this resulted in the development of cultivars suited to specific products, Crimsonvee for ketchup and concentrated strained products (Kerr and Cook, 1979), Veebrite, Veemore, Basketvee and Wondervee for juice and ketchup, Veepro, Veeroma, Rubyvee and Veeking for ketchup and Veepick for paste (Kerr and Cook, 1981a-d, 1983a,b, 1984), UC 82 A and UC 82 B for paste (Mutton et al., 1982), Luo Hong for paste (Yongjian et al., 1982), Ohio 7814 for concentrates (Berry and Gould, 1983), Sichuanzao for paste (Lin et al., 1984), Ohio 832 for ketchup (Berry and Gould, 1986) and Processor 40 for canning and tomato products (Leeper and Cox, 1986).

I. Ketchup yield and its chemical composition

ISI (1967a) prescribes a minimum TSS of 25% and acidity of 1.20% as acetic acid in tomato ketchup to satisfy IS requirement. Swamy et al. (1963) evaluated 11 Czechoslovakian varieties of tomatoes for their suitability to prepare tomato ketchup. They reported variations in the chemical composition of tomato ketchup as, acidity 1.86% to 2.40%, ascorbic acid 27.48 mg to 64.03 mg/100 g, β carotene 451.20 µg to 1256.00 µg/100 g and lycopene 238.90 µg to 10640.00 µg/100 g. They also found that ketchup from varieties Kosparex and Rybizove were deep red coloured and had excellent consistency and very good flavour. Pruthi et al. (1980) evaluated seven tomato varieties for making ketchup. Varietal variations were observed in the physico-chemical composition of ketchup. TSS varied from 29.50 to 32.50° Brix, acidity from 1.60% to 1.95%, ascorbic acid from 14.00 mg to 36.40 mg/100 g and pH from 3.95 to 4.35. Based on better quality characteristics like colour retention, consistency and flavour during storage, Punjab Chhuhara was selected as the best variety for ketchup. Beerh (1982) reported that commercial ketchup is often adulterated with pulps of apple, papaya, ashgourd, pumpkin, sweet potato and carrot to increae the bulk and reduce the cost. Ram and Bains (1986) analysed experimental and commercial ketchups. They found that ° Brix and total acidity of experimental and commercial samples varied from 40 to 42, 1.64% to 2.17% and 29 to 38, 1.22% to 2.36%, respectively. Bhatnagar et al. (1987) found that the ketchup yield, from four tomato varieties whose TSS was adjusted to 26° Brix, varied from 24.55% to 36.00%. The acidity showed a range of 2.00% to 2.60%. The organoleptic score made out of a total of 40 varied from 29.00 to 35.80. Setty et al. (1987) evaluated four Bulgarian and two Indian tomato varieties for processing into ketchup. The yield of product ranged from 40.00% to 46.40%. Acidity showed a range of 1.43% to 1.85% and lycopene 9.30 mg to 12.52 mg. The TSS of ketchup was adjusted to 28.00%. They also found that higher the initial TSS and pulp content in the juice, better was the yield of ketchup. Similarly the viscosity also was higher if the pulp content were more. Rani et al. (1989) reported the composition of 'cold break' tomato ketchup showing extensive seepage of liquid protion. It had 28.50% total solids, 1.84% acidity, 15.90% reducing sugar and 3.85 pH.

2. Paste yield and its chemical composition

ISI (1967b) prescribes a minimum total solids of 26.00% to satisfy the IS requirements of tomato paste. Madaiah et al. (1986) evaluated 15 varieties for making tomato paste. Product recovery varied from 9.50 to 19.50%. The variations in the chemical composition reported were, acidity 1.97% to 3.42%, ascorbic acid 21.10 mg to 156.80 mg/100 g, lycopene 10.10 mg to 33.80 mg/100 g and pH 4.00 to 4.20. All the pastes had 28° Brix. Bhatnagar et al. (1987) reported that paste yield in four varieties varied from 12.42% to 17.14%. The acidity ranged from 6.50% to 6.70% but the TSS was adjusted to 26° Brix. Setty et al. (1987) evaluated six varieties for paste manufacture. Variations in the paste with TSS of 28.00%, were acidity (1.90% to 3.30%), ascorbic acid (75.20 mg to 116.20 mg/100 g) and lycopene (19.70 mg to 29.40 mg/100 g).

C. Evaluation of tomatoes for long shelf life of ketchup

1. Changes in physico chemical characteristics

Stradtz et al. (1952) indicated that carotenoids are relatively unaffected by various processing techniques. Swamy et al. (1963) reported variations in retention of ascorbic acid, β carotene and lycopene during preparation of ketchup. Variations ranged from 50.83% to 90.53%, 26.50% to 100% and 48.50 to 95.60% for ascorbic acid, β carotene and lycopene, respectively. The variety Rybizove showed marked tendency for serum separation of ketchup during storage which was explained by low pectin content. They also found that all the varieties tried, did not satisfy the lycopene index of 675 µg lycopene/g of tomato solids, tentatively fixed for tomato ketchup, due to combined effect of processing as well as varietal characters. Goose and Binstead (1973) found high break temperature to darken colour due to slight caramelization effects.

Narkviroj and Ranganna (1976) reported changes in physico-chemical characteristics of tomato products during processing and storage. Oxidative degradation of lycopene at 50°C leads to fragmentation of molecules yielding acetone, methyl heptenone, laevulinic aldehyde and glyoxal. Degradation of lycopene also occurs during heating of serum free tomato pulps in presence of oxygen. Rate of breakdown as measured by colour loss varies according to availability of oxygen, temperature and intensity of illumination. Loss of ascorbic acid during storage was also observed. A six months storage of paste at room temperature resulted in three times decrease of ascorbic acid when compared to solid pack tomatoes or juice. After 12 months, the loss was as high as 70%. In addition, the extent of concentration of juice was also a factor of prime importance with regard to ascorbic acid content. The more concentrated products should be stored at lower temperature. Canned tomato ketchup stored at 20 to 30°C showed rapid chemical changes than ketchup stored above 20°C. Consequent to this, the serum colour was darkened and the acidity increased. To maintain good quality they advocated that the ketchup should be stored at 20°C or lower. Also, they opined that measurement of serum colour to be useful for detecting storage condition. The presence of air, which after the bottle is capped cannot escape, causes darkening of ketchup at the neck of the bottle.

Sherkat and Luh (1976) studied changes in quality factors of tomato pastes made at several break temperatures. Pectin retention decreased as break temperature decreased from 108°C to 64°C. Also varietal variations in pectic material were observed. Ascorbic acid retention decreased as the break temperature increased due to the oxidation and thermal degradation of ascorbic acid at higher processing temperatures. In the manufacturing process, ascorbic acid is oxidised to dehydro-ascorbic acid when is further degraded to products with no vitamin C activity. The rate of oxidation depends on availability of oxygen and the break temperature. Tomatoes macerated at 108°C were lower in acidity and higher in pH than those at lower temperatures due to inactivation of enzymes. Losses of volatile acids and carbondioxide also occur at higher break temperature. Colour as indicated by Hunter colour difference meter showed a better colour in the samples macerated at lower temperature. A higher break temperature resulted in a thicker consistency.

Pruthi et al. (1980) studied physico-chemical changes in ketchups from seven varieties of tomatoes during 12 months storage at room temperature. Initially no black neck and phase separation were observed but during storage, ketchup from a few varieties showed these defects. Gelation was also observed in certain ketchups. Loss in ascorbic acid ranged from 17.20% to 74.40% and 12.20% to 63.60% during manufacture and after 12 months storage at room temperature, respectively. The pH and TSS did not change significantly during storage and ranged from 3.95 to 4.35 and 29.50% to 32.00%, respectively. The colour loss (OD value) during eight months storage, ranged from 12.90% to 58.40%, but none of the varieties showed significant change visually. The varieties varied in colour retention. They also found that the chemical changes were slowed down and the ketchup remained in good condition for a longer time when stored at 5°C to 7°C. Drdak and Pribela (1981) investigated the non-enzymic browning and tomato puree colour. Changes in the content of 5 hydroxy methyl furaldehyde 2 (HMF) were used to detect changes caused by non-enzymic browning during heating of tomato puree at 95°C. Content of total carotenoids decreased from 18.46 mg to 16.96 mg/100 g sample. The increase in heating time resulted in higher content of HMF from original 2.70 mg to 938.30 mg/kg. The effect of heat treatment over the range of 20°C to 90°C during pulping on juice colour showed that colour quality (Hunter a/b value) decreased but consistency and viscosity increased with increasing heat treatment (Lajos, 1981-1982). Abdel-Rahman (1982) analysed the nutritional value of fresh tomatoes, canned juice and concentrate. The canned products were not good sources of ascorbic acid. The original ascorbic acid content of 16.5 mg/100 g in fresh tomatoes was reduced to 8.2 mg and nil mg/100 g, respectively in canned juice and concentrates.

The keeping quality of whole tomato concentrate was examined (Sethi and Anand, 1982). The retention of carotenoids was not much affected and varied from 82.24% to 88.01% and the retention of ascorbic acid ranged from 40.10% to 92.30% during 12 months storage. Warnock (1983) analysed the ascorbic acid content of fresh and processed purees from 12 varieties and reported that varieties Rowpac and VF 109 lost less ascorbic acid upon processing than VF 145 B 7879. Wilska-Jeska et al. (1983) observed reduction in ascorbic acid and carotenoid contents to the extent of 20% to 30% and 20% to 25% respectively during pulping for concentrate manufacture. During storage of the concentrate at room temperature, sugar, ascorbic acid and carotenoid contents were reduced further by 10%, 35% to 50% and 15 to 30%, respectively. Kwasniewska et al. (1984) studied changes in quality characteristics of tomato concentrate (30%) stored at 7°C, 18°C to 20°C and 37°C during six months of storage. Organoleptic changes in storage at 7°C and 18°C to 20°C were slight but pronounced at 37°C mainly affecting colour and aroma. Takada (1984) found that sterilization of paste and storage for ten months at 30°C did not alter consistency significantly.

Effect of break temperature on changes in organic acids and sugars in canned juices made from VF 145-7879 and UC 82 B tomatoes were investigated by high pressure liquid chromatography (Gancedo and Luh, 1986). Analysis revealed presence of oxalic, citric, galacturonic, malic and pyrolidine carboxylic acids in canned juices. Oxalic and galacturonic acids decreased as the break temperature increased. Fructose was present in slightly higher amounts than glucose. Break temperature did not cause significant changes in sugar content of the canned juices from UC 82 B tomatoes.

Jane et al. (1986) while evaluating 12 tomato cultivars for juice production and storage for retention of β carotene reported 20% loss during extraction and another 20% loss after seven months of storage. Madaiah et al. (1986) reported that losses in ascorbic acid content in the prepared paste ranged from 10% to 20% during concentration and losses in lycopene content were marginal and reasonable. Bhatnagar et al. (1987) found the keeping quality of paste and ketchup under room storage conditions to be reasonably good upto six months. However, there was an increase in optical density and decrease in acid content of the products due to degradation of acid contents and the enzymatic and non-enzymatic browning. Wolcott et al. (1987) reported that heating of the pulp prior to juice extraction provided a better extraction of pulp from the skins and also inactivated the enzymes which would otherwise degrade the pectic enzymes important to consistency.

2. Micro-organisms causing spoilage in processed products

Weiser et al. (1971) reported that moulds and yeasts find a favourable environment in ketchup and reflect the general sanitary practices used in the processing of the product. In fact, mould counts by Howard method are a routine laboratory procedure for ketchup. The presence of yeasts gave an yeasty flavour along with gas formation. The usual sugar concentration of ketchup is not sufficient to inhibit growth of most microbes. Also moulds and yeasts are very resistant to sodium benzoate used as a preservative in ketchup (Woodroof and Luh, 1975).

Krishnaswamy et al. (1971) gave an account of the microbial contamination of spices and spice mixtures. Yeast and mould infestation were present in all types of spices but in black pepper, the infestation was heavy (9800/g). Martinez and Christensen (1973) assessed the fungal flora of black and white pepper. They observed fungal colonies in 42 samples of black and white, whole and ground peppers which averaged 53,000/g. The major fungi present were *Aspergillus flavus*, *Aspergillus glaucus*, *Aspergillus ochraceus*, *Aspergillus restrictus*, *Aspergillus tamarii*, *Aspergillus versicolor* and *Penicillium* sp. Guergue and Ramirez (1977) warned about potential contamination of sausages through aflatoxin contained in red and black pepper used in the preparation. They isolated 525 strains of moulds from samples of red and black pepper, commonly used for spanish sausages. Of these, 100 isolates belonged to *Aspergillus flavus* group out of which 31 were from black pepper among which eight strains produced aflatoxin B_1. Estelitta (1982) also found *Aspergillus flavus* as one among the organisms contaminating black pepper. The fungal population in different grades varied from 26 to 48,000/g. Ranganna (1977) mentioned that starch, sugar, spices, and other ingredients used in the formulation of ketchup were important sources of contamination.

Fermentation in canned tomato juice was principally due to *Lactobacilli*. Mould and yeast spoilage may raise the pH, decrease refractive index and develop off-flavour. The sources of contamination were fruit, cannery yard, conveyer belts etc. (Narkviroj and Ranganna, 1976). Thompson (1981) found that certain strains of *Bacillus coagulans* cause spoilage in tomato products. Cichowicz *et al.* (1982) estimated the micro-analytical quality of tomato products by Howard mould count. Incidence of mould ranged from 55.44% of soup samples to 98.80% of paste samples. Spotti *et al.* (1984) investigated the capacity of mould strains belonging to *Rhizopus*, *Penicillium*, *Aspergillus*, *Cladosporium* and *Fusarium* to produce gas in fruit juices and strained tomatoes. They found that strained tomatoes were fermented by most of the strains tested. Bhatnagar *et al.* (1987) found that microbial examination of the products indicated no definite trend in the changes of microbial counts. Bacterial and yeast colonies were absent. Predominant moulds which caused spoilage of the products in storage were *Alternaria*, *Aspergillus* and *Rhizopus* sp.

Transfer of processing traits to a bacterial wilt resistant genetic background

I. Combining ability

a. Fruit yield components

Mishra and Khanna (1977) observed significant σ^2 gca for plant height. Singh and Mital (1978) observed significant σ^2 sca for plant height. Lines and hybrids showing negative gca and sca effects were reported by Anbu et al. (1980). According to Sidhu et al. (1981) estimates of σ^2 gca were higher than σ^2 sca while Govindarasu et al. (1981) observed a reverse trend. Khalaf-Allah (1970) reported Fire Ball to have the highest gca and Fire Ball x Pritchard the highest sca for earliness. According to Singh and Singh (1980), the components of variance for gca were higher than those of sca for days to flower. Singh and Nandpuri (1974) found the cultivars S 12, Pusa Ruby and Sioux having high gca for fruit number. The crosses involving cultivars with high gca for fruit number showed high sca also. Singh and Mital (1978) observed small fruited varieties to be the best general combiners for fruits/plant whereas large fruited lines were poor combiners. Courtney and Peirce (1979) suggested that high yielding parents should be selected in breeding programmes aimed at improving yield. Peter and Rai (1980), Anbu et al. (1980) and Govindarasu et al. (1981) observed significant σ^2 sca for yield and the magnitude was higher than σ^2 gca. Virdelwala et al. (1981) reported that F_1s which expressed significant and positive sca effects had atleast one good general combining parent indicating that additive x dominance epistatic effects contributed to high sca effects.

b. Fruit characteristics

Khalaf-Allah (1970) identified 'Pritchard' which produced large fruits, having high gca for fruit size. Mital and Singh (1978) found large fruited varieties to be good combiners for fruit weight. Anbu et al. (1980) found that gca effects of line LE 113 and tester LE 68 highly significant and positive which resulted in the high sca effect of LE 113 x LE 68.

Virdelwala <u>et</u> <u>al</u>. (1981) reported Rossol x Punjab Chhuhara as the best cross which showed positive and significant sca effect for fruit size. It resulted from poor x poor combiners indicating that additive x additive epistatic effects contributed to high sca effects.

Tarrega and Nuez (1983) found significant σ^2 gca for fruit shape. Ahuja (1968) from a diallel study of eleven lines found that the parents differed significantly in their gca effects. None of the F_1s had higher locule number than the parents which was confirmed by negative sca effects. Singh <u>et</u> <u>al</u>. (1980) assessed 36 hybrids along with their parents for pericarp thickness. The parents which had high gca effects, showed high sca effects in hybrids. Dixit <u>et</u> <u>al</u>. (1980) observed significant σ^2 sca for pericarp thickness while the σ^2 gca was non-significant. Sidhu <u>et</u> <u>al</u>. (1981) and Patil and Bojappa (1986) reported highly significant differences due to σ^2 gca and σ^2 sca for pericarp thickness.

c. Fruit juice characteristics

Stoner and Thompson (1966b) studied differences in σ^2 gca and σ^2 sca for total soluble solids in a diallel cross. The combining ability estimates indicated that A 408, A 276 and Red Cherry are of value in breeding for high solids. Singh and Nandpuri (1975) from a diallel analysis of six varieties, estimated σ^2 gca and σ^2 sca for acidity and observed the predominance of additive gene action. But for TSS, the σ^2 gca and σ^2 sca were of same magnitudes. Trinklein and Lambeth (1975) reported that the variety Floradov had the highest gca effect for high total acidity and the variety Mosage transmitted high soluble solids content to its progeny. Trinklein (1975) further stated that σ^2 gca and σ^2 sca were non-significant for TSS, titrable acidity and pH. Fedrowitz and Tigchelaar (1979) found significant gca effects for pH, titrable acidity and ascorbic acid content of fruit. Singh <u>et</u> <u>al</u>. (1980) also reported significant σ^2 gca and σ^2 sca for acidity and TSS. Peter and Rai (1980) reported that the variety Mobeci had good gca value for fruit juice, pH and average gca for TSS. Another parent EPH 7 had good gca for TSS. The magnitude of σ^2 sca was higher for TSS. Khalaf-Allah et al. (1985) found the cultivar Yellow Plum to be a good combiner for TSS and cultivar Napoli for TSS, acidity and pH. Raijadhav and Kale (1987) conducted line x tester analysis to estimate gca and sca effects. For TSS, the hybrid PAU x Pusa Ruby had the highest sca effect which was attributed to the good x good combiner. For lycopene content, the F_1, Brech x Pusa Ruby had the highest sca followed by Patriot x Roma which resulted from good x good and average x good general combiners, respectively. For acidity, Kewalo x Pusa Ruby having average x average combiners had the highest sca effects. Yadav et al. (1988) from a diallel analysis of 15 parents concluded that fruit dry matter content of F_1 hybrids increased when both or one of the parents involved in the cross had high content of fruit dry matter with high positive gca effect.

2. Gene action

The genetic analysis indicated that both additive and non-additive gene effects are equally important in controlling genetic expression of yield and yield contributing characters in tomato. The relative magnitude of these two components of total genetic variation, differs from character to character, location to location and the genotype used. A brief account of the gene actions for important characters is summarised (Table 2).

3. Heterosis in tomato

Heterosis in tomato was first observed by Hedrick and Booth (1908) for higher yield and more fruits. Since then, heterosis for yield, its components and quality traits were extensively studied. Choudhary et al. (1965) emphasised the extensive utilization of heterosis to step up tomato production. According to Anbu et al. (1976) it is a convenient way of combining desirable characters.

Table 2. Review of gene action for polygenic characters in tomato

Characters	Type of gene action	Reported by
Plant height	Additive	Singh *et al.* (1976), Singh and Mital (1978), Singh and Singh (1980) and Sidhu *et al.* (1981)
	Non-additive	Kalloo *et al.* (1974), Mital *et al.* (1974a), Anbu *et al.* (1980), Govindarasu *et al.* (1981) and Sidhu *et al.* (1981)
	Additive and non-additive	Baromcelli *et al.* (1972) and Peter and Rai (1980)
Days to harvest	Additive	Peat and Whittingten (1965), Singh and Singh (1980) and Cuartero and Cubero (1982)
	Non-additive	Baromcelli *et al.* (1972) and Virdelwala *et al.* (1981)
	Additive and dominance	Scossiroli *et al.* (1976)
Fruits/plant	Additive	Kolhe (1967), Avarado and Cortazar (1972), Kalloo *et al.* (1974), Singh *et al.* (1974), Dixit *et al.* (1980), Singh and Singh (1980) and Swamy and Mathai (1982)
	Non-additive	Mital *et al.* (1974b), Singh and Nandpuri (1974), Rattan and Saini (1976), Mital and Singh (1978), Anbu *et al.* (1980), Peter and Rai (1980), Govindarasu *et al.* (1981) and Sidhu *et al.* (1981).
	Additive and non-additive	Baromcelli *et al.* (1972), Nandpuri *et al.* (1974), Singh and Nandpuri (1974) and Raijadhav and Kale (1983)

Characters	Type of gene action	Reported by
Yield /plant	Additive	Kalloo et al. (1974), Singh and and Nandpuri (1974), Trinklein (1975), Maggiore et al. (1976), Peter and Rai (1976), Dixit et al. (1980) and Dholaria and Qudri (1983)
	Non-additive	Khalaf-Allah (1970), Avarado and Cortazar (1972), Conti (1974), Anbu et al. (1980), Singh and Singh (1980), Bhutani (1981), Govindarasu et al. (1981), Sidhu et al. (1981) and Swamy and Mathai (1982)
	Additive and non-additive	Rarjadhav and Kale (1985)
	Additive and dominance epistatic	Virdelwala et al. (1981)
	Additive and dominant	Baronecelli et al. (1972) and Rarjadhav and Kale (1987)
Average fruit weight	Additive	Kolhe (1967), Khalaf-Allah (1970), Avarado and Cortazar (1972), Singh and Nandpuri (1974), Mital and Singh (1978), Dixit et al. (1980), Govindarasu et al. (1981) and Swamy and Mathai (1982)
	Non-additive	Mital et al. (1974b), Anbu et al. (1980) and Gibrel et al. (1982)
	Additive and non-additive	Singh and Nandpuri (1974), Rarjadhav and Kale (1985)
	Additive and additive epistatic effects	Virdelwala et al. (1981)

Characters	Type of gene action	Reported by
Fruit shape index	Additive	Mital and Singh (1978), Singh and Mital (1978), Maret and Tarrega (1984) and Raijadhav and Kale (1987)
	Additive and non-additive	Mital and Singh (1977)
	Additive and additive x additive	Mital and Singh (1977)
Locule/fruit	Additive	Ahuja (1968), Kalloo *et al.* (1984), Mital *et al.* (1974b), Mital and Singh (1977), Singh and Mital (1978), Singh and Singh (1980) and Govindarasu *et al.* (1981)
	Non-additive	Anbu *et al.* (1980)
	Dominance	Nandpuri and Tyagi (1976)
	Partial dominance	Bhutani (1981)
Pericarp thickness	Additive	Dixit *et al.* (1980) and Sidhu *et al.* (1981)
	Non-additive	Bhutani (1981)
	Over dominance and dominance	Daskaloff *et al.* (1983)
	Partial dominance	Kano and Kamimura (1981)
Fruit cracking	Additive	Armstrong and Thompson (1966)
	Additive and partial dominance	Lancaster and Morelock (1984) and Lancaster (1985)
Total soluble solids	Additive	Conti (1974), Gibrel (1983) and Khalaf-Allah *et al.* (1985)
	Non-additive	Kalloo *et al.* (1974), Mital and Singh (1979), Peter and Rai (1980), Govindarasu *et al.* (1981), Swamy and Mathai (1982) and Raijadhav and Kale (1987)

Characters	Type of gene action	Reported by
	Additive and non-additive	Singh and Nandpuri (1975), Rao and Choudhary (1979) and Rattan *et al*. (1978)
Total solids	Additive	Yadav *et al*. (1988)
Alcohol insoluble solids	Additive	Stevens (1976)
Acidity	Additive	Mital *et al*. (1974a), Singh and Nandpuri (1975) and Gibrel (1983)
	Non-additive	Kalloo *et al*. (1974)
	Additive with epistasis	Lukyanenko and Lukyanenko (1986)
	Partial dominance	Nandpuri *et al*. (1975), Bhutani (1981), Monma and Kamimura (1982) and Khalaf-Allah *et al*. (1985)
pH	Additive	Daskaloff and Constantinova (1981), Gibrel (1983)
	Non additive	Khalaf Allah *et al*. (1985) and Rajadhav and Kale (1987)
Lycopene	Non additive	Rajadhav and Kale (1987)
	Dominance	Daskalov *et al*. (1978) and Bhutani and Kalloo (1983)

a) Fruit yield components

Mishra and Khanna (1977) observed heterobeltiosis in 14 hybrids for plant height in a 8 x 8 diallel cross. Govindarasu <u>et</u> <u>al.</u> (1982) reported relative heterosis and heterobeltiosis for plant height in F_1 hybrids.

Culkova and Culkova (1969) observed earliness in flowering in 31% of the hybrids. Kurganskaya and Agentova (1974) found that heterosis for earliness occurred most often when both the parents were early. Hewitt and Stevens (1979) reported delayed maturity in hybrids.

Singh and Nandpuri (1970) observed heterosis for fruits/plant while Kolhe (1970) found a negative correlation between fruits/plant and fruit size. He observed that fruit number was more important than size for yield. Grill and Burger (1971), Hal (1971) and Kaul <u>et</u> <u>al</u>. (1972) observed increased fruit number in majority of the hybrids with smaller average fruit weight. Singh <u>et</u> <u>al</u>. (1975) pointed out that heterosis for total yield was due to increase in fruit number, size and weight. On the contrary, Williams (1959) did not find heterosis for fruits/plant.

According to Popova and Petrova (1979) heterosis was the most marked in the hybrid obtained by crossing late parents. Courtney and Peirce (1979) suggested that high yielding inbreds should be selected as parents in breeding programmes aimed at yield improvement. Kolhe (1970), Choudhary and Khanna (1972b), Dhillon <u>et</u> <u>al</u>. (1975) and Virdelwala <u>et</u> <u>al.</u> (1981) reported heterosis for yield/plant. Tikoo (1987) reported that F_1 hybrids suitable for processing are finding favour with growers because of their very high yields. Heterosis above 50% were observed in crosses between tomato lines suitable for processing and the marketable yield ranged from 52 to 63 t/ha.

b) Fruit characteristics

According to Larson and Currence (1944), hybrids with larger fruit size were derived from those inbred lines having larger fruit. Hybrids which produced fruits which were intermediate in size between parents were also reported (Tesi _et al._, 1970; Kaul _et al._, 1972; Conti, 1974). No difference in fruit size between hybrids and parents was also found (Williams, 1959). Khalaf-Allah (1970) reported that the F_1 hybrids were generally closer to the smaller fruited parents. Anbu _et al._ (1976) reported relative heterosis in 12 hybrids and heterobeltiosis in six hybrids. Sonone _et al._ (1981) and Sidhu _et al._ (1981) observed increased fruit weight in a few of the hybrids.

Rao and Choudhary (1981) found that F_1 hybrids were intermediate in fruit shape index (shape index 0.81-0.88) in F_1s of Pusa Ruby (shape index 0.70) and pear shaped varieties (shape index 1.21-1.25). In crosses, where both the parents were pear shaped (Roma and Sugar Gimar), the hybrids had increased shape index (1.33). Dorairaj (1983) found a hybrid LE 113 x LE 413 having desired fruit shape index. Conti _et al._ (1984) analysed fruit uniformity in hybrids and back cross progenies and found that ratio between vertical and horizontal diameters of fruit was more uniform in hybrids than in the parental lines.

Tesi _et al._ (1970) pointed out that in fruit shape and size and number of locules, hybrids were intermediate between parents. Nandpuri and Tyagi (1976) and Peter and Rai (1978) could not observe heterosis for locules/fruit. Similarly, Rao and Choudhary (1981) reported that F_1 hybrids between Pusa Ruby (many loculed) and pear shaped varieties (a few loculed) were intermediate. Kalloo _et al._ (1974) found increased locule number in hybrid tomato fruits. Anbu _et al._ (1976) also reported a heterotic hybrid LE 113 x LE 68 for locules/fruit. They observed heterosis (20.90%) over top parent and heterosis (60.40%) over better parent. Ponnuswamy _et al._ (1980) reported three F_1s exhibiting relatively higher mean locules/fruit.

El-Sayed _et al._ (1966b) observed the F_1 to be similar to the soft parent. Further, the F_2 progenies segregated for fruit firmness with majority, having soft fruits. The back cross to the firm parent segregated into a 1:1 ratio while the backcross to the soft parent, all plants had soft fruits. On the contrary, heterosis for pericarp thickness was reported by Mital et al. (1974a) in Kuber x HB 5 and Nandpuri et al. (1976) in EC 55055 x Punjab Tropic. Al-Falluji and Lambeth (1980) also reported evidence of heterosis for firmness. Rao and Choudhary (1981) observed increased firmness and flesh thickness in F_1 hybrids, if the second parent was firm fruited. Sidhu et al. (1981) reported heterosis over better parent and top parent for pericarp thickness in Gamed x Labonitha. Al-Falluji et al. (1982) reported that fruit firmness in F_1, F_2, and BC_1 approached their respective midparental values. Tikoo (1982) reported heterosis for pericarp thickness which can be exploited while breeding for F_1s. Yoshikawa et al. (1982) studied fruit firmness in 13 F_1 hybrids from crosses among six varieties. Fruit firmness was intermediate to that of the parents in six hybrids but the remaining hybrids produced soft fruits. Pericarp percentage was similar to that of the lower parent or lower in nine hybrids. Fruit firmness of F_1, F_2 and BC_1 generations of a cross between firm and soft population was evaluated. Firmness of the F_1 approached closely with the mean parental value and backcross means deviated towards their respective parental means (Al-Falluji, 1984).

Lampe and Watada (1971) found that tomato genotypes with high pigment crimson genes (hpog) have prolonged shelf life. They advocated the use of such genes in commercial varieties for increased shelf life. Kopeliovitch et al. (1979) also observed similar enhancement of keeping quality in ripening inhibitor (rin) x non ripening (nor) hybrids. Bhatnagar et al. (1980) studied keeping quality of tomato fruits and reported that Punjab Chhuhara was acceptable upto 16 days, HS 110 and Punjab Kesari upto 14 days when stored at 21 $\pm$ 4°C. Jones and Millet (1984) reported the fruits of 76 VFT 30 x 76 T36 having good shelf life.

Reynard (1951) reported that all the cultivars, he studied, were susceptible to cracking except 'Crack Proof' which showed high degree of resistance. He could recover resistant progenies from crosses with Crack

Proof and noted that resistance was recessive. From crosses between crack resistant and crack susceptible cultivars Prashar and Lambeth (1960) concluded that cracking is a quantitative character and the inheritance involved several major and minor genes.

c) Fruit juice characteristics

The improvement in fruit quality for appearance, flavour and chemical composition is an important goal of plant breeders. The improvement in fruit quality of tomato hybrids was reported by Dhillon et al. (1979) and Lukyanenko and Garanko (1975).

[illegible] (1963) using two small fruited lines observed a heterotic increase in soluble and total solids in F_1. Stoner and Thompson (1966a) explored the possibility of obtaining large fruits with high solids from crosses of small × large fruited types. Segregates were found in the F_2 generation that had solids equal to the better parent. Some of the F_3 progenies had fruit weight comparable to that of the large fruited parent, but exceeded the parents in soluble solids by 0.50% to 1.00%. Anbu (1978), [illegible] et al. (1981) and Zhou et al. (1982) also reported heterosis for total soluble solids. Singh and Singh (1982) reported that, out of 120 F_1's, 113 exhibited significantly positive relative heterosis and 80, heterobeltiosis. Dorairaj et al. (1983) reported LE 113 x LE 413 having high content of TSS, sugars and acidity. Jones and Millet (1984) developed a hybrid 'Sierra Sweet' having bright orange colour and high total soluble solids.

Inheritance of soluble solids in tomato fruits was studied by Xhou and Xu (1984). In crosses between 11 processing varieties with varying soluble solids, heterosis was observed in 13 of 18 F_1's and in the other five, the F_1 value was better than the parental average. Raijadhav and Kale (1985) also reported heterosis for TSS and acidity. Tikoo et al. (1987) used a breeding line V 6714-2 (IIHR-249-2) with TSS above 9% in a crossing programme and developed advanced lines with TSS of 6.00% to 6.50%. But the fruits of these lines were smaller. They pointed out that efforts are now directed to evolve high TSS processing lines from IHR 249-2 crosses. However, the polygenic nature of high solids (Stoner and Thompson, 1966b; Ibarbia and Lambeth, 1969), its inverse relationship to yield (Goldenberg and Pahlen, 1966), together with its associated fruit defects, softness in particular (Rick, 1974) are important factors in determining the ultimate utility of high solids trait in the development of commercially acceptable F_1 hybrids. Conti *et al*. (1988) studied inheritance of quality traits in processing tomato in a 8 x 8 diallel cross without reciprocals. They observed that the average heterosis effects tended in a favourable direction from a quality point of view. As compared with parents, hybrids showed significantly high TSS. But the F_2 populations were inferior to parents. They pointed out the ineffectiveness of selection based on F_2 plant evaluation and recommended family selection in more advanced generations as the suitable breeding procedure.

Rick (1974) found that *Lycopersicon esculentum* genotypes have only limited potential for increasing the solids content of fruits. An interspecific cross with *Lycopersicon chmielewskii* produced breeding lines which have considerable potential for increased fruit solids. Hewitt and Stevens (1979) reported a breeding line LA 1563 with high content of solids derived from an interspecific cross.

Rick (1974) developed a high sugar breeding line 75781-4-1 from an interspecific cross. Stevens (1979) reported that F_1 hybrids had much higher levels of reducing sugar than the standard cultivar 'Cal Ace'. Jones and Scott (1984) also made similar observations.

Anbu (1978) and Stevens (1979) observed heterosis in hybrids for titratable acidity. Jones and Scott (1984) observed higher content of acids in F_1 hybrids between high sugar and high acid lines. Lukyanenko and Lukyanenko (1986) studied inheritance of organic acid content in tomato fruits. In crosses involving four varieties with a high content of titratable acids and a number of varieties with low acidity, the acidity values in the F_1s were mainly intermediate between parental values, with occasional dominance of high acidity. Maternal effects were apparent, values being generally higher when maternal parent had a high acid content.

Stevens (1979) in an attempt to develop F_1 hybrids having high sugar and acid contents, found that F_1 hybrids had lower pH than the standard cultivar 'Cal Ace'. Conti et al. (1988) also observed that the F_1 hybrids had lower pH.

Torres and Quackenbush (1968) reported that 'Caro Red' developed from Rutgers x Lycopersicon hirsutum had ten times more β carotene than the standard variety. Piccinio and Scott (1985) found that fruit colour was enhanced in the hybrids produced by crossing ripening mutants. The heterozygotes for F_1s had internal colour ratings equal to Walter, but external colour ratings lower than Walter.

Heterosis for ascorbic acid content in fruits of cultivated tomato was studied by Vienchu Thi Ngoc and Stein (1983). Out of 30 F_1s studied, four were superior to the parent with lower ascorbic acid content but none showed positive heterosis relative to the better parent. Five progenies which had Petito or IN 1073 C as one parent showed positive heterosis. Mochizuki and Kamimura (1984) studied inheritance of ascorbic acid content and its relation to other characters in crosses between hp, og and og^c varieties of tomatoes. In the F_1s of these crosses, ascorbic acid content was similar to the lower parent. F_1 hybrids carrying both hp and og did not have higher ascorbic acid content than those carrying hp alone.

4. Evaluation of hybrid progenies for processing

Rao and Choudhary (1981) evaluated five tomato cultivars, their F_1 hybrids, back crosses and F_2 progenies for canning behaviour. Cut out tests and evaluation of canned tomatoes revealed that Roma and the F_1

and back crosses to both parents of Pusa Ruby x Chiku Grande and the F_1 of Pusa Ruby x Italian Red Pear were suitable for whole fruit canning. The F_1s of Pusa Ruby x Chiku Grande which outyielded all others, hold promise as the best material for canning. The only material which got the over all score of Grade I canned tomatoes was the back cross (Pusa Ruby x Chiku Grande) x Chiku Grande while four others got Grade II rating.

5. Inheritance of bacterial wilt resistance

Genetic experiments indicated two primary sources of resistance to bacterial wilt caused by *Pseudomonas solanacearum* E.F. Smith (Russel, 1978). The first being the North Carolina type expressed by derivatives of Louisiana Pink, is inherited as a recessive character and controlled by polygenes (Singh, 1961). A second source of resistance derived from *Lycopersicon pimpinellifolium* (PI 127805 A) is partially dominant in the seedling stage. In mature plants, resistance was controlled by recessive genes and that expression of the resistant variety is a function of age of plant and changes in temperature (Acosta *et al.*, 1964). They found a complex picture of inheritance in which the host reaction was altered by temperature. Acosta (1964) stated that resistance in *Lycopersicon pimpinellifolium* is controlled by a single pair of genes. Association of resistance within determinate growth habit and small fruit size was observed. Acosta *et al.* (1964) observed no association between the gene 'u' controlling uniform fruit colour and resistance to bacterial wilt. Report of the Faculty of Agriculture, University of West Indies (1968-69) indicated that resistance to *Pseudomonas solanacearum* had a close linkage with genes for poor fruit characteristics. AVRDC (1975) reported that resistance to bacterial wilt is controlled by multiple recessive genes acting additively.

The trial conducted at College of Horticulture, Vellanikkara, Thrichur indicated resistance in CL 32 d-0-1-19 GS out of 78 lines/varieties evaluated (Celine, 1981). This line had too small fruits to be of commercial acceptance. Sreelathakumary (1983) found that no F_1 hybrids involving 10 lines from Louisiana Pink as female and Lycopersicon pimpinellifolium as male showed resistance. She reported a complimentary and hypostatic type of digenic recessive gene system responsible for wilt resistance. Tikoo et al. (1983) observed presence of two independent gene systems for wilt resistance. In CRA-66-Sel A from Hawaii, resistance was governed by multiple recessive genes and the genotype 663-12-3 from Taiwan had a monogenic dominant reaction. Rajan (1985) attempted to improve the resistant line CL 32 d-0-1-19 GS for high fruit weight and better plant type through four selection methods. Mass, pureline and SSD methods of selection were effective to improve fruits/plant, locules/fruit, yield/plant and fruit weight. Single seed descent method resulted in higher realised genetic gain for fruits/plant, locules/fruit and yield/plant. Sheela (1986) evaluated 14 tomato lines for bacterial wilt resistance. She found LE 79 and LE 214 to be resistant and LE 206 to be moderately resistant. The fruits of LE 79 and LE 214 were not uniform in colour whereas LE 206 had uniform fruits.

Broad based F_1 hybrids

Prasad (1978) reported that bacterial wilt disease is very difficult to be controlled by chemical or cultural methods. Resistance breeding is an effective alternative.

Four F_7 lines from a cross HPR 199 x Floradel showed good tolerance to Pseudomonas solanacearum (IRAT, 1970). Three tomato cultivars (VC 11-1, Saturn and Kewalo) resistant to bacterial wilt and the corresponding F_1 progeny of the two way and three way crosses were inoculated with a weak isolate and virulent isolate of Pseudomonas solanacearum. The progeny was more resistant than the parents (AVRDC, 1975). Graham and Yap (1976) performed a diallel among six cultivars Walter, CRA 66, H 7741, Venus, VC-4 and Llanos de Colce representing a range of susceptibility/resistance of 99.5 to 20.8 on a disease resistant scale They reported that wilt resistance attained a high level in a breeding procedure of repeated selfing and selection followed by intercrossing of resistant selections.

Churnvisoot and Lambeth (1983) crossed 12 accessions as female to three tester lines Saturn, Kewalo and Venus. Seedlings of parents and hybrids were leaf or stem inoculated with Pseudomonas solanacearum. Five accessions and their hybrids with Kewalo had low tolerance. Peterson et al. (1983) observed resistance in the cultivar scorpio. Sreelathakumary (1983) reported that no F_1 hybrids involving 10 lines from Lycopersicon esculentum as female and Lycopersicon pimpinellifolium as male showed resistance. Out of the four non-segregating lines (Saturn LE 79 Pusa Ruby and Pusa Ruby x LE 79 F_1) and two segregating lines (Pusa Ruby x LE 79 F_2, Saturn x LE 79 F_2) evaluated the F_2 hybrids of Saturn x LE 79 were resistant (Narayanankutty, 1985). In a repeated trial F_3s were evaluated along with the F_2s and non-segregating populations (Saturn x LE 79). Resistance was observed in Saturn x LE 79 F_3 (percentage of wilt, 16.7) and Saturn x LE 79 F_2 (percentage of wilt, 18.23). Pusa Ruby x LE 79 F_2 and F_3s were susceptible to moderately susceptible.

AVRDC (1985) reported of a seven parents diallel set comprised of diverse genetic stocks and tested for bacterial wilt resistance at both seedling and mature plant stages. Lines L 96 (cv Saturn from North Carolina) and L 285 (a small fruited Taiwan collection with the highest BW resistance level among AVRDC germplasm) showed far better average bacterial wilt resistance among their hybrid progenies than other stocks, as well as the ability to transmit this trait uniformly among their crosses. Certain stocks showed high bacterial wilt resistance in some crosses, but not in others. This non additive gene action appears also to be an important feature of the genetic system conditioning bacterial wilt resistance, implying that F_1 hybrid breeding for the trait is a possibility.

Rodade, a tomato variety bred in South Africa with resistance to race I of Pseudomonas solanacearum is grown successfully in other countries where bacterial wilt is a problem. Rodade has a complex pedigree and its resistance to bacterial wilt was derived from the BW2 line from North Carolina. Fruits were large, firmer and less prone to cracking (Bosch et al., 1985). The hybrid Redlands Summer Taste was bred using a sister line 1356 of Scorpio with a selection 1360 of Floradade, resistant to bacterial wilt;, verticillium wilt and Fusarium wilt (Herrington and Saranah, 1985).

Noda et al. (1986) in a resistance breeding programme compared ten F_2, F_4 and F_5 progenies of various ancestories with varieties Sao Sebastiao and Kada in plots naturally infested with Pseudomonas solanacearum. Resistance assessed by five different methods was the highest in the F_4 population HT 16-9-1 from IRAT III 40 x UH 7976. Opena et al. (1986) reported revisions in the breeding techniques for bacterial wilt resistance. Cognizant of the genetic complexity of bacterial wilt resistance, selection for this trait is now deferred to the stage when genetic materials reached family or line status. Early generation selections were restricted mainly to highly heritable simple traits. Hybrid progenies were evaluated for better horticultural types before selecting for complex traits like bacterial wilt resistance.

Tikoo et al. (1986) attempted development of heterotic F_1 hybrids of tomato, resistant to bacterial wilt. Two resistant sources CRA 66 Sel A and IIHR 663 12 3 (individual plant selection from Taiwan SSD line VC 8-1-2-1) were crossed with susceptible varieties like Pusa Ruby, HS 101 and Sel 24. Large fruited selections were recovered only in crosses with IIHR 663 12 3. None of the CRA 66 derivatives showed absolute resistance but survival beyond 80 days after inoculation in the field resulted in acceptable yields. Resistance in selections from Taiwanese lines was very high, most lines having 100% survival even

120 days after planting. Pedigree selection in the crosses between IIHR 663-12-3 and firm fruited wilt susceptible lines Arka Saurabh and Florida 1011, resulted in medium fruited selections in the range of 80 to 125 g and yield of 1 kg to 3 kg/plant. These selections were determinate in growth habit and were characterised by deep red, firm and uniformly ripening thick fleshed fruit.

Tikoo *et al.* (1987) found that 14 F_1 hybrids evolved using IIHR 663-12-3 (BWR 1) as female and wilt susceptible varieties as male, exhibited 100% survival even upto 120 days after planting confirming dominance of wilt resistance in BWR 1. Out of the hybrids only one (BWR 1 x KH det) had significantly higher yield of 2.24 kg/plant as against 1.4 kg/plant in BWR 1. The only other promising hybrid was BWR 1 x 674 (a processing line) as the fruits were uniformly ripening, square round in shape and good for processing. Since BWR 1 has soft fruits, the F_1s even with firm fruited lines was soft or medium firm.

Materials and Methods

MATERIALS AND METHODS

The whole project consisted of four main experiments

A. Evaluation of tomato genotypes for processing characteristics

B. Identification of tomatoes for ketchup and paste

C. Evaluation of tomatoes for long shelf life of ketchup

D. Transfer of processing traits to a bacterial wilt resistant genetic background

A. Evaluation of tomato genotypes for processing characteristics

I. Variability, heritability and genetic advance

a. Experimental materials

The tomato genotypes comprised of 61 lines, consisting a few from India and processing lines from abroad. Three resistant/tolerant sources of bacterial wilt resistance - Sakthi, LE 214 and LE 206 were also included. The genotypes were genetically catalogued for important morphological characters (Table 3).

The lines were grown in pots under disease free condition for two consecutive seasons (September 1986 to January 1987 and September 1987 to January 1988). Pots were filled to capacity with potting mixture. The filled pots were sterilized using 40% formaldehyde solution. A gap of 15 days between soil fumigation and planting was allowed to avoid harmful effects. Twelve pots maintained for each genotype were arranged in an open well-lit area. Seedlings were transplanted after 30 days of sowing. Fertilizer mixture was applied as per package of practices recommendations of Kerala Agricultural University (1986). The pots were watered regularly

Table 3. Genetic cataloguing of tomato genotypes

Genotypes	Sources	Genetic cataloguing							
Ohio 832	Vegetable Research Station, Ontario, Canada	spsp.,	jj..,	ntnt.,	bk^{+}-.,	uu.,	f^{+}-.,	oo.,	clcl.,
Ohio 7814	"	spsp.,	jj..,	ntnt.,	bk^{+}-.,	uu.,	f^{+}-.,	oo.,	clcl.,
Ohio 8129	"	spsp.,	jj..,	ntnt.,	bk^{+}-.,	uu.,	f^{+}-.,	oo.,	cl^{+}-.,
Sx 61	"	spsp.,	jj..,	nt^{+}-.,	bkbk.,	uu.,	f^{+}-.,	oo.,	cl^{+}-.,
Sx 64	"	spsp.,	jj..,	ntnt.,	bk^{+}-.,	uu.,	f^{+}-.,	oo.,	clcl.,
Sx 97	"	spsp.,	jj..,	nt^{+}-.,	bk^{+}-.,	uu.,	f^{+}-.,	oo.,	clcl.,
[illegible] 828	"	spsp.,	jj..,	ntnt.,	bk^{+}-.,	uu.,	f^{+}-.,	oo.,	clcl.,
[illegible] 8210	"	spsp.,	jj..,	nt^{+}-.,	bk^{+}-.,	uu.,	f^{+}-.,	oo.,	clcl.,
H 722	"	spsp.,	jj..,	ntnt.,	bk^{+}-.,	uu.,	f^{+}-.,	oo.,	cl^{+}-.,
H 2653	"	spsp.,	jj..,	nt^{+}-.,	bk^{+}-.,	uu.,	f^{+}-.,	oo.,	clcl.,
H 7998	"	spsp.,	jj..,	ntnt.,	bk^{+}-.,	uu.,	f^{+}-.,	oo.,	clcl.,
PW 6203	"	spsp.,	j^{+}-.,	nt^{+}-.,	bk^{+}-.,	uu.,	f^{+}-.,	oo.,	clcl.,
HW 208 F	"	spsp.,	jj..,	nt^{+}-.,	bk^{+}-.,	uu.,	f^{+}-.,	oo.,	clcl.,
TH 318	"	spsp.,	jj..,	ntnt.,	bk^{+}-.,	uu.,	f^{+}-.,	oo.,	clcl.,
Veepick	Stokes Seeds Ltd.	spsp.,	j^{+}-.,	ntnt.,	bk^{+}-.,	uu.,	f^{+}-.,	oo.,	clcl.,
[illegible]	St. Catharins, ONT L2 R6R6, USA	spsp.,	j^{+}-.,	nt^{+}-.,	bk^{+}-.,	uu.,	f^{+}-.,	oo.,	clcl.,
[illegible]	"	spsp.,	jj..,	nt^{+}-.,	bk^{+}-.,	uu.,	f^{+}-.,	o^{+}-.,	clcl.,
Veemore	"	spsp.,	j^{+}-.,	nt^{+}-.,	bk^{+}-.,	uu.,	ff.,	o^{+}-.,	clcl.,
Veeroma	"	spsp.,	j^{+}-.,	ntnt.,	bk^{+}-.,	uu.,	f^{+}-.,	oo.,	clcl.,
[illegible]	"	spsp.,	jj..,	nt^{+}-.,	bk^{+}-.,	uu.,	ff.,	oo.,	clcl.,
[illegible] 25	USDA, Vegetable Laboratory, Beltsville, Maryland	spsp.,	j^{+}-.,	nt^{+}-.,	bk^{+}-.,	uu.,	f^{+}-.,	oo.,	clcl.,
[illegible] 12	"	spsp.,	j^{+}-.,	nt^{+}-.,	bk^{+}-.,	uu.,	f^{+}-.,	oo.,	cl^{+}-.,
E [illegible]203	"	spsp.,	j^{+}-.,	nt^{+}-.,	bk^{+}-.,	uu.,	f^{+}-.,	oo.,	clcl.,
Roma	"	spsp.,	j^{+}-.,	ntnt.,	bk^{+}-.,	uu.,	f^{+}-.,	oo.,	cl^{+}-.,
San Marzano	"	spsp.,	j^{+}-.,	nt^{+}-.,	bk^{+}-.,	uu.,	f^{+}-.,	oo.,	clcl.,
Heinz 1350	"	spsp.,	j^{+}-.,	nt^{+}-.,	bk^{+}-.,	uu.,	ff.,	o^{+}-.,	clcl.,
Sioux	"	spsp.,	j^{+}-.,	nt^{+}-.,	bk^{+}-.,	uu.,	ff.,	o^{+}-.,	clcl.,
Fresh Market 9	Foundation Seed Service, USA	spsp.,	j^{+}-.,	nt^{+}-.,	bk^{+}-.,	uu.,	f^{+}-.,	o^{+}-.,	clcl.,

Contd.

Genotypes	Sources		
[illegible] AC	Foundation Seed Service, USA	spsp.,	[illegible]
IIHR 574	IIHR, Bangalore	spsp.,	[illegible]
Sel [illegible]	[illegible]	spsp.,	[illegible]
Punjab Chhuhara	GB Pant University, Pantnagar	spsp.,	[illegible]
Punjab Kesari	"	spsp.,	[illegible]
[illegible]	"	spsp.,	[illegible]
Pant T_3	"	spsp.,	[illegible]
AC 142	"	spsp.,	[illegible]
AC 238	"	sp*-.,	[illegible]
AC 2301	"	spsp.,	[illegible]
Sweet 72	"	sp*-.,	[illegible]
Pusa Early Dwarf	"	spsp.,	[illegible]
Kt 1	Vegetable Research Station, Katrain	sp*-.,	[illegible]
Kt 2	"	sp*-.,	[illegible]
Kt 3	"	sp*-.,	[illegible]
Kt 4	"	sp*-.,	[illegible]
HS 101	IARI, New Delhi	spsp.,	[illegible]
HS 102	"	spsp.,	[illegible]
S 12	"	sp*-.,	[illegible]
Pusa Ruby	"	sp*-.,	[illegible]
[illegible]	NBPGR, New Delhi	sp*-.,	[illegible]
EC [illegible]	"	spsp.,	[illegible]
EC [illegible]162/P_2-1	"	spsp.,	[illegible]
EC [illegible]	"	spsp.,	[illegible]
EC [illegible]-1-1	"	spsp.,	[illegible]
EC [illegible]/P_1	"	spsp.,	[illegible]
EC [illegible]	"	spsp.,	[illegible]
EC [illegible]	"	spsp.,	[illegible]
EC [illegible]	"	spsp.,	[illegible]
EC [illegible]	"	sp*-.,	[illegible]
[illegible]	"	spsp.,	[illegible]
[illegible]	TNAU, Coimbatore	spsp.,	[illegible]
Money Maker	KAU, Vellanikkara	spsp.,	[illegible]
LE 206	"	sp*-.,	[illegible]
LE 214	"	sp*-.,	[illegible]
[illegible]	"	sp*-.,	[illegible]

Genetic cataloguing

nt*-..	bk*-..	uu..	f*-..	00..	lclc..
nt*-..	bk*-..	uu..	f*-..	00..	lclc..
nt*-..	bk*-..	uu..	f*-..	00..	lc*-..
nt*-..	bk*-..	uu..	f*-..	00..	lc*-..
nt*-..	bk*-..	uu..	f*-..	00..	lclc..
nt*-..	bk*-..	uu..	f*-..	00..	lc*-..
nt*-..	bk*-..	uu..	f*-..	00..	lclc..
nt*-..	bk*-..	uu..	f*-..	0*-..	lc*-..
nt*-..	bk*-..	uu..	f*-..	0*-..	lclc.,
nt*-..	bk*-..	uu..	ff..	0+-..	lclc.,
nt*-..	bk*-..	uu.,	f*-..	0*-..	lclc.,
nt*-.,	bk*-..	uu.,	f*-..	0*-..	lclc.,
nt*-..	bk*-..	uu..	f*-..	0+-.,	lclc.,
nt*-..	bk*-..	uu.,	ff.,	0*-.,	lclc.,
nt*-..	bk*-..	uu.,	ff.,	0*-.,	lclc.,
nt*-..	bk*-..	uu.,	f*-.,	0*-.,	lclc.,
nt*-.,	bk*-..	uu.,	f*-.,	0+-.,	lclc.,
nt*-..	bk*-..	uu.,	f*-.,	0+-.,	lclc.,
nt*-.,	bk*-..	uu.,	f*-.,	0*-.,	lclc.,
nt*-.,	bk*-..	uu.,	ff.,	0+-.,	lclc.,
ntnt.,	bk*-.,	uu.,	f*-.,	00.,	lc*-.,
nt*-..	bk*-.,	u*-.,	f*-.,	0+-.,	lclc.,
nt*-..	bk*-.,	uu.,	f*-.,	00.,	lclc.,
nt*-..	bk*-..	uu.,	f+-.,	0+-.,	lclc.,
nt*-..	bk*-.,	u*-.,	f*-.,	0*-.,	lclc.,
nt*-..	bk*-.,	u*-.,	f*-.,	0*-.,	lclc.,
nt*-..	bkbk.,	uu.,	f*-.,	00.,	lclc.,
nt*-.,	bk*-.,	uu.,	f*-.,	00.,	lclc.,
ntnt.,	bk*-.,	uu.,	f*-.,	00.,	lclc.,
nt*-.,	bk+-.,	u*-.,	ff.,	0+-.,	lclc.,
nt*-.,	bk*-.,	uu.,	f+-.,	0+-.,	lclc.,
nt*-.,	bk*-.,	u*-.,	f*-.,	0+-.,	lclc.,
nt*-.,	bk*-.,	u+-.,	f+-.,	0+-.,	lclc.,
nt*-.,	bk*-.,	uu.,	f+-.,	0+-.,	lclc.,
nt*-.,	bk*-.,	u+-.,	f+-.,	0+-.,	lclc.,
nt*-.,	bk*-.,	u+-.,	f+-.,	0+-.,	lclc.,

twice a day. Five plants were tagged to observe fruit and yield characters.

The observations recorded were:

b. Fruit yield components

(i) Plant height (cm)
(ii) Days to flower
(iii) Days to harvest
(iv) Index to earliness
(v) Fruits/plant
(vi) Fruit yield/plant (g)

Index to earliness was estimated using the formula

$$\text{Index to earliness (IE)} = \frac{a_1 + a_2 + a_3}{c_1 + c_2 + c_3}$$

where,

a_i = yield of genotype on i^{th} day

c_i = yield of control (Sakthi) on i^{th} day

c. Fruit characteristics

(i) Average fruit weight (g)

(ii) Fruit shape index

Fruit shape index was derived by dividing polar diameter/equatorial diameter.

(iii) Locules/fruit

(iv) Pericarp thickness (mm)

(v) Cracking percentage

The number of fruits cracked out of the total number of fruits harvested from a plant was noted and expressed as percentage.

(vi) Storage life

Twenty five fruits of uniform maturity (turning stage) were selected at random from each genotype. Five fruits formed one replication and were kept in polythene bags punched on an area of 2 cm^2, at the rate of 0.25 cm^2/punch for aeration and the bags were tied with rubber band and kept under room conditions. The economic storage life was calculated as number of days from harvest till the commencement of spoilage of 80% of the ripe fruits.

d. Fruit juice characteristics

(i) Juice yield

Freshly harvested red ripe fruits, free from cracking were used to extract juice. A weighed quantity of fruits were washed, sliced and crushed coarsely in a mixy to obtain coarse pulp. The pulp was heated immediately to 85°C and then strained in a plastic mesh to remove seeds and skins. Juice obtained by the 'hot break' method was weighed and expressed as per cent on a weight basis. The juice thus obtained was chemically analysed as detailed below:

(ii) TSS

TSS was determined using a hand refractometer and expressed as %.

(iii) Total solids

Total solids was worked out by drying 20 g of juice placed in a flat bottom dish in an oven at 70°C ± 2°C, till two consecutive weights agreed.

(iv) Insoluble solids

For determining the insoluble solids, 20 g juice was centrifuged and washed with hot water repeatedly for four times and filtered through a weighed filter. The insoluble matter was dried in a covered dish for 2 h at 100 ± 2°C.

(v) Total solids: insoluble solids ratio

From the total solids insoluble solids, the ratio was worked out.

(vi) Reducing sugar

Reducing sugar was estimated as per AOAC (1980).

(vii) Acidity

Acidity was determined by titration with standard NaOH solution and expressed as citric acid %.

(viii) Sugar acid ratio

From the reducing sugar and acid contents, the sugar acid ratio was worked out.

(ix) pH

pH was determined using an Elico pH meter.

(x) Consistency

Consistency was measured by finding out the precipitate weight ratio (Takada and Nelson, 1983). Weighed quantity of sample was taken in pre-weighed centrifuge tubes and centrifuged for 40 minutes at 8000 rpm. The supernatant was drained out and the pulp settled at the bottom was weighed and the precipitate weight ratio (PPT) was calculated. Pulp content was determined by the above method and expressed as per cent.

(xi) **Lycopene**

Lycopene was estimated by the rapid spectrophotometric method suggested by Adsule and Dan (1976). One ml of juice was shaken with 20 ml acetone in a mechanical shaker for 30 minutes. Then 40 ml of petroleum ether was added and the colour extracted was read in a Spectrophotometer (Spectronic 20) at 503 nm.

(xii) β carotene

β carotene was estimated following methods of vitamin assay and the colour intensity was read in a spectrophotometer (Spectronic 20) at 452 nm.

(xiii) Ascorbic acid

The visual titration method of vitamin assay using 2,6-dichlorophenol indophenol dye was followed for estimating ascorbic acid.

e. Statistical analyses

Analyses of variance was done wherever necessary for a completely randomised design (Panse and Sukhatme, 1978). Variability for quantitative characters were estimated as suggested by Burton (1952).

(i) Genotypic coefficient of variation (gcv)

$$= \frac{\text{Genotypic standard deviation}}{\text{Mean of character}} \times 100$$

(ii) Phenotypic coefficient of variation (pcv)

$$= \frac{\text{Phenotypic standard deviation}}{\text{Mean of the character}} \times 100$$

(iii) Standard error of mean

$$= \frac{\text{Environmental standard deviation}}{\text{Replications}} \times 100$$

(iv) Genotypic variance

$$= \frac{\text{Mean square due to genotypic - mean square due to error}}{\text{Number of replications}}$$

(v) Phenotypic variance = Genotypic variance + Error variance

(vi) Error variance = Mean square due to error

(vii) Heritability in broad sense

$$h^2(b) = \frac{\text{Genotypic variance}}{\text{Phenotypic variance}}$$

(viii) Expected genetic advance

$$GA = h^2 \cdot \sigma P \times i$$

where,

h^2 = heritability in broad sense

σP = phenotypic standard deviation

i = coefficient of intensity of selection (2.06 at P = 0.05)

(ix) Genetic advance as (%) of mean

$$= \frac{\text{Genetic advance}}{\text{Mean of the character}} \times 100$$

2. Somatic analyses

Fruit shape index was considered as the effect factor in a closed system of "cause and effect" variables, the causal variables being insoluble solids, consistency, total solids, total soluble solids, juice yield, acidity, pH, reducing sugar, lycopene, locules/fruit and pericarp thickness.

The estimates of direct and indirect effects in such a closed system of variables were calculated by the path coefficient analysis as suggested by Dewey and Lu (1959).

3. Identification of processing types based on selection index

Selection index was calculated according to Conti et al. (1981) based on most important agronomic and processing traits, yield/plant, fruit shape index, pericarp thickness, juice yield, TSS, total solids, insoluble solids, reducing sugar, acidity, pH, consistency and lycopene. The index was calculated according to the formula $I = \Sigma b_i c_i$, where b_i is the weighting coefficient and c_i value of each trait. The value of each trait was standardised to make it independent units of measurement. Based on the index value, the 64 genotypes were ranked.

B. Identification of tomatoes for ketchup and paste

1. Ketchup

a. Preparation of ketchup and chemical analyses

Genotypes which showed excessive cracking (>5%) were eliminated and 42 genotypes were evaluated for preparing tomato ketchup. Irrespective of cracking, Sakthi and LE 214 were also included for evaluation. Red ripe fruits from each of the genotype were gathered and juice extracted by the 'hot break' method outlined before. Ketchup was prepared by the open pan concentration technique adopting the CFTRI recipe (Anon., 1985). TSS of the finished product was adjusted to 38%.

The hot ketchup was filled into pre-sterilized glass jars and closed with screw caps. The bottles were washed with warm water and wiped dry outside. The yield of ketchup was worked out based on quantity of juice taken for preparing ketchup. The chemical composition of ketchup was estimated as in the case of juice characteristics. The prepared ketchup was compared with a commercial sample (Maggi ketchup).

b. Sensory evaluation

Panelists were initially screened for taste acuity and trained to use score sheet. Finally a group of five panelists evaluated the ketchup for colour, consistency, flavour and absence of defects, adopting a 100 point numerical scoring procedure followed by Bureau of Indian Standards (ISI, 1967a). The method of giving scores for ketchup is appended (Appendix I). The scores as number of points for each factor given by judges for ketchup from each genotype was recorded in a tabular form in the score card and the average score calculated for each factor with overall average for each genotype.

c. Assignment of grade

The maximum and minimum number of points to be scored through different factors were as follows:

Factor	Maximum	Minimum	
		Grade I	Grade II
Colour	25	19	16
Consistency	25	19	16
Flavour	25	19	16
Absence of defects	25	18	17

The ketchup which scored 85 points and above were rated as Grade I and 75 points and above but below 85 were rated as Grade II.

2. Paste

a. Preparation of paste and chemical analyses

Sixteen genotypes were selected for preparing tomato paste. This included ten genotypes which were ranked in the top list for ketchup, three genotypes high in TSS and three resistant/tolerant lines. The juice extracted by the 'hot break' method from each genotypes was concentrated by open pan concentration under low temperature. Sodium benzoate (200 ppm) was added as preservative. No other additives were added. TSS was adjusted to 28%. The paste was heated to 90°C and filled into pre-sterilized glass jars and closed with screw caps. Finally the bottled paste was processed in boiling water for 30 minutes and cooled in running cold water and wiped dry out side. The yield of paste was worked out based on juice taken for concentration. Chemical composition of paste was estimated as in case of fruit juice characteristics. The prepared paste was compared with Hunt's paste (USA) and NAFED paste (India).

b. Sensory evaluation

A group of five panelists evaluated the paste for colour and absence of defects adopting a 100 point numerical scoring procedure followed by Bureau of Indian Standards ISI (1967b). Method of giving scores for paste is appended (Appendix - II). Overall score was arrived as in case of ketchup.

c. Assignment of grade

The maximum and minimum number of points to be scored for the two factors were as follows:

Factors	Maximum	Minimum	
		Grade I	Grade II
Colour	60	45	39
Absence of defects	40	35	26

The paste which scored 85 points and above were graded as Grade I and 75 points and above but below 85 points were graded as Grade II.

C. Evaluation of tomatoes for long shelf life of ketchup

1. Changes in physico-chemical composition and sensory scores

The bottled ketchups were stored at room temperature for 12 months. Changes in physical appearance of ketchup were noted. Compositional analyses of ketchup for [illegible], acidity, reducing sugar, pH, TSS, lycopene, β carotene and ascorbic acid and sensory evaluation were done before storage and at three month interval. Appropriate methods of analyses as outlined for juice characteristics were followed here also.

2. Micro-organisms causing spoilage

a. Estimation of microflora

The quantitative assay of microflora in samples showing visible infection was carried out by serial dilution technique (Stainer et al., 1977). Samples were mixed thoroughly in a pestle and mortar. Ten g of sample was transferred to 100 ml sterile distilled water and shaken well in a rotary shaker for one hour. From these, dilutions upto 10^{-7} were prepared in sterile distilled water. The best dilutions for each group of organisms were previously determined and those dilutions were used for further studies.

Fungus

One ml of solution from 10^{-5} dilution was pipetted into sterile petri dishes to which melted and cooled, 20 ml of Martin's rose bengal streptomycin agar was poured. Five petri dishes were used for each sample. The petri dishes with the media were swirled thoroughly to get a uniform distribution. After solidification, the dishes were incubated at room temperature for four days. The fungal colonies developed at the end of four days were counted using dark field colony counter and values were expressed as number of colonies per gram of tomato ketchup.

Bacteria

Procedure followed was similar to that of fungus except for the 10^{-7} dilution, nutrient agar media and incubation for 48 h at room temperature.

Actinomycetes

The procedure followed was same as that of fungus except for the 10^{-6} dilution, Kuster's agar media and incubation for seven days at room temperature.

Only fungal flora developed in dilution plate method.

b. Identification of microflora

The young colonies developed in the dilution plate method were isolated and cultured in potato-dextrose agar. Single hyphal tip isolation was done for maintaining pure culture.

Morphological characters of the fungal flora were studied by growing fungi in petri dishes and by slide culture technique. All the cultures were incubated at room temperature. Czapek's agar medium was used for the study (Ainsworth, 1977).

D. Transfer of processing characteristics to a bacterial wilt resistant genetic background

I. Combining ability, gene action and heterosis

a. Experimental materials

The wilt resistant sources selected were Sakthi, LE 206 and LE 214. Sakthi and LE 214 were moderately resistant to bacterial wilt and the fruits possessed green neck and cracking. LE 206 was moderately susceptible but the fruits were uniform and did not crack. The processing lines selected based on evaluation for processing were HW 208 F, Ohio 8129 and St 64. Fresh Market 9 and TH 318 were also selected for large fruit size and high yield. The resistant genotypes were crossed with five male testers HW 208 F, St 64, Ohio 8129, TH 318 and Fresh Market 9. The fifteen F_1 hybrids were raised in pots, during September 1988 to January 1989. They were maintained, observations recorded and chemical analyses done as in Experiment A.

b. Statistical analyses

i. Combining ability and gene action

Combining ability and gene action were studied using Line x Tester analysis following Kempthorne (1957).

ii. Estimation of heterosis

Heterosis over better parent (heterobeltiosis) and mid parent (relative heterosis) were calculated (Briggle, 1963; Hayes et al., 1965).

The formula used were

$$\text{Heterobeltiosis} = \frac{\overline{F}_1 - \overline{BP}}{\overline{BP}} \times 100$$

$$\text{Relative heterosis} = \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$$

where,

$\overline{F_1}$ = mean of the hybrid

$\overline{BP}$ = mean of better parent

$\overline{MP}$ = mean of mid parent

Heterobeltiosis was tested using standard error

$$SE = \sqrt{\frac{2\sigma^2 e}{r}}$$

σ^2 = error mean square

r = number of replications

Relative heterosis was tested using standard error

$$SE = \sqrt{\frac{3/2\ \sigma^2 e}{r}}$$

2. Evaluation of F_1 hybrids for ketchup and paste

Based on processing qualities seven hybrids for ketchup and four hybrids for paste were selected and the products were prepared, chemically analysed and sensory rating done as in Experiment B.

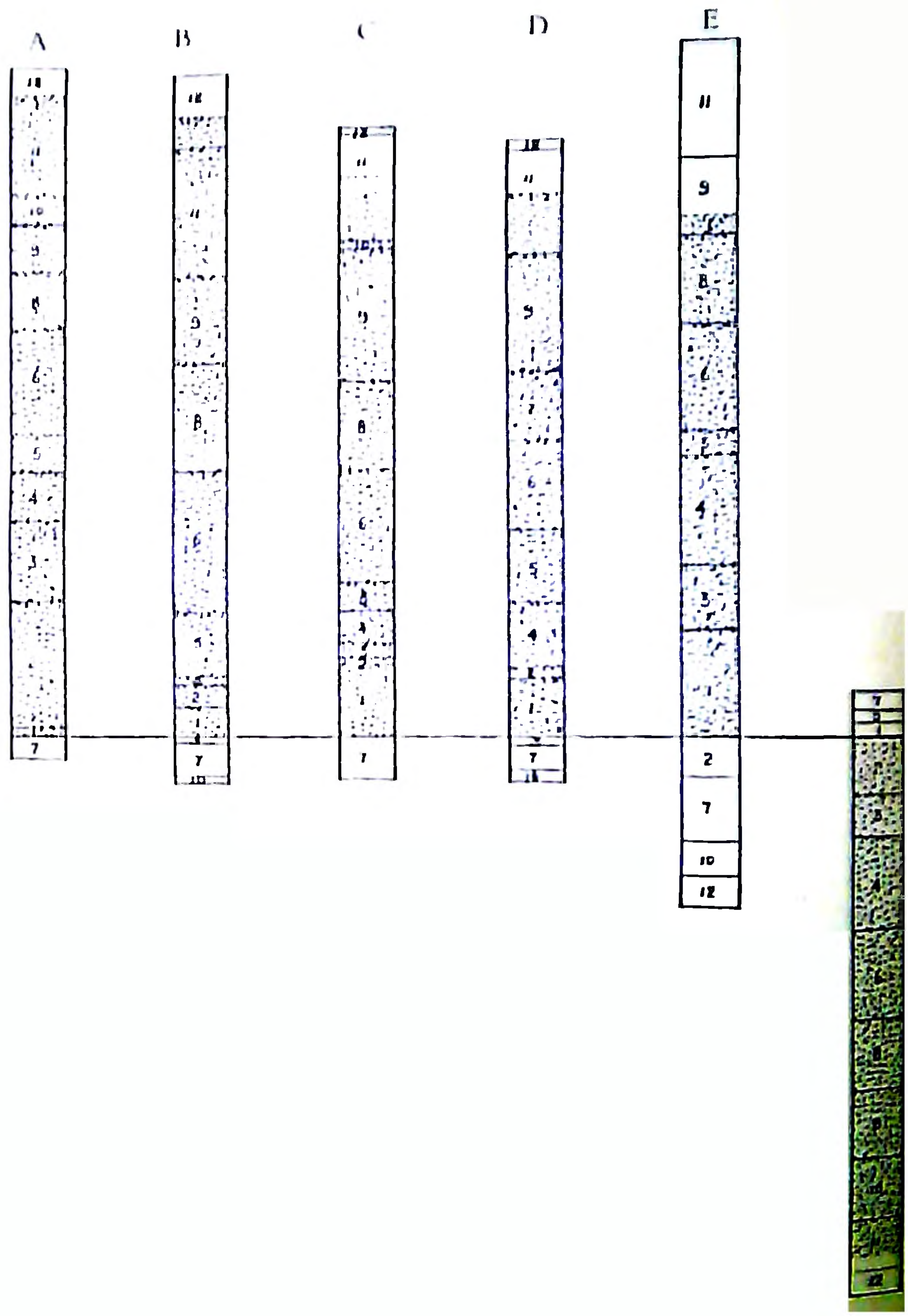
3. Evaluation for wilt resistance

Bacterial wilt reaction of the 64 genotypes was assessed by growing them in wilt sick plot of the Olericulture Department during September 87 to January 1988. Six F_1's, their parents and 6 F_2's were then evaluated for their wilt reaction during September 89 to January 1990. Twenty plants for the 64 tomato genotypes, 30 plants for the 7 parents and 6 F_1 hybrids and 150 plants for the 6 F_2 segregants were raised. Wilt incidence was assessed by number of plants wilted confirmed by ooze test. Spot planting with susceptible Pusa Ruby was done to confirm resistance.

Results


1
2
3
4
5

Fig.1 Selection index based on multiple characters



RESULTS

Results of the present investigations are presented under the following heads.

A. Evaluation of tomato genotypes for processing characteristics

B. Identification of tomatoes for ketchup and paste

C. Evaluation of tomatoes for long shelf life of ketchup

D. Transfer of processing characteristics to a bacterial wilt resistant genetic background

A. Evaluation of tomato genotypes for processing characteristics

I. Variability, heritability and genetic advance

Analyses of variance indicated significant differences during two seasons among 64 tomato genotypes for fruit yield and its components, fruit characteristics and fruit juice characteristics (Tables 4 to 6). Performance of the 64 genotypes are appended (Appendix III and IV).

The extent of variability for the above characteristics were measured in terms of range, mean, coefficient of variation at genotypic, phenotypic and environmental levels. Heritability, genetic advance and genetic advance as % of mean were also estimated (Tables 7 to 9).

a. Fruit yield and its components

Plant height ranged from 60.60 to 136.00 cm and 61.00 121.80 cm, in the first and second seasons respectively. In both the seasons, ONt 8210 was the dwarfest line (60.60 and 61.00 cm respectively). Kt 4 (136.00 cm) during the first season and Kt 1 (121.80 cm) during the second season were the tallest genotypes.

Table 4. General analyses of variance for fruit yield components in tomato

Sources of variation		df	Mean squares: Plant height (cm)	Days to flower	Days to harvest	Index to earliness	Fruits/plant	Fruit yield/ plant (g)
Genotypes	S_1	63	1598.89**	94.64**	135.30**	0.39**	530.43**	294877.24**
	S_2		929.56**	112.76**	144.82**	0.41**	439.34**	303229.66**
Error	S_1	256	139.04	7.35	18.62	0.08	89.58	35240.19
	S_2		90.86	3.95	11.64	0.08	72.76	28554.19

** - Significant at P = 0.01

S_1 - September 1986-January 1987

S_2 - September 1987-January 1988

Table 5 . General analyses of variance for fruit characteristics in tomato

Sources of variation		df	Mean squares: Average fruit weight (g)	Fruit shape index	Locules/fruit	Pericarp thickness (mm)	Cracking (%)	Storage life (days)
Genotypes	S_1	63	1738.05**	0.34**	0.41**	5.89**	10.07**	253.41**
	S_2		1866.01**	0.29**	0.40**	6.29**	11.63**	216.48**
Error	S_1	256	200.82	0.004	0.03	0.45	1.22	6.94
	S_2		192.40	0.020	0.03	0.21	1.27	2.81

** - Significant at P = 0.01

S_1 - September 1986-January 1987

S_2 - September 1987-January 1988

Table 6. General analyses of variance for fruit juice characteristics in tomato

Sources of variation		df	Juice yield (%)@	Juice yield (t ha^{-1})@	TSS (%)@	Total solids (%)	Insoluble solids (%)	Total solids: insoluble solids ratio	Reducing sugar (%)	Acidity (%)	pH@
			Mean squares								
Genotypes	S_1	63	100.06**	156.76**	1.77**	1.82**	0.15**	17.23**	0.77**	0.04**	0.27**
	S_2		67.25**	163.52**	1.24**	1.81**	0.14**	12.81**	0.83**	0.04**	0.20**
Error	S_1	128	16.76	17.60	0.23	0.16	0.003	1.49	0.15	0.006	0.13
	S_2		10.75	14.83	0.20	0.14	0.003	1.04	0.14	0.005	0.21

** - Significant at P = 0.01

S_1 - September 1986-January 1987

S_2 - September 1987-January 1988

@ - df for error 256

Table 6 (contd.)

Sources of variation		df	Mean squares					
			Sugar acid ratio	Pulp content (%)	Consistency (PPT)	Lycopene (mg/100 g)	β carotene (μg/100 g)	Ascorbic acid (mg/100 g)
Genotypes	S_1	63	6.69**	8[illegible].17**	0.009**	2.84**	22655.84**	103.36**
	S_2		7.15**	69.67**	0.007**	3.12**	20479.40**	89.12**
Error	S_1	128	1.92	8.88	0.001	0.34	1353.44	18.32
	S_2		2.14	1.31	0.0002	0.14	1928.33	3.10

** - Significant at P = 0.01

S_1 - September 1986-January 1987

S_2 - September 1987-January 1988

The earliest to flower was AC 238 (57.80 days) and LE 214 (59.20 days) during the first and second seasons respectively. This was closely followed by Pusa Early Dwarf (60.40 and 59.60 days respectively) during both seasons. Irrespective of the seasons, H 722 (76.80 days) took the maximum time to flower.

On an average, the tomato lines were ready for harvest by 99 DAS. As the flowering was early in AC 238 it was ready for harvest early (91.20 days) during the first season. Pusa Early Dwarf which was one among the early flowering types, could be harvested early during the second season (87.40 days). FM 6203 (110.40 days) and HW 208 F (109.40 days) were the latest to harvest during the first and second seasons respectively.

Index to earliness ranged widely from 0.01 to 1.41. Compared to the standard variety Sakthi, LE 206 (S_1 = 1.32 and S_2 = 1.41) showed maximum economic earliness followed by AC 142 (S_1 = 1.12 and S_2 = 1.16). The known processing tomatoes were relatively late as indicated by the low index values. (ONI 8210 - S_1 & S_2 = 0.01; HW 208 F - S_1 = 0.01 and S_2 = 0.06; Ohio 832 - S_1 = 0.03 and S_2 = 0.05; Roma - S_1 = 0.03 and S_2 = 0.04; H 722 - S_1 = 0.04 and S_2 = 0.08).

In both the seasons, Sioux produced a fewer fruits (6.00 and 5.40. respectively), while AC 142 produced maximum number of fruits (52.40 an 59.00 respectively). The other lines which produced a fewer fruits were ONI 8210 (S_1 = 7.80 and S_2 = 10.20), Heinz 1350 (S_1 = 8.20 and S_2 = 8.00) and H 2653 (S_1 = 10.60 and S_2 = 10.80). EC 129968 (S_1 = 52.40 and S_2 = 47.20), EC 129355 (S_1 = 43.60 and S_2 = 45.40) and Fire Ball (S_1 = 42.40 and S_2 = 40.00) produced fairly a large number of fruits.

The range in fruit yield/plant was from 256.56 g to 1315.49 g. The lowest yielder was AC 238 (S_1 = 256.56 g and S_2 = 296.66 g) and the best yielder was EC 129355 (S_1 = 1258.98 g and S_2 = 1315.49 g),

Plate I Variability in fruit shape - 1. Round (<1) 2. Elongate (>1) 3. Pear shaped 4. Nipple tipped 5. Beaked

Plate II Right: Jointless pedicel, Left: Jointed pedicel during both the seasons. The other high yielding genotypes were TH 1 (S_1 = 1241.56 and S_2 = 1313.83 g), Fresh Market 9 (S_1 = 1021.00 g a S_2 = 1254.38 g), Veemore (S_1 = 1164.94 g and S_2 = 1254.38 g) and St (S_1 = 1012.04 g and S_2 = 1013.48 g). The check variety Sakthi also yielded high (S_1 = 1142.20 g and S_2 = 1216.32 g).

Among components of yield, index to earliness recorded maximum variability (gcv - S_1 = 70.85 and S_2 = 71.27; pcv - S_1 = 106.51 and S_2 = 104.05) followed by fruits/plant (gcv - S_1 = 37.93 and S_2 = 35.12, pcv - S_1 = 53.85 and S_2 = 49.50). Though heritability was only moderate (S_1 = 0.44 and S_2 = 0.47), genetic advance as per cent of mean was the highest (S_1 = 97.10 and S_2 = 100.57) followed by fruits/plant (S_1 = 55.03 and S_2 = 51.25). Days to harvest recorded minimum variability (gcv - S_1 = 4.84 and S_2 = 5.18). Though heritability was moderately high (S_1 = 0.56 and S_2 = 0.76), genetic advance as per cent of mean was very low (S_1 = 7.43 and S_2 = 8.90) (Table 7).

b. Fruit characteristics

Average fruit weight ranged from 12.17 g to 103.22 g. In b[oth] the seasons, Sweet 72 produced the smallest fruits (S_1 = 12.17 g [a]nd S_1 = 12.60 g) and Sioux, the biggest fruits (S_1 = 103.22 g [and] S_2 = 100.44 g). The genotypes AC 238 and AC 142 which produc[ed] [maxi]mum [or fai]rly large number of fruits also had small fruits (mean 14.52 g and 15.50 g, respectively). The other large fruited genotypes were Fresh Market (96.16 g), Heinz 1350 (90.90 g), HW 208 F (81.49 g), EC 54645 (72.71 g) and TH 318 (66.56 g).

The range in fruit shape index (0.70 to 2.02) was indicative of the wide variation in fruit shape. The lowest shape index was recorded by Pusa Early Dwarf (0.71) and AC 2301 (0.70) in the first and second seasons. The highest index value was recorded by Veepick (S_1 = 2.02 and S_2 = 1.88) followed by DMM (S_1 = 1.67 and S_2 = 1.60).

Table 7. Range, mean, genotypic (gcv), phenotypic (pcv) and environmental (ecv) coefficients of variation, heritability (h^2), genetic advance and genetic advance as per cent of mean for fruit yield and its components in tomato

		Plant height (cm)	Days to flower	Days to [illegible]	Index of earliness	Fruits/plant	Fruit yield/plant (g)
Range	S_1	60.60-136.30	[illegible]	[illegible]	[illegible]	6.00 - 59.00	236.56-1258.93
	S_2	61.00-121.30	[illegible]	[illegible]	[illegible]	5.40 - 52.40	292.66-1315.49
mean ± SE	S_1	91.90 ± 5.27	[illegible]	[illegible]	[illegible] ± 0.13	24.76 ± 4.23	769.42 ± 83.95
	S_2	89.00 ± 4.26	[illegible]	[illegible]	[illegible] ± 0.12	24.38 ± 3.81	787.02 ± 75.57
gcv	S_1	18.59	6.19	[illegible]	70.85	37.93	29.62
	S_2	14.55	6.96	[illegible]	71.27	35.12	29.78
pcv	S_1	22.59	7.33	[illegible]	106.51	53.85	38.37
	S_2	18.07	7.56	[illegible]	104.05	49.57	36.71
ecv	S_1	12.83	4.22	4.32	79.10	38.23	24.40
	S_2	10.71	2.96	3.62	75.82	34.98	21.47
Heritability	S_1	0.68	[illegible]	[illegible]	0.44	0.50	0.60
	S_2	0.65	[illegible]	[illegible]	0.47	0.50	0.66
Genetic advance	S_1	28.97	7.22	[illegible]	0.34	13.62	362.32
	S_2	21.49	3.34	[illegible]	0.37	12.50	391.63
Genetic advance (% of mean)	S_1	31.52	[illegible]	[illegible]	[illegible]	55.03	47.09
	S_2	24.14	11.13	[illegible]	[illegible]	51.25	49.76

S_1 - September 1986-January 1987 S_2 - September 1987-January 1988

Locules/fruit exhibited a narrow range (2.00 to 6.40). The genotypes which recorded the lowest and highest number of locules remained consistent in both the seasons. Heinz 1350 recorded the highest number of locules (S_1 = 6.20 and S_2 = 6.40). Veemore and AC 238 (S_1 = 5.60 and S_2 = 5.40), Kt 3 (S_1 = 5.00 and S_2 = 4.60), HW 208 F (S_1 = 4.80 and S_2 = 5.00) and Fresh Market 9 (S_1 = 5.00 and S_2 = 4.80) also had more number of locules.

Fruit pericarp thickness ranged from 2.70 mm to 7.46 mm and 2.84 mm to 7.58 mm in the first and second seasons respectively. Sweet 72 (2.70 mm) and AC 238 (2.84 mm) were the thin fleshed genotypes in the first and second seasons. The flesh thickness of Pusa Ruby (S_1 = 3.14 mm and S_2 = 3.02 mm) and Marutham (S_1 = 3.38 mm and S_2 = 3.28 mm) were also low. Most fleshy types in both seasons were Ohio 832 (S_1 = 7.46 mm and S_2 = 7.58 mm) closely followed by San Marzano (S_1 = 7.16 mm and S_2 = 7.19 mm), Veepro (S_1 = 7.16 mm and S_2 = 7.07 mm), EC 129355 (S_1 = 7.06 mm and S_2 = 6.86 mm) and E 6203 (S_1 = 7.00 mm and S_2 = 6.89 mm).

Among 66 tomato genotypes, 30 did not crack at all. Among the cracked types, the intensity of fruit cracking varied and the cracking percentage ranged from 0.60 to 57.28. Sioux recorded the maximum cracking (%) during both the seasons (S_1 = 54.29 and S_2 = 57.28). Fairly high cracking (%) was observed in EC 50366-1-1 (S_1 = 37.87 and S_2 = 30.39), AC 2301 (S_1 = 23.72 and S_2 = 27.40) and S 12 (S_1 = 22.89 and S_2 = 25.62). Sakthi recorded on an average 27.32% cracking and LE 214 8.70% cracking. LE 206 did not crack.

The storage life measured in terms of 80% spoilage ranged from 4.60 to 34.00 days. During first season, highly perishable fruits were from LE 214 (4.60 days) closely followed by DMM (4.80 days) whereas during second season, DMM (8.00 days) had the lowest storage life. H 722 (33.20 days) and St 87 (34.00 days) were the least perishable during the first and second seasons respectively.

Among the fruit characteristics, maximum variability was observed for fruit cracking (Table 8). The pcv observed was 82.20 and 85.00 and gcv 63.22 and 66.97 in first and second seasons respectively. Though heritability was only moderate (S_1 = 0.59 and S_2 = 0.62), the genetic advance as (%) of mean was the highest (S_1 - 100.17 and S_2 - 108.68). Average fruit weight also recorded high variability (gcv - S_1 = 45.84 and S_2 - 47.00; pcv - S_1 - 58.94 and S_2 = 58.98). Heritability was the highest for fruit shape index (0.95) during first season and storage life (0.94) during second season.

c. Fruit juice characteristics

Juice yield (%) averaged 78.80 and 79.53 during first and second seasons respectively. St 64 (87.20%) and HW 208 F (85.20%) recorded maximum juice yield during first and second seasons respectively. EC 167162/F[illegible]-1 had only a low juice content (S_1 = 66.40% and S_2 - [illegible]) during both seasons. TH 318 recorded the highest juice yield/ha in both seasons (S_1 - 28.16 t/ha and S_2 - 30.60 t/ha).

Total soluble solids ranged from 3.76% to 6.80% with an overall mean of [illegible]. Veeroma recorded the highest TSS (S_1 = 6.60% and S_2 - 6.80%) during both seasons. Pant T_2 (S_1 - 6.00% and S_2 = 6.30%), Punjab Chhuhara (S_1 and S_2 - 6.20%) and Labonitha (S_1 = 6.10% and S_2 - 6.20%) also had high TSS. GNL 8210 had the lowest TSS (3.90%) the first season. Pusa Ruby recorded the lowest TSS (3.76%) in t second season.

Total solids averaged 6.15% with a range of 4.49% to 8.03% and 4.73% to 8.30% in the first and second seasons respectively. HW 208 F recorded the maximum total solids (S_1 = 8.03% and S_2 = 8.30%) followed by Ohio 8129 (S_1 - 7.76% and S_2 = 7.87%) and Veeroma (S_1 = 7.69% and S_2 - 7.79%). The lowest total solids was in Punjab Kesari (S_1 = 4.49% and S_2 = 4.73%).

[illegible]. Range, mean, genotypic (gcv), phenotypic (pcv) and environmental (ecv) coefficients of variation, heritability (h^2), genetic advance and genetic advance as per cent of mean for fruit characteristics in tomato

		Average fruit weight (g)	Fruit shape [illegible]	Locule [illegible]	Pericarp thickness (mm)	Fruit cracking (%)	Storage life (days)
[illegible]	S_1	12.17-1[illegible].22	[illegible]	[illegible]	2.7[illegible] - 7.46	0.00 - 34.29 ** (1.00 - 7.15)	4.60 - 3[illegible]
	S_2	12.60-1[illegible]	[illegible]	[illegible]	2.84 - 7.58	0.00 - 57.28 ** (1.00 - 7.32)	8.00 - 3[illegible]
[illegible]	S_1	38.2[illegible] ± [illegible]	[illegible]	[illegible]	[illegible].22 ± 0.30	2.10 ± 0.49	18.71 ± [illegible]
	S_2	3[illegible].93 ± [illegible]	[illegible]	[illegible]	[illegible] ± 0.2[illegible]	2.15 ± 0.50	19.18 ± 0.7[illegible]
[illegible]	S_1	[illegible]	[illegible]	[illegible]	2[illegible].0[illegible]	63.22	37.3[illegible]
	S_2	[illegible]	[illegible]	[illegible]	2[illegible].9[illegible]	66.97	34.08
[illegible]	S_1	53.94	[illegible]	[illegible]	23.75	82.20	40.08
	S_2	53.93	[illegible]	[illegible]	22.71	85.00	35.18
[illegible]	S_1	36.55	[illegible]	[illegible]	12.80	76.21	14.08
	S_2	35.6[illegible]	12.85	[illegible]	8.73	76.74	8.74
[illegible]	S_1	0.61	0.95	0.72	0.71	0.59	0.88
	S_2	0.64	0.73	0.71	0.85	0.62	0.94
[illegible]	S_1	28.09	0.52	0.48	1.81	2.11	13.54
[illegible]	S_2	30.03	0.41	0.47	2.10	2.34	13.04
[illegible]	S_1	73.[illegible]	47.67	26.98	34.70	100.17	72.38
[illegible]	S_2	77.[illegible]	36.98	26.64	39.87	108.68	68.00

- September 1986-January 1987
- September 1987-January 1988

* Parenthesis indicate $\sqrt{x}$ transformed values

** Parenthesis indicate $\sqrt{x+1}$ transformed values

The insoluble solids ranged from 0.38% to 1.28%. H 208 (S_1 = 1.21% and S_2 = 1.28%) contained maximum insoluble solids. Ohio 832 (S_1 = 1.18% and S_2 = 1.15%), Ohio 8129 (S_1 = 1.16% and S_2 = 1.13%), H 2653 (S_1 = 1.15% and S_2 = 1.10%), H 722 (S_1 = 1.14% and S_2 = 1.07%) and St 64 (S_1 = 1.06% and S_2 = 1.20%) also had high insoluble solids. Punjab Kesari (0.39%) and EC 129968 (0.38%) recorded the lowest insoluble solids in the first and second seasons respectively.

Total solids:insoluble solids ratio averaged 9.40 with a range of 6.06 to 16.16. During the first season, H 722 had the lowest ratio (6.06) closely followed by Kt 4 (6.14) whereas during the second season the trend was reversed (Kt 4 - 6.21 and H 722 - 6.39). EC 50366-1-1 (16.16) and LE 206 (13.64) recorded the highest values in the first and second seasons respectively.

Reducing sugar content averaged 3.21% with a range of 2.28% to 4.55%. The sweetest genotypes as indicated by high reducing sugar content were Lalmitha (4.47%) and EC 128965 (4.55%) during first and second seasons respectively. HHR 674 (S_1 = 4.1% and S_2 = 4.28%), AC 238 (S_1 = 4.12% and S_2 = 4.03%) and AC 142 (S_1 = 3.97% and S_2 = 4.08%) also had high content of reducing sugar. Processor 40 recorded the lowest reducing sugar in both the seasons (S_1 = 2.35% and S_2 = 2.28%).

The range in acidity was from 0.28% to 0.74%. Pusa Early Dwarf emerged as the highly acidic genotype (S_1 = 0.74% and S_2 = 0.73%) irrespective of the seasons. Veeking (S_1 = 0.28% and S_2 = 0.35%), Ohio 832 (S_1 = 0.29% and S_2 = 0.34%), St 87 (S_1 = 0.30% and S_2 = 0.35%) and UC 28 (S_1 = 0.30% and S_2 = 0.34%) had comparatively low acidity.

The pH of the fruit had a narrow range (3.84 to 4.82). UC 28 (4.82) and ONt 8210 (4.80) recorded the highest pH during first and second seasons respectively. The lowest pH values were recorded by LE 206 (3.84) during first season and Kt 3 (3.94) during second season. Excepting a few (UC 28 - S_1 = 4.82 and S_2 = 4.52; ONt 8210 - S_1 = 4.[illegible] S_2 = 4.80; TH 318 - S_2 = 4.60; H 7038 - S_2 = 4.60; ONt [illegible] S_1 = 4.58; Processor 40 - S_1 = 4.56 and H 722 - S_1 = 4.[illegible] genotypes had pH values within the limit prescribed (4.5).

Sugar acid ratio ranged from 3.55 to 11.76 with a general mean 7.21. The highest sugar acid ratio was in ONt 8210 (10.99) during I season and EC 128965 (11.76) during second season. Pusa Ruby recorded the lowest sugar acid ratio (S_1 = 3.55 and S_2 = 3.72) closely followed by Punjab Kesari (S_1 = 4.41 and S_2 = 4.75).

Pulp content ranged from 14.31% to 34.84% and 15.57% to 33.66% during the first and second season respectively. In both seasons, the highly pulpy genotypes were HW 208 F (S_1 = 34.84% and S_2 = 33.66%), H 722 (S_1 = 33.[illegible] and S_2 = 32.40%) and St 87 (S_1 = 33.42% and S_2 = 32.14%). Similarly the less pulpy genotypes included EC 129599/P_1 (14.31%), Sweet 72 (14.63%), IE 214 (15.57%) and AC 142 (16.03%).

Pulp with high consistency was obtained from HW 208 F (S_1 = 0.3[illegible] and S_2 = 0.36) and St 87 (S_1 = 0.34 and S_2 = 0.32). EC 129599/P_1 (S_1 = 0.14 and S_2 = 0.16), Sweet 72 (S_1 = 0.14 and S_2 = 0.17), IE 214 (S_1 = 0.17 and S_2 = 0.16) and AC 142 (S_1 = 0.16 and S_2 = 0.19) had less consistency.

Lycopene content ranged from 2.31 mg to 6.62 mg/100 g. Ohio 8129 (6.36 mg/100 g) and I 6203 (6.62 mg/100 g) had the maximum lycopene in the first and second seasons respectively. The lowest lycopene content was observed in EC 50366-1-1 (2.31 mg/100 g) in the first season and Sakthi (2.34 mg/100 g) in the second season. Other high lycopene lines were St 64 (S_1 = 6.20 mg/100 g and S_2 = 6.35 mg/100 g and HW 208 F (S_1 = 5.50 mg/100 g and S_2 = 5.76 mg/100 g) whereas Pusa Ruby (S_1 = 2.80 mg/100 g and S_2 = 2.63 mg/100 g), ONt 8210 (S_1 = 2.56 mg/100 g and S_2 = 3.48 mg/100 g) and Marutham (S_1 = 2.68 mg/100 g and S_2 = 2.67 mg/100 g) were low lycopene lines.

Table 5. Range, mean, genotypic (gcv), phenotypic (pcv) and environmental (ecv) coefficients of variation, heritability (h^2), genetic advance and genetic advance as per cent of mean for fruit juice characteristics in tomato

		Juice yield (%)	TSS (%)	Total solids (%)	Insoluble solids (%)	Total solids insoluble solids ratio	Reducing sugar (%)	Acidity (%)	pH
Range	S_1	66.40-87.20	3.90-6.60	[illegible]	[illegible]	[illegible]	2.35 - 4.47	0.28 - 0.74	3.84 - 4.82
	S_2	69.60-85.20	3.70-6.30	[illegible]	[illegible]	[illegible]	2.28 - 4.35	0.34 - 0.73	3.94 - 4.80
Mean ± SE	S_1	78.80 ± 1.32	4.92 ± 0.22	6.11 ± 0.21	[illegible]	[illegible]	3.19 ± 0.22	0.45 ± 0.04	[illegible].23 ± 0.05
	S_2	79.33 ± 1.47	4.91 ± 0.20	6.19 ± 0.22	[illegible]	4.2[illegible] ± 0.59	3.22 ± 0.21	0.48 ± 0.04	[illegible].24 ± 0.07
gcv	S_1	5.18	11.23	12.18	32.2[illegible]	24.05	14.26	22.44	3.31
	S_2	4.23	11.32	12.03	29.67	21.49	14.90	21.84	4.50
pcv	S_1	7.34	14.94	13.80	33.4[illegible]	27.20	18.68	27.88	3.97
	S_2	5.90	14.52	13.48	30.72	24.18	18.84	26.71	5.67
ecv	S_1	5.20	9.79	6.43	9.76	12.71	12.03	17.07	2.80
	S_2	4.12	9.23	6.57	7.66	11.07	11.52	16.09	3.48
Heritability	S_1	0.50	0.57	0.78	0.93	0.78	0.58	0.65	0.79
	S_2	0.51	0.61	0.80	0.93	0.79	0.63	0.67	0.63
Genetic advance	S_1	5.94	0.86	1.35	0.44	4.19	0.72	0.17	0.41
	S_2	4.96	0.90	1.37	0.42	3.63	0.78	0.18	0.31
Genetic advance (% of mean)	S_1	7.53	17.56	22.15	64.30	43.71	22.43	37.21	9.73
	S_2	6.24	18.30	22.13	59.55	39.35	24.29	36.77	7.37

S_1 - September 1986-January 1987

S_2 - September 1987-January 1988

Table [illegible] (contd.)

		Sugar acid ratio	Pulp content (%)	Consistency (PPT)	Lycopene (mg/100 g)	β carotene (µg/100 g)	Ascorbic acid (mg/100 g)
Range	S_1	3.55-10.99	14.31-34.34	0.14 - 0.35	2.31 - 6.36	204.03 - 580.37	10.65 - 45.50
	S_2	3.72-11.76	15.57-33.00	0.16 - 0.34	2.34 - 6.62	218.10 - 569.47	10.60 - 38.36
Mean ± SE	S_1	7.36 ± 0.30	[illegible]	0.24 ± 0.018	3.94 ± 0.34	387.56 ± 21.24	24.63 ± 2.07
	S_2	7.06 ± 0.34	[illegible]	0.24 ± 0.007	4.01 ± 0.22	387.56 ± 25.35	24.16 ± 1.02
GCV	S_1	17.13	[illegible]	21.32	23.15	21.74	21.62
	S_2	13.30	19.36	19.75	24.86	20.29	22.17
PCV	S_1	25.44	[illegible]	24.84	27.51	23.73	27.74
	S_2	27.64	[illegible]	20.41	26.58	23.24	23.33
ECV	S_1	13.31	12.51	13.25	14.86	9.49	17.38
	S_2	20.72	[illegible]	—	9.40	11.33	7.29
Heritability	S_1	[illegible]	[illegible]	0.74	0.71	0.84	0.61
	S_2	0.44	[illegible]	[illegible]	0.88	0.76	0.90
Genetic advance	S_1	[illegible]	[illegible]	[illegible]	1.58	159.09	8.55
	S_2	[illegible]	[illegible]	[illegible]	1.92	141.43	10.48
Genetic advance (% of mean)	S_1	23.77	[illegible]	37.69	40.14	41.25	34.71
	S_2	25.06	[illegible]	39.37	47.90	36.49	43.38

S_1 - September 1986-January 1987

S_2 - September 1987-January 1988

β carotene averaged 387.56 µg/100 g with the highest content in AC 2301 (580.37 µg/100 g) and S 12 (569.47 µg/100 g) in the first and second seasons respectively. In the first season, St 87 recorded the lowest β carotene content (204.04 ug/100 g) whereas in the second season EC 54645 (218.10 µg/100 g) had the lowest content.

Among 64 genotypes evaluated, LE 214 was the richest source of ascorbic acid with a mean content of 40.93 mg/100 g. This was closely followed by Money Maker (S_1 = 35.19 mg/100 g and S_2 = 32.82 mg/100 g) and DMM (S_1 = 31.16 mg/100 g and S_2 = 32.31/100 g). Ohio 832 (S_1 = 11.49 mg/100 g and S_2 = 12.20 mg/100 g) and ONt 828 (S_1 = 12.47 mg/100 g and S_2 = 14.31 mg/100 g had low contents of ascorbic acid.

Among the fruit juice characteristics, insoluble solids showed the highest gcv (S_1 = [illegible] and S_2 = 30.72) and pcv (S_1 = 32.29 and S_2 = 29.67) followed by lycopene (pcv - S_1 = 27.51 and S_2 = 26.54; gcv S_1 = [illegible] and S_2 = 24.86). High heritability (0.93) coupled with high genetic advance as (%) of mean (S_1 = 64.30 and S_2 = 59.05) was also observed for insoluble solids. Sugar acid ratio had the lowest heritability (S_1 = 0.45 and S_2 = 0.46) (Table 9).

2. Somatic analyses for fruit shape index and quality parameters

The maximum correlation at genotypic and phenotypic level was observed between consistency and fruit shape index (rg = 0.64, rp = 0.56). Positive correlations also existed with pericarp thickness (rg = 0.62), insoluble solids (rg = 0.50), lycopene (rg = 0.35), total solids (rg = 0.33), pH (rg = 0.26) and TSS (rg = 0.09). A strong negative correlation was observed between fruit shape index and locules/fruit (rg = -0.53). Reducing sugar, juice yield and acidity also showed a negative correlation (Table 10).

Insoluble solids showed maximum positive direct effect (0.77) on fruit shape index followed by pericarp thickness (0.35) (Table 11). Acidity,

Table 10. Genotypic (rg) and phenotypic (rp) correlation between fruit shape index and fruit quality parameters in tomato

Quality parameters	Fruit shape index	
	Genotypic correlation (rg)	Phenotypic correlation (rp)
Consistency	0.64	0.56**
Pericarp thickness	0.62	0.53**
Insoluble solids	0.50	0.46**
Lycopene	0.35	0.31*
Total solids	0.33	0.30*
pH	0.26	0.23
TSS	0.09	0.05
Reducing sugar	-0.16	-0.07
Juice [illegible]	0.22	-0.16
Acidity	-0.34	-0.29*
Locules/fruit	-0.53	-0.42**

* and ** Significant at P ≤ 0.05 and P ≤ 0.01 respectively

Table 11. Direct and indirect genotypic effect of eleven quality parameters on fruit shape index in tomato

Quality parameters	rg	Direct effect	Indirect effect via: Insoluble solids	Pericarp thickness	Acidity	Consistency	TSS	pH	Juice yield	Lycopene	Reducing sugar	Locule number	Total solids
Insoluble solids	0.50	0.77	—	0.2[illegible]	-0.2[illegible]	0.34	0.001	-0.04	-0.03	-0.15	0.03	0.08	-0.52
Pericarp thickness	0.62	0.55	0.38	—	-0.3[illegible]	0.28	-0.09	-0.02	0.02	-0.11	0.06	0.09	-0.19
Acidity	-0.34	0.44	-0.38	-0.41	—	-0.24	0.19	0.03	-0.01	0.10	-0.13	-0.03	0.10
Consistency	0.64	0.43	0.62	0.35	-0.25	—	-0.03	-0.04	-0.01	-0.16	0.05	0.12	-0.43
TSS	0.09	0.36	0.003	-0.14	0.24	-0.03	—	0.03	-0.01	0.01	-0.13	0.07	-0.30
PH	0.26	-0.07	0.41	0.13	-0.21	0.27	-0.14	—	0.001	-0.09	0.05	0.07	-0.22
Juice yield	-0.22	-0.13	0.13	-0.09	0.05	0.04	0.04	0.001	—	-0.09	-0.006	0.01	-0.21
Lycopene	0.35	-0.24	0.59	0.26	-0.19	0.29	-0.01	-0.03	-0.05	—	0.04	0.10	-0.42
Reducing sugar	-0.10	-0.26	-0.08	-0.13	0.22	-0.08	0.18	0.01	-0.003	-0.04	—	0.09	-0.08
Locule number	-0.53	-0.33	-0.13	-0.15	0.04	-0.15	-0.07	0.01	0.003	0.07	0.07	—	0.16
Total solids	0.33	-0.65	0.62	0.16	-0.07	0.28	0.16	-0.02	-0.04	-0.15	-0.03	0.08	—

Fig.1 Selection index based on multiple charac

Characters		Genotypes	
1.	pH	A	Veeroma
2.	TSS (%)	B	HW 208 F
3.	Shape index	C	Ohio 8129
4.	Pericarp thickness (mm)	D	St 64
5.	Juice yield (%)	E	Ohio 832
6.	Total solids (%)	F	Marutham
7.	Acidity (%)		
8.	Consistency (PPT)		
9.	Lycopene (mg/100 g)		
10.	Reducing sugar (%)		
11.	Insoluble solids (%)		
12.	Yield/plant		

Dotted length indicate the index value

Table 12. Ranking of tomato genotypes based on index values

Rank	Genotypes	Index value	Rank	Genotypes	Index value
1	Veeroma	12.11	33	EC 101652	-1.14
2	HW 208 F	11.44	34	EC 129599	-1.22
3	Ohio 8129	10.26	35	San Marzano	-1.33
4	St 64	9.86	36	UC 82	-1.42
5	Ohio 832	9.32	37	Veemore	-1.67
6	Ohio 7814	7.77	38	Kt 3	-1.68
7	St 87	7.44	39	ONt 8210	-2.00
8	Pant T_2	6.79	40	AC 2301	-2.18
9	ONt 828	6.47	41	LE 206	-2.33
10	H 722	5.84	42	Sakthi	-2.34
11	TH 318	5.76	43	Pusa Early Dwarf	-2.62
12	H 7033	5.44	44	Fresh Market 9	-2.66
13	H 2653	5.21	45	EC 54645	-2.73
14	E 6203	4.77	46	AC 142	-3.09
15	St 61	4.17	47	Kt 4	-3.72
16	FM 6203	3.98	48	EC 50366-1-1	-3.88
17	Punjab Chhuhara	3.[illegible]1	49	LE 28	-3.98
18	EC 12933[illegible]	3.[illegible]	50	HS 102	-4.39
19	Roma	2.79	51	Sioux	-4.43
20	Labonitha	2.64	52	EC 104162/P_2-1	-4.63
21	Veepro	2.61	53	AC 238	-4.66
22	DMM	1.36	54	EC 129599/P_1	-4.99
23	Veepick	1.26	55	Processor 40	-5.36
24	Sel 11	0.47	56	LE 214	-5.55
25	EC 128965	0.42	57	Heinz 1350	-5.90
26	S 12	0.33	58	Sweet 72	-5.99
27	Rubyvee	0.14	59	Money Maker	-6.18
28	IHR 674	0.01	60	Veeking	-6.22
29	Kt 2	-0.33	61	Kt 1	-6.83
30	EC 129968	-0.94	62	Punjab Kesari	-8.09
31	Fire Ball	-1.00	63	Pusa Ruby	-9.61
32	HS 101	-1.09	64	Marutham	-9.70
	CD (P = 0.05)	2.67		CD (P = 0.01)	3.51

Table 13. Analyses of variance for selection index

Sources of variation	df	Mean squares
Genotypes	63	81.97**
Error	128	2.78

** Significant at P = 0.01

Table 14. Analyses of variance for ketchup yield and its chemical composition

Sources of variation	df	Ketchup* recovery (%)	Ketchup* yield ($t\ ha^{-1}$)	Consistency (PPT)	Lycopene (mg/100 g)	Total acidity (%)	Reducing sugar (%)	pH	β carotene (μg/100 g)	Ascorbic acid (mg/100 g)
		Mean squares								
Genotypes	42	30.84**	15.36**	0.014**	27.67**	0.29**	7.20**	0.14**	100611.23**	388.55**
Error	86	0.27	0.009	0.001	0.13	0.01	0.24	0.01	2255.44	3.91

** Significant at P = 0.01

* df for genotypes and error 41 and 84 respectively

Table 15. Ketchup yield and economic factors

Genotypes	Ketchup recovery (%)	Ketchup yield (t ha^{-1})	Ketchup/juice ratio	Water evaporated t/t of ketchup	Energy cost/ t ketchup (Rs)
Ohio 832	38.29	5.13	0.38	1.61	644
Ohio 7814	36.12	7.74	0.36	1.76	704
Ohio 8129	36.93	6.76	0.37	1.71	684
St 61	36.58	8.70	0.37	1.73	692
St 64	36.30	7.71	0.36	1.76	704
St 87	36.50	8.63	0.37	1.74	696
ONt 823	34.92	7.40	0.35	1.86	744
ONt 8210	33.20	3.51	0.33	2.01	804
H 722	37.36	5.04	0.37	1.68	672
H 2653	35.42	3.17	0.35	1.83	732
H 7018	34.96	10.36	0.35	1.86	744
FM 6203	35.52	4.52	0.36	1.82	728
HW 208 F	39.13	10.95	0.39	1.56	624
TH 318	35.17	10.79	0.35	1.84	736
Veepack	33.75	1.81	0.35	1.96	784
Veepro	31.17	5.62	0.31	2.21	884
Veeking	27.88	4.21	0.28	2.59	1036
Veemore	34.08	5.87	0.34	1.93	772
Veeroma	35.04	7.55	0.35	1.85	740
Rubyvee	34.83	5.42	0.35	1.87	748
UC 28	33.17	[illegible]	0.33	2.01	804
UC 82	33.02	[illegible]	0.33	2.02	808
E 6203	34.92	6.51	0.35	1.86	744
Processor 40	33.14	6.06	0.33	2.01	804
Roma	34.76	4.32	0.35	1.88	752
San Marzano	35.17	4.42	0.35	1.84	736
Punjab Chhuhara	32.83	4.33	0.33	2.05	820
Labonitha	32.75	3.65	0.33	2.05	820
IHR 674	32.16	5.10	0.32	2.11	844
Pant F_2	36.25	4.95	0.36	1.92	768
Fresh Market 9	32.00	9.18	0.32	2.13	832
DMM	32.16	5.65	0.32	2.09	836
Kt 4	31.25	6.64	0.33	2.01	804
HS 101	30.33	5.22	0.30	2.30	920
AC 142	30.25	5.63	0.31	2.25	900
Punjab Kesari	26.92	2.37	0.27	2.71	1084
Pusa Early Dwarf	27.17	2.53	0.27	2.68	1072
Money Maker	29.49	3.16	0.29	2.39	956
Pusa Ruby	28.45	2.60	0.28	2.52	1008
LE 206	27.59	5.26	0.28	2.62	1048
LE 214	26.58	4.05	0.27	2.76	1104
Sakthi	29.55	7.95	0.30	2.38	952
CD (P = 0.05)	0.84	0.15			
CD (P = 0.01)	1.12	0.20			

The β carotene content was exceptionally high in Maggi ketchup (1496.82 µg/100 g). Veepro (1253.20 µg/100 g) and Veeking (1225.58 µg/100 g) also had high content of β carotene. Pant T_2 recorded the lowest content (508.83 µg/100 g) closely followed by St 87 (515.45 µg/100 g). In contrast to the content of β carotene, the ascorbic acid content in the Maggi ketchup was the lowest (18.05 mg/100 g), St 61 (21.33 mg/100 g), Ohio 832 (24.55 mg/100 g) and Pusa Ruby (25.98 mg/100 g) also had low content. LE 214 was exceptionally high in ascorbic acid content (77.96 mg/100 g) (Table 16).

b. Sensory evaluation

The genotypes differed significantly for the factors considered for sensory [illegible] consistency, colour, flavour and absence to defects. The differences [illegible] significant for the total scores also (Table 17).

[illegible] was maximum for HW 208 F (23.40). Maggi [illegible] comparatively high for consistency (22.00). [illegible] (16.60). Ohio 8129 scored the maximum for colour [illegible], followed by St 64 (23.60). HW 208 F (22.20). LM [illegible] (22.20) also had a high score for colour. The lowest [illegible] was recorded in Money Maker (12.20). Flavour score ranged from 11.60 (LE 214) to 22.40 (H 722). Veeroma (21.80) and Ohio 832 (21.60) also had high scores for flavour. The score for absence of defects had the lowest range (15.60 to 22.60). Maggi ketchup recorded the maximum score (22.60) while KT 4 had the lowest score (15.60).

Based on sum total of these scores, HW 208 F (85.00) was the most ideal for making ketchup, closely followed by Ohio 8129 (85.40), St 64 (85.20) and Ohio 832 (84.20). Maggi ketchup recorded a score of 85.00. These genotypes (85 and above did not differ significantly and were grouped under Grade I. Ohio 832, H 722, Veeroma, Ohio 7814, Veepro, St 87, Rubyvee, F 6203, ONI 828, H 7038, LM 6203, Roma, H 2653 and St 61 which scored 75 and above were grouped as Grade II (Table 18).

Plate III Right Uniform ripening fruits

Left Non uniform ripening fruits with green shoulder

Plate IV Bottled tomato ketchup

consistency and TSS also showed positive direct effect on fruit shape index (0.44, 0.43 and 0.36 respectively). In case of total solids and lycopene, the direct effect was negative (-0.65 and -0.24 respectively) but the correlation was positive. Insoluble solids and consistency influenced indirectly the positive correlation between total solids (0.33) and lycopene (0.35) with fruit shape index. The indirect effects of insoluble solids and consistency on total solids were 0.62 and 0.28 respectively and on lycopene were 0.59 and 0.29 respectively.

Direct effect of acidity on fruit shape index was positive (0.44) but the correlation was negative (-0.34). Negative direct effect on fruit shape index was observed for total solids (-0.65), locules/fruit (-0.33), reducing sugars (-0.26), lycopene (-0.24) and pH (-0.07).

3. Identification of processing type(s) based on selection index

The 64 tomato genotypes were ranked based on selection indices calculated from multiple characters (Table 12). Analyses of variance indicated significant differences among the genotypes (Table 13). Veeroma (12.61), HW 208-1 (11.44), Ohio 8129 (10.26), St 64 (9.86) and Ohio 832 (9.32) did not differ significantly for the index values. Marutham was ranked as the least ideal genotype (-9.70) for processing closely followed by Pusa Ruby (-9.61). The genotypes LE 206, Sakthi and LE 214 were ranked 41st (-2.33), 42nd (-2.34) and 56th (-5.55) respectively.

B. Identification of tomatoes for ketchup and paste

1. Ketchup

a. Ketchup yield and its chemical composition

The tomato genotypes differed significantly for ketchup recovery, ketchup yield/ha, consistency, lycopene, acidity, reducing sugar, pH, β carotene and ascorbic acid (Table 14).

Table 16. Chemical composition of tomato ketchup

Genotypes	Consistency (PPT)	Lycopene (mg/100 g)	Total acidity (%)	Reducing sugar (%)	pH	β carotene (μg/100 g)	Ascorbic acid (mg/100 g)
Ohio 832	0.52	14.38	1.74	17.17	3.92	660.28	24.58
Ohio 7814	0.48	12.52	1.83	18.14	3.97	812.64	41.67
Ohio 8129	0.50	17.50	1.86	18.11	3.90	660.27	36.02
St 61	0.46	11.44	2.21	16.56	3.80	1062.10	21.11
St 64	0.48	16.62	1.97	17.57	3.93	850.36	40.82
St 87	0.49	14.24	1.88	14.88	3.82	515.45	42.65
ONt 828	0.43	13.26	2.18	16.94	3.88	942.00	27.93
ONt 8210	0.43	7.49	2.09	18.37	4.13	642.20	32.00
H 722	0.51	10.97	1.82	19.19	3.82	900.32	38.90
H 2653	[illegible]	[illegible]	2.15	16.75	3.73	952.03	25.08
H 7038	[illegible]	[illegible]	2.19	17.80	3.97	858.95	39.05
FM 6203	[illegible]	[illegible]	[illegible]	16.74	3.85	810.31	32.98
HW 208 F	[illegible]	[illegible]	1.86	17.24	3.92	690.16	41.72
TH 318	[illegible]	[illegible]	2.28	17.38	4.05	530.34	29.21
Veepick	[illegible]	[illegible]	[illegible]	[illegible]	3.47	750.73	33.38
Veepro	[illegible]	[illegible]	[illegible]	[illegible]	3.58	[illegible]	[illegible]
Veeking	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Veemore	[illegible]	[illegible]	[illegible]	17.26	[illegible]	[illegible]	[illegible]
Veerama	[illegible]	[illegible]	[illegible]	[illegible]	3.27	[illegible]	[illegible]
Rubyvee	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
JC 28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
JC 82	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3 6203	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Processor 95	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Roma	[illegible]	[illegible]	[illegible]	17.85	[illegible]	[illegible]	[illegible]
San Marzano	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Punjab Chhuhara	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Labonitha	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HR 674	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Pant T_2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fresh Market 9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
DMM (EC 108759)	[illegible]	[illegible]	2.19	[illegible]	[illegible]	[illegible]	[illegible]
St 4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	50.09
HS 101	[illegible]	[illegible]	[illegible]	19.66	[illegible]	858.83	38.38
AC 142	[illegible]	[illegible]	[illegible]	19.66	3.40	[illegible]	[illegible]
Punjab Kesari	0.26	[illegible]	2.42	[illegible]	3.80	875.42	[illegible]
Pusa Early Dwarf	0.29	8.86	3.17	19.61	3.50	758.55	30.08
Money Maker	[illegible]	[illegible]	2.24	16.78	3.90	[illegible]	[illegible]
Pusa Ruby	0.37	[illegible]	2.50	16.82	3.85	802.00	23.98
IE 206	0.31	12.71	[illegible]	17.48	[illegible]	921.96	[illegible]
IE 214	0.27	10.87	2.21	17.66	3.31	830.48	27.90
Sakthi	0.37	5.98	2.48	19.31	3.65	858.75	33.29
Maggi ketchup	0.38	4.94	1.70	11.91	3.93	1496.82	18.05
CD (P = 0.05)	0.04	0.57	0.17	0.80	0.12	77.05	3.21
CD (P = 0.01)	0.06	0.76	0.23	1.06	0.15	102.18	4.23

MAS - Months after storage

Table 17. Analyses of variance for sensory scores of tomato ketchup

Sources of variation	df	Mean squares				
		Consistency	Colour	Flavour	Absence of defects	Overall scores
Genotypes	42	48.21**	48.53**	45.48**	7.10**	421.27**
Error	172	0.84	0.98	1.34	0.75	4.42

** Significant at P = 0.01

Table 18. Sensory scores for tomato ketchup

Genotypes	Consistency (25)	Colour (25)	Flavour (25)	Absence of defects (25)	Total (100)
Ohio 832	20.8	21.6	21.6	20.2	84.2
Ohio 7814	21.0	21.4	21.2	18.4	82.0
Ohio 8129	20.6	23.8	21.0	20.0	85.4
St 61	19.4	20.4	17.0	18.2	75.0
St 64	21.0	23.4	21.0	19.8	85.2
St 87	21.0	21.4	20.2	18.0	80.6
ONt 825	19.0	20.2	19.2	19.2	77.6
ONt 8210	18.4	14.4	20.4	17.2	70.4
H 722	21.0	21.8	22.4	18.4	83.6
H 2653	[illegible]	19.6	17.0	18.6	75.2
H [illegible]	[illegible]	18.8	21.2	19.2	77.4
FM 6203	[illegible]	22.2	16.8	[illegible]	77.0
HW 208 F	[illegible]	22.2	21.0	19.4	85.8
TH 318	[illegible]	18.2	19.6	16.8	74.0
Veepick	[illegible]	[illegible]	15.8	17.2	65.0
Veepro	[illegible]	[illegible]	20.6	18.8	81.2
Veeking	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Veemore	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Veeroma	[illegible]	[illegible]	21.8	[illegible]	[illegible]
Rubyvee	[illegible]	[illegible]	[illegible]	[illegible]	75.8
UC 28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
UC 82	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
E 6203	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Processor [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Roma	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
San Ma[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HIR [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Pant T2	[illegible]	17.2	[illegible]	[illegible]	[illegible]
Fresh Market 9	17.6	17.2	15.4	17.8	67.8
DMM (EC 108739)	16.2	15.0	15.2	18.2	63.6
Kt 4	18.2	13.8	14.8	15.6	62.8
HS 101	15.6	13.2	13.8	16.6	58.2
AC 142	13.0	15.0	16.6	16.4	63.0
Punjab Kesari	11.2	16.8	13.4	18.0	59.4
Pusa Early Dwarf	11.2	15.8	12.6	17.8	57.4
Money Maker	16.2	12.2	16.6	16.8	61.8
Pusa Ruby	10.8	13.4	11.4	17.2	52.8
LE 206	13.0	20.4	15.4	19.6	70.8
LE 210	10.6	12.4	11.6	16.8	51.4
[illegible]	12.4	13.6	13.6	18.6	58.2
[illegible]	22.0	19.8	20.6	22.6	85.0
CD (P = 0.05)	1.13	1.21	1.44	1.07	2.61
CD (P = 0.01)	1.49	1.61	1.89	1.41	3.42

Plate V Standards for tomato ketchup (Maggi) and paste (Hunt's)

Plate VI Tomato paste samples

1. HW 208 F 2. Ohio 8129 3. Hunt's

2. Paste

a. Paste yield and its chemical composition

The genotypes differed significantly for paste recovery and yield, consistency, lycopene, acidity, reducing sugar, pH and ascorbic acid (Table 19).

HW 208 F recorded the maximum paste recovery (24.75%) closely followed by Ohio 832 (24.35%) and Ohio 8129 (24.17%). HW 208 F also yielded the maximum paste (6.93 t/ha) followed by St 87 (5.85 t/ha) and Veeroma (5.13 t/ha). The higher paste/juice ratio (0.25) was observed for HW 208 F and St 87, which resulted in the minimum quality of water to be evaporated (3.[illegible] t/t of paste), reducing the cost for water removal (Rs.1216/t of paste). LE 214 recorded the lowest paste recovery (11.51%), paste yield ([illegible] t/ha), paste/juice ratio (0.12) resulting in the highest quantity of water to be evaporated (7.66 t/t of paste) and cost for water removal (Rs.[illegible]/t of paste) (Table 20).

Hunt's tomato paste had a distinctly high consistency (0.98) and differed significantly from other genotypes. NAFED paste (0.82) was comparable to HW 208 F (0.81) in consistency. The lowest consistency (0.40) was recorded for LE 214. The colour measured in terms of lycopene content ranged from 16.08 mg to 25.44 mg/100 g. Hunt's paste had very good red colour (25.44 mg/100 g) and this was comparable to that of Ohio 8129 (25.37 mg/100 g) and St 64 (24.79 mg/100 g).

The acidity of paste ranged from 1.32% (Ohio 832 and Ohio 8129) to 3.24% (LE 214). The reducing sugar content was the highest in LE 214 (24.91%) and the lowest in St 87 (8.42%). The pH ranged from 4.06 to 4.60. The lowest pH was observed in Labonitha and LE 206 (4.06) and the highest in Ohio 832 and Ohio 8129 (4.60). The processing tomatoes, inherently low in ascorbic acid content had a low content of ascorbic acid in the paste also. The lowest content (19.90 mg) was observed in Ohio 832 and the highest content (117.71 mg) was observed in LE 214 (Table 21).

Table 19. Analyses of variance for paste yield and its chemical composition

Sources of variation	df	Mean squares							
		Paste* recovery (%)	Paste* yield ($t\ ha^{-1}$)	Consistency (PPT)	Lycopene (mg/100 g)	Acidity (%)	Reducing sugar (%)	Ascorbic acid (mg/100 g)	pH++
Genotypes	17	[illegible]**	6.61**	[illegible]**	78.82**	1.34**	64.59**	3081.42**	0.167**
Error	36	1.22	[illegible]	[illegible]	1.13	0.005	1.33	15.84	0.003

* df for genotypes and error 15 and 32 respectively

++ df for error 72

** Significant at P < 0.01

Table 20. Paste yield and economic factors

Genotypes	Paste recovery (%)	Paste yield (t ha^{-1})	Paste/ juice ratio	Water evaporated (t/t of paste)	Energy cost/ t paste (Rs.)
Ohio 832	24.35	3.26	0.24	3.11	1244.00
Ohio 7814	21.46	4.60	0.21	3.66	1464.00
Ohio 8129	24.17	4.42	0.24	3.14	1256.00
St 64	23.40	4.97	0.23	3.28	1312.00
St 87	23.76	5.85	0.25	3.04	1216.00
H 722	20.30	2.74	0.20	3.92	1568.00
HW 208 F	24.75	6.93	0.25	3.04	1216.00
Veepro	17.02	3.23	0.18	4.59	1836.00
Veeroma	23.81	5.13	0.24	3.20	1280.00
Rubyveer	18.75	3.03	0.19	4.32	1728.00
Punjab Chhuhara	18.12	2.39	0.18	4.52	1808.00
Labonitha	18.49	2.06	0.18	4.42	1768.00
Pant T_2	19.82	2.34	0.20	4.05	1620.00
LE 206	13.68	2.61	0.14	6.30	2520.00
LE 214	11.51	1.76	0.12	7.66	3064.00
Sakthi	13.70	3.69	0.14	6.29	2516.00
CD (P = 0.05)	1.84	0.32			
CD (P = 0.01)	2.47	0.43			

Table 21 . Chemical composition of tomato paste

	Consistency (PPT)	Lycopene (mg/100 g)	Acidity (%)	Reducing sugar (%)	pH	Ascorbic (mg/100 g)
Ohio 832	0.76	19.69	1.32	10.89	4.60	19.90
Ohio 7814	0.70	14.44	1.21	14.38	4.48	37.95
Ohio 8129	0.75	25.37	1.32	10.72	4.60	28.04
St 64	0.77	24.79	1.45	10.50	4.51	32.15
St 87	0.72	18.68	1.34	8.42	4.55	33.57
H 722	0.72	14.48	1.66	16.05	4.52	32.24
HW 208 F	0.81	18.82	1.47	10.09	4.48	30.93
Veepro	0.61	16.31	1.80	15.27	4.21	37.92
Veeroma	0.63	12.66	1.62	12.31	4.37	61.40
Rubyvee	0.66	15.56	1.90	13.11	4.43	44.10
Punjab Chhuhara	0.55	16.11	2.72	18.45	4.21	73.29
Labonitha	0.58	12.40	2.61	18.20	4.06	101.34
Pant T$_2$	0.69	11.12	2.99	16.09	4.34	74.19
LE 206	0.46	17.62	2.70	19.22	4.06	86.79
LE 214	0.40	10.26	3.24	24.91	4.18	117.71
Sakthi	0.47	10.08	3.16	21.77	4.18	114.81
NAFED Paste	0.82	18.05	1.84	9.52	4.51	29.34
Hunt's Paste	0.98	25.44	1.83	10.47	4.52	29.35
CD (P = 0.05)	0.05	1.76	0.12	1.91	0.07	6.59
CD (P = 0.01)	0.06	2.36	0.16	2.56	0.09	8.84

b. Sensory evaluation

The sensory evaluation of paste in terms of colour, absence of defects and overall score showed significant differences (Table 22).

The score for colour (56.40), absence of defects (37.80) and overall score (94.20) was maximum for Hunt's paste. Ohio 8129 (56.20) and St 64 (55.20) was comparable to Hunt's paste in score for colour, which were at par. The NAFED paste recorded an overall score of 86.20. The lowest score for colour (30.40), absence of defects (22.40) and overall score (57.20) was observed for LE 214. Ohio 8129 (88.60), St 64 (87.60), HW 208 F (85.60) and St 87 (85.00) scored for Grade I paste. Ohio 832 (84.00), Ohio [illegible] (81.60), H 722 (80.80) and Veeroma (76.40) which scored above 75.00 were grouped under Grade II paste (Table 23).

C. Evaluation of tomatoes for long shelf life of ketchup

1. Changes in physico-chemical characteristics

Physical appearance of ketchup was not much affected during storage except for blackneck formation and phase separation observed in a few genotypes. No blackneck was observed initially but was observed after nine months of storage in HS 101 and Punjab Kesari. Phase separation was observed only in Veeking, Processor 40, HHR 674, Fresh Market 9, DMM, HS 101, Punjab Kesari and LE 214. Phase separation was pronounced nine months after storage but Veeking, Fresh Market 9 and LE 214 showed slight phase separation even from six months of storage.

Analyses of variance indicated significant changes in consistency, lycopene, total acidity, reducing sugar, pH, β carotene and ascorbic acid during storage. The genotypes differed significantly for the above characters. The interaction effects between genotypes and storage period were significant for β carotene and ascorbic acid (Table 24).

Table 22. Analyses of variance for sensory scores of tomato paste

Sources of variation	df	Colour	Absence of defects	Overall score
Paste from varieties	17	321.63**	68.78**	627.65**
Error	72	2.80	2.01	4.99

** Significant at P 0.01

Table 23 . Sensory scores for tomato paste

Genotypes	Score			
	Colour (60)	Absence of defects (40)	Overal score (100)	Grade
Ohio 832	52.20	31.80	84.00	II
Ohio 7814	50.40	30.60	81.00	II
Ohio 8129	56.20	32.40	88.60	I
St 64	55.20	32.40	87.60	I
St 87	53.00	32.00	85.00	I
H 722	50.00	30.80	80.80	II
HW 208 F	50.40	34.60	85.00	I
Veepro	43.40	31.40	74.80	
Veeroma	46.40	30.00	76.40	II
Rubyvee	44.80	30.00	74.80	
Punjab Chhuhara	35.40	28.00	63.40	
Labonitha	41.40	30.80	72.20	
Pant T_2	44.00	30.80	74.80	
LE 206	42.80	23.00	65.80	
LE 214	30.40	22.20	52.60	
Sakthi	30.80	26.40	57.20	
NAFED Paste	50.80	35.40	86.20	I
Hunt's Paste	56.40	37.80	94.20	I
CD (P = 0.05)	2.11	1.79	2.82	
CD (P = 0.01)	2.80	2.37	3.74	

Table 24. Analyses of variance for changes in chemical composition of tomato ketchup during storage upto 12 months

Source of variation	df	Mean squares						
		Consistency (PPT)	Lycopene (mg/100 g)	Total acidity (%)	Reducing sugar (%)	pH	β carotene (µg/100 g)	Ascorbic acid (mg/100 g)
Genotypes (G)	42	0.09**	133.06**	0.99**	36.62	0.57**	179104.78**	1017.12**
Stages (S)	4	0.03**	89.63**	3.02**	0.04	0.42**	3022331.95**	4480.27**
G x S	168	0.0004	0.17	0.02	0.006	0.03	8994.76**	25.26**
Error	430	0.001	0.12	0.02	0.24	0.03	1971.54	4.42

** Significant at P = 0.01

TSS did not change significantly with storage (Table 25). The maximum reduction in TSS was observed in Veeking and LE 214. The initial content (38.00%) was reduced to 36.00% after 12 months. Ohio 832, Ohio 7814, Ohio 8129, St 64, H 722, H 2653, HW 208 F, Veeroma, Rubyvee, E 6203, Roma and San Marzano did not exhibit changes in TSS.

Influence of storage period on consistency was not much pronounced (Table 26). Consistency was only slightly reduced (0.41 to 0.38) during storage. The change in consistency upto nine months after storage was not significant. HW 208 F (0.52), Ohio 8129 (0.50), St 64 (0.48), Ohio 7814 ([illegible]), Veeroma (0.46) and Rubyvee (0.45) were exceptional in retention of consistency throughout storage. Mean consistency value over the storage period showed that HW 208 F had the highest consistency (0.52) and LE 214 the lowest consistency (0.23).

The lycopene content showed a decreasing trend as the storage period advanced (Table 27). Lycopene content before storage (9.59 mg/100 g) was reduced to 7.45 mg/100 g in 12 months time. Ohio 8129 ([illegible] mg/100 g) and St 64 (16.62 mg/100 g) which had high lycopene content initially retained the same without marked reduction (16.40 and 15.48 mg/100 g respectively). The lowest lycopene content (4.94 mg/100 g) in Maggi ketchup was reduced to 3.03 mg/100 g during 12 months storage. The retention percentage of lycopene dropped after three months of storage to 92.72. It was further dropped to 76.12% after 12 months. The average retention (%) for genotypes ranged from 94.83% (Ohio 8129) to 74.61% in Maggi ketchup.

A progressive decrease in acid content was observed as the period of storage increased (2.18 to 1.80%). The decrease was linear and Pusa Early Dwarf which recorded the highest acidity before storage (3.17%) retained the same throughout the storage period. Similar trend was observed for Maggi ketchup which had the lowest acidity (1.70% to 1.41%). All throughout the storage period, the genotypes did not fall below 1.2% acidity (Table 28).

Table 25. Changes in TSS (%) of ketchup during storage upto 12 months*

Genotypes	3 MAS	6 MAS	9 MAS	12 MAS	Genotypes (mean)
Ohio 832	38.0	38.0	38.0	38.0	38.00
Ohio 7818	38.0	38.0	38.0	38.0	38.00
Ohio 8029	38.0	38.0	38.0	38.0	38.00
St 61	38.0	38.0	37.8	37.8	37.92
St 64	[illegible]	38.0	38.0	38.0	38.00
St 87	38.0	38.0	38.0	37.9	37.98
ONt 828	38.0	38.0	37.8	37.8	37.90
ONt 8210	[illegible]	37.8	37.6	37.6	37.80
H 722	38.0	38.0	38.0	38.0	38.00
H 2653	[illegible]	38.0	38.0	38.0	38.00
H 7038	[illegible]	37.8	37.5	37.5	[illegible]
FM 6203	[illegible]	[illegible]	38.0	37.9	37.98
HW 208 1	[illegible]	38.0	38.0	38.0	38.00
TH 318	[illegible]	[illegible]	37.5	[illegible]	37.74
Veepick	[illegible]	[illegible]	37.5	37.5	37.72
Veepro	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Veeking	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Veemore	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Veeroma	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rubyvee	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
UC 78	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
UC 82	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
E 6203	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Processor 96	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Roma	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
San Marzano	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Punjab Chhuhara	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Lalomtha	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
IHR 679	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Pant T2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fresh Market 7	[illegible]	17.1	17.2	17.1	[illegible]
DMM (EC 108799)	[illegible]	18.0	17.6	17.6	[illegible]
Kt 4	[illegible]	17.6	17.6	17.4	17.72
HS 101	17.1	17.3	17.2	17.2	17.60
AC 142	17.8	17.8	17.5	17.3	17.68
Punjab Kesari	18.0	17.7	17.6	17.6	17.78
Pusa Early Dwarf	18.0	18.0	17.7	17.7	17.88
Money Maker	17.2	17.2	17.2	17.1	17.36
Pusa Ruby	17.7	17.2	17.1	17.1	17.52
LE 206	17.5	17.2	17.1	16.0	17.16
LE 214	17.7	17.6	17.6	17.5	17.68
Sakthi	18.0	18.0	17.8	17.8	17.92
Maggi ketchup					
Stages (Mean)	17.86	17.79	17.68	17.37	

* TSS was adjusted to 38% before storage

MAS - Months after storage

Table 26. Changes in consistency (PPT) of ketchup during storage upto 12 months

Genotypes	Before storage	3 MAS	6 MAS	9 MAS	12 MAS	Genotypes (mean)
Ohio 832	0.52	0.52	0.52	0.51	0.50	0.51
Ohio 7814	0.48	0.48	0.48	0.48	0.48	0.48
Ohio 8129	0.50	0.50	0.50	0.50	0.50	0.50
St 61	0.46	0.46	0.46	0.44	0.42	0.45
St 64	0.48	0.48	0.48	0.48	0.48	0.48
St 5?	[illegible]	[illegible]	[illegible]	0.48	0.47	0.48
ONt 828	0.48	0.47	0.47	0.46	0.45	0.47
ONt 8210	[illegible]	0.43	0.42	0.40	0.38	0.41
H 722	[illegible]	0.51	0.51	0.51	0.50	0.51
H 2653	[illegible]	0.49	0.48	0.48	0.47	0.48
H 7038	[illegible]	0.43	0.41	0.39	0.37	0.41
FM 6203	[illegible]	0.47	0.47	0.47	0.46	0.47
HW 208 1?	[illegible]	0.52	0.52	0.52	0.52	0.52
TH 318	[illegible]	0.42	0.41	0.39	0.38	0.41
Veep[illegible]k	[illegible]	0.37	0.36	0.35	0.35	0.36
Veepr[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.41
Veeking	[illegible]	[illegible]	[illegible]	0.21	0.21	[illegible]
Veer[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Veer[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Ruby [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
UC 28?	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
UC 82	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
E 6203	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Roma	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
San Ma[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Punjab [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Labonith[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HIR [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Pant T[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
DMM [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Kt 4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HS 101	[illegible]	[illegible]	0.28	0.26	[illegible]	[illegible]
At 102	[illegible]	[illegible]	0.30	0.30	0.29	0.31
Punjab Kesari	0.26	0.26	[illegible]	0.22	0.22	[illegible]
Pusa Early Dwarf	0.23	0.23	0.27	0.24	0.23	0.26
Money Maker	0.35	0.35	0.33	0.31	0.29	0.33
Pusa Ruby	0.37	0.36	0.35	0.29	0.29	0.33
LE 206	0.31	0.31	0.30	0.26	0.26	0.29
LE 218	0.27	0.26	0.24	0.20	0.20	0.23
Sakthi	0.37	0.37	0.35	0.32	0.31	[illegible]
Maggi ketchup	0.38	0.38	0.37	0.36	0.35	0.37
Stages (Mean)	0.41	0.41	0.40	0.39	0.38	

	Genotypes	Stages
CD (P = 0.05)	0.02	0.01
CD (P = 0.01)	0.02	0.01

MAS - Months after storage

Table 27 . Changes in lycopene (mg/100 g) of ketchup during stages upto 12 months

Genotypes	Before storage	3 MAS	6 MAS	9 MAS	12 MAS	Genotypes (Mean)
Ohio 832	14.38 (95.62)	13.69 (95.21)	13.08 (91.00)	12.92 (89.85)	12.60 (87.63)	13.33 (90.92)
Ohio 7814	12.52 (86.44)	11.68 (93.36)	10.61 (84.80)	10.37 (82.83)	9.60 (76.73)	10.95 (84.43)
Ohio 8129	17.50 (98.80)	16.83 (96.23)	16.57 (94.69)	16.55 (94.61)	16.40 (93.79)	16.27 (94.83)
St 61	11.44 (77.62)	10.92 (95.47)	10.18 (89.05)	9.60 (83.97)	9.07 (79.32)	10.24 (86.95)
St 64	16.62 (95.01)	16.15 (97.20)	15.76 (94.82)	15.57 (93.72)	15.46 (93.03)	15.91 (94.69)
St 87	14.24 (92.33)	13.03 (91.53)	12.55 (88.15)	12.20 (85.70)	11.35 (79.73)	12.67 (86.28)
ONt 828	13.26 (91.33)	12.85 (96.89)	12.13 (91.50)	11.68 (88.12)	11.08 (83.59)	12.20 (90.02)
ONt 8210	7.49 (71.47)	6.84 (91.31)	6.42 (85.66)	6.08 (81.29)	5.77 (77.07)	6.52 (83.84)
H 722	10.97 (74.26)	10.37 (94.47)	10.02 (91.29)	9.62 (87.63)	9.15 (83.39)	10.02 (89.19)
H 2653	9.81 (69.74)	8.70 (88.71)	8.07 (82.26)	7.53 (76.82)	6.87 (70.02)	8.19 (70.45)
H 7038	8.55 (73.25)	8.51 (93.72)	7.45 (27.23)	6.73 (78.79)	6.22 (72.81)	7.39 (83.14)
FM 6201	11.65 [illegible]	10.38 (93.[illegible])	10.65 (90.65)	9.50 (86.02)	9.10 (82.35)	10.00 (88.23)
HW 208 1	13.58 (92.27)	13.12 (96.57)	12.47 (91.79)	11.90 (87.62)	11.27 (82.39)	12.47 (89.73)
TH 318	[illegible] (77.18)	10.05 [illegible]	9.53 (89.78)	9.03 (85.68)	8.58 (80.83)	9.56 (87.58)
Veepick	[illegible]	[illegible]	6.28 (82.17)	5.80 (75.85)	5.03 (65.83)	6.31 (78.19)
Veepro	[illegible]	[illegible]	[illegible]	8.53 (81.73)	7.89 (75.55)	9.12 (84.16)
Veeking	[illegible]	[illegible]	[illegible]	11.13 [illegible]	10.25 [illegible]	[illegible] (89.52)
Veemore	[illegible]	[illegible]	[illegible]	6.33 (80.61)	[illegible]	[illegible] (84.29)
Veeroma	[illegible]	[illegible]	[illegible]	[illegible]	7.42 [illegible]	[illegible] (87.63)
Rubyvee	[illegible]	[illegible]	[illegible]	7.17 (82.61)	[illegible]	[illegible] (85.04)
JC 28	[illegible]	[illegible]	[illegible]	5.55 (82.67)	[illegible]	[illegible] (86.87)
HC 82	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] (81.20)
E 6203	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Processor [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Roma	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
San Marzano	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Punjab [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Labonnita	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HIR 676	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Pant T_3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fresh Market [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
DMM (Ec [illegible])	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] (78.59)
Kt 4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HS 101	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
AC 142	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Punjab Kesari	[illegible]	[illegible]	6.11 [illegible]	[illegible]	[illegible]	[illegible]
Pusa Early Dwarf	[illegible]	[illegible]	[illegible]	6.51 [illegible]	[illegible]	[illegible]
Money Maker	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Pusa Ruby	[illegible]	6.12 [illegible]	[illegible]	4.92 (74.95)	4.22 [illegible]	[illegible] (80.12)
LE 206	[illegible]	[illegible]	11.08 (87.22)	10.75 (84.61)	10.23 [illegible]	11.29 (86.03)
LE 210	[illegible]	[illegible]	9.48 (82.28)	8.65 [illegible]	7.69 (70.80)	9.35 (82.50)
Sakthi	[illegible] (75.59)	[illegible] (89.62)	[illegible] (83.30)	4.63 (77.73)	4.18 [illegible]	[illegible] (80.11)
Maggi ketchup	[illegible]	[illegible] (89.23)	3.97 (80.19)	3.30 (67.06)	3.03 (61.67)	[illegible] (78.61)
Stages (Mean)	9.59	8.91 (92.72)	8.41 (87.10)	7.94 (81.55)	7.49 (76.12)	

	Genotypes	Stages
CD (P = 0.05)	0.25	0.09
CD (P = 0.01)	0.33	0.11

Parenthesis indicate percentage retention

Table 28. Changes in total acidity (%) of ketchup during storage upto 12 months

Genotypes	Before storage	3 MAS	6 MAS	9 MAS	12 MAS	Genotypes (Mean)
Ohio 832	1.74	1.67	1.64	1.62	1.55	1.64
Ohio 7814	1.83	1.74	1.69	1.60	1.53	1.68
Ohio 8129	1.86	1.95	1.68	1.55	1.51	1.67
St 61	2.21	2.10	2.02	1.83	1.83	2.00
St 64	1.97	1.87	1.80	1.78	1.66	1.82
St 87	1.88	1.78	1.71	1.61	1.53	1.71
ONt 828	2.18	2.10	2.03	1.83	1.83	1.99
ONt 8210	2.09	1.97	1.91	1.80	1.78	1.91
H 722	1.82	1.72	1.68	1.59	1.53	1.67
H 2601	2.15	2.05	2.00	1.88	1.86	1.99
H 7083	2.19	2.11	2.03	1.90	1.88	2.02
FM 6203	1.89	1.79	1.72	1.72	1.58	1.74
HW 208 F	1.86	1.79	1.74	1.73	1.58	1.74
TH 318	2.28	2.17	2.07	1.90	1.89	2.06
Veepuk [illegible]	2.38	2.22	2.16	1.93	1.93	2.13
Veepro [illegible]	2.15	2.02	1.93	1.78	1.76	1.93
Veeking	1.83	1.75	1.70	1.66	1.64	1.72
Veemore	[illegible]	2.17	2.05	1.97	1.96	2.09
Veerona	2.17	2.07	1.95	1.88	1.85	1.99
Rubygem	[illegible]	1.93	1.93	1.85	1.77	1.92
UC 28	[illegible]	[illegible]	1.57	1.51	1.65	[illegible]
UC 82	[illegible]	1.97	1.77	[illegible]	1.63	[illegible]
E 6203	[illegible]	[illegible]	1.75	1.79	1.63	[illegible]
Processor [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.78	1.92
Roma	[illegible]	[illegible]	[illegible]	2.02	[illegible]	2.25
San Marzano	[illegible]	[illegible]	[illegible]	1.70	[illegible]	[illegible]
Punjab [illegible]	[illegible]	[illegible]	2.25	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.91	[illegible]
HHR [illegible]	[illegible]	2.41	2.31	[illegible]	[illegible]	2.28
Pant T	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fresh [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
DMM [illegible]	[illegible]	2.12	[illegible]	[illegible]	[illegible]	[illegible]
KT [illegible]	[illegible]	2.01	[illegible]	1.78	[illegible]	[illegible]
HS 101	2.37	[illegible]	2.12	[illegible]	[illegible]	2.11
AC 152	2.38	2.41	2.21	2.12	[illegible]	[illegible]
Punjab Kesari	2.52	2.27	2.15	[illegible]	[illegible]	2.17
Pusa Early Dwarf	[illegible]	[illegible]	2.81	2.66	2.65	2.78
Money Maker	2.24	2.15	[illegible]	1.93	1.84	2.05
Pusa Ruby	2.30	2.41	2.28	2.24	2.02	2.29
LE 206	2.35	2.36	2.19	2.06	2.02	2.23
LE 214	2.21	2.10	2.06	2.06	1.82	2.05
Sakthi	2.48	2.25	2.07	2.03	1.97	2.16
Maggi ketchup	1.70	1.58	1.53	1.51	1.41	1.55
Stages (Mean)	2.18	2.07	1.97	1.86	1.80	

	Genotypes	Stages
CD (P 0.05)	0.11	0.04
CD (P 0.01)	0.15	0.05

MAS - Months after storage

Table 29 . Changes in pH of ketchup during storage upto 12 months

Genotypes	Before storage	3 MAS	6 MAS	9 MAS	12 MAS	Genotypes (Mean)
Ohio 832	3.92	3.93	3.93	3.95	4.05	3.96
Ohio 7814	3.97	3.98	3.98	4.00	4.08	4.00
Ohio 8129	3.90	3.90	3.92	3.95	4.03	3.94
St 61	3.80	3.80	3.82	3.83	3.92	3.83
St 64	3.93	3.93	3.93	3.97	4.07	3.97
St [illegible]	3.82	3.83	3.83	3.88	4.00	3.88
ONt 828	3.88	3.88	3.92	3.93	4.03	3.93
ONt 8210	4.13	4.13	4.13	4.13	4.23	4.15
H 722	3.82	3.83	3.87	3.88	3.97	3.87
H 2653	3.73	3.73	3.78	3.80	3.90	3.79
H 7038	3.97	3.97	3.98	3.98	4.08	4.00
FM 6203	3.85	3.90	3.90	4.02	4.00	3.93
HW 208 F	3.92	4.05	4.02	4.03	4.08	4.01
TH 318	4.05	4.05	4.05	4.08	4.15	4.08
Veepick	[illegible]	3.47	3.52	3.55	3.60	3.52
Veepro	[illegible]	3.58	3.66	3.60	3.68	3.61
Veeking	[illegible]	[illegible]	3.52	3.52	3.67	3.54
Veemore	[illegible]	[illegible]	3.63	3.67	3.70	3.64
Veeroma	[illegible]	[illegible]	3.75	3.81	3.93	3.81
Rubyvee	[illegible]	[illegible]	[illegible]	3.77	3.87	3.75
UC 23	[illegible]	[illegible]	[illegible]	4.02	[illegible]	4.02
UC 82	[illegible]	[illegible]	[illegible]	3.78	3.85	3.78
E 6203	[illegible]	[illegible]	[illegible]	3.72	[illegible]	3.65
Professor [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.71
Roma	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
San Marzano	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Punjab [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HIR [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Pant T_2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fresh Market [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Kt [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HS 101	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
AC 142	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Punjab [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Pusa Early Dwarf	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Money Maker	[illegible]	[illegible]	[illegible]	[illegible]	4.00	[illegible]
Pusa Ruby	[illegible]	3.92	3.92	3.97	3.97	3.91
LE 206	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LE 216	3.53	3.58	3.58	3.62	3.63	3.59
Sakthi	3.65	3.65	3.65	3.65	3.73	3.67
Maggi ketchup	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.91
Stages (Mean)	3.71	3.72	3.75	3.77	3.86	

	Genotypes	Stages
CD (P = 0.05)	0.29	0.04
CD (P = 0.01)	0.38	0.06

MAS - Months after storage

Table 30. Changes in reducing sugar (%) of ketchup during storage upto 12 months

Genotypes	Before storage	3 MAS	6 MAS	9 MAS	12 MAS	Genotypes (Mean)
Ohio 832	17.17	17.18	17.18	17.19	17.20	17.19
Ohio 7814	18.14	18.15	18.15	18.16	18.17	18.15
Ohio 8129	18.11	18.12	18.13	18.13	18.15	18.13
St 61	16.56	16.57	16.57	16.57	16.58	16.57
St 64	17.57	17.58	17.58	17.59	17.60	17.58
St 87	14.88	14.89	14.90	14.90	14.91	14.90
ONt 828	16.94	16.94	16.94	16.95	16.97	16.95
ONt 8210	18.37	18.37	18.38	18.39	18.41	18.38
H 722	19.19	19.20	19.21	19.22	19.24	19.21
H 2653	16.75	16.75	16.76	16.76	16.76	16.76
H 7038	17.80	17.81	17.81	17.82	17.85	17.81
FM 6203	16.74	16.76	16.77	16.76	16.78	16.76
HW 208 F	17.24	17.25	17.25	17.26	17.29	17.26
TH 318	17.38	17.40	17.39	17.41	17.43	17.40
Veepick	18.68	18.74	18.77	18.83	18.86	18.78
Veepro	17.82	17.82	17.81	17.76	17.73	17.79
Veeking	[illegible]	16.62	16.63	16.66	16.69	16.63
Veemore	[illegible]	17.27	17.29	17.28	17.29	17.28
Veerona	[illegible]	[illegible]	17.87	17.87	17.85	17.86
Rubyvee[illegible]	[illegible]	[illegible]	16.83	16.84	16.85	16.83
UC 28	[illegible]	[illegible]	[illegible]	15.88	15.91	[illegible]
UC 82	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
E 6203	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Pro[illegible]	[illegible]	[illegible]	[illegible]	16.57	[illegible]	[illegible]
Roma	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
San Marzano	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Punjab [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Labonitha	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HIR 674	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	20.33
Pant F_1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fresh Mark[illegible]	[illegible]	[illegible]	17.61	[illegible]	[illegible]	[illegible]
DMAI [illegible]	[illegible]	[illegible]	[illegible]	18.11	18.13	[illegible]
KT 4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HS 101	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
AC 142	[illegible]	[illegible]	[illegible]	[illegible]	19.81	[illegible]
Punjab Kesari	[illegible]	[illegible]	[illegible]	[illegible]	17.03	[illegible]
Pusa Early Dwarf	[illegible]	[illegible]	[illegible]	[illegible]	19.61	19.61
Money Maker	16.78	[illegible]	[illegible]	16.77	16.78	16.78
Pusa Ruby	16.82	16.82	16.82	16.82	16.82	16.82
LE 206	17.48	17.49	17.50	17.53	17.56	17.51
LE 214	17.66	17.71	17.74	17.81	17.82	17.75
Sakthi	19.51	19.53	19.54	19.56	19.57	19.54
Maggi ketchup	11.91	11.91	11.90	11.88	11.88	11.90
Stages (Mean)	17.66	17.68	17.68	17.70	17.70	

	Genotypes	Stages
CD (P = 0.05)	0.35	0.12
CD (P = 0.01)	0.46	0.16

MAS - Months after storage

Table 31. Changes in β carotene (µg/100 g) of ketchup during storage upto 12 months

Genotypes	Before storage		3 MAS		6 MAS		9 MAS		12 MAS		Genotypes (Mean)	
Ohio 832	660.28	(72.79)	590.45	(89.45)	513.84	(77.86)	425.42	(64.54)	358.83	(54.33)	509.76	(71.55)
Ohio 7814	812.64	(72.38)	616.75	(75.90)	498.59	(61.34)	400.22	(49.22)	325.42	(40.02)	530.72	(56.62)
Ohio 8129	660.27	(80.95)	535.24	(81.12)	408.66	(61.95)	375.11	(56.86)	317.07	(48.03)	459.27	(61.99)
St 61	1042.10	(79.60)	800.31	(76.91)	688.58	(66.13)	603.83	(58.00)	515.47	(49.49)	730.06	(62.63)
St 64	830.36	(87.90)	713.67	(81.98)	633.33	(74.60)	521.86	(61.94)	450.40	(53.02)	633.92	(68.27)
St 87	[illegible]	(76.29)	425.11	(82.54)	383.55	(74.47)	342.08	(66.41)	312.15	(60.62)	395.71	(71.01)
ONt 828	942.00	(76.25)	875.48	(92.97)	783.58	(83.12)	717.00	(76.15)	650.07	(68.94)	793.63	(80.30)
ONt 8210	642.20	(84.53)	545.35	(85.13)	475.42	(74.26)	425.58	(66.53)	375.40	(68.74)	492.79	(71.17)
H 722	900.32	(81.80)	775.30	(86.02)	641.67	(71.25)	571.97	(63.49)	505.32	(56.16)	678.91	(69.29)
H 2653	952.03	(80.32)	800.25	(84.11)	708.56	(74.51)	608.63	(64.05)	513.72	(54.09)	716.64	(69.24)
H 7038	853.93	(90.05)	725.23	(84.44)	633.73	(73.96)	550.40	(64.27)	475.42	(55.46)	648.75	(69.20)
FM 6203	810.31	(72.73)	705.33	(86.46)	625.48	(77.25)	542.08	(66.93)	413.57	(51.09)	618.36	(70.44)
HW 208 F	[illegible]	(77.75)	[illegible]	(92.97)	571.82	(82.80)	503.58	(72.94)	408.90	(59.24)	563.29	(76.99)
TH 318	533.36	(54.13)	464.92	(87.52)	403.59	(76.29)	333.42	(63.23)	284.10	(53.85)	403.07	(70.22)
Veepick	[illegible]	[illegible]	[illegible]	[illegible]	583.60	(77.61)	495.20	(65.95)	420.28	(56.00)	584.99	(72.38)
Veepro	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Veeking	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Veemore	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	(71.26)
Veeroma	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	577.05	[illegible]	481.72	[illegible]	[illegible]	(71.19)
Rubyvee	[illegible]	[illegible]	[illegible]	[illegible]	613.62	[illegible]	371.88	(62.39)	321.92	[illegible]	442.56	[illegible]
HC 28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HC 82	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
E 6203	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Processor 90	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Roma	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
San Marzano	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Punjab Chhuhara	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	(68.58)
Labonitha	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	(68.55)
IHR 674	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Pant T2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fresh Market 9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	(73.44)
DMM (EC 108769)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	(71.12)	[illegible]	[illegible]	[illegible]	(51.31)	[illegible]	[illegible]
Kt 4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HS 101	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	(71.88)
AC 142	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	(76.29)
Punjab Kesari	873.52	(61.61)	767.18	(87.61)	641.92	[illegible]	562.23	(64.77)	459.71	(52.48)	662.10	(69.55)
Pusa Early Dwarf	758.55	(67.12)	641.76	(84.58)	538.78	(73.59)	467.00	(61.51)	325.65	(49.67)	560.35	(67.29)
Money Maker	638.68	(31.65)	620.10	(49.55)	552.12	(78.88)	506.85	(72.38)	420.38	(60.23)	559.67	(74.99)
Pusa Ruby	802.00	(65.36)	641.90	(86.41)	611.98	(76.44)	560.30	(62.58)	392.03	(49.18)	594.64	(68.66)
LE 206	921.99	(56.99)	266.98	(83.15)	666.90	(72.32)	560.25	(60.79)	425.47	(46.18)	618.31	(65.62)
LE 214	830.08	(56.85)	716.96	(84.03)	628.92	(74.15)	510.46	(60.10)	445.03	(52.58)	630.45	(67.82)
Sakthi	818.73	(84.08)	730.35	(87.41)	638.65	(76.64)	551.75	(64.44)	451.77	(52.72)	653.05	(70.33)
Maggi ketchup	1496.82		891.97	(59.60)	778.60	(52.02)	632.03	(42.26)	558.50	(37.33)	871.58	(57.81)
Stages (Mean)	827.16		687.96	(85.07)	599.22	(73.20)	514.74	(62.95)	433.28	(53.68)		

	Genotypes	Stages	G x S
CD (P = 0.05)	31.78	10.85	71.06
CD (P = 0.01)	41.76	14.24	93.38

Parenthesis indicate percentage retention

Table 32. Changes in ascorbic acid (mg/100 g) of ketchup during storage upto 12 months

Genotypes	Before storage	3 MAS	6 MAS	9 MAS	12 MAS	Genotypes (Mean)
Ohio 832	24.58 (77.01)	22.82 (92.70)	20.92 (85.03)	19.17 (77.97)	18.33 (74.63)	21.16 (82.59)
Ohio 7814	41.67 (68.02)	38.57 (92.74)	34.07 (82.03)	31.13 (74.86)	28.63 (68.88)	34.81 (79.63)
Ohio 8129	36.02 (76.57)	34.33 (95.39)	31.80 (88.30)	29.67 (82.44)	27.83 (77.34)	31.93 (85.87)
Sc 61	21.33 (73.61)	17.57 (82.13)	15.97 (74.65)	14.63 (68.47)	13.43 (62.87)	16.59 (72.03)
Sc 64	40.82 (79.81)	37.87 (92.60)	35.53 (86.86)	34.42 (83.97)	33.03 (80.55)	36.33 (86.00)
Sc 87	[illegible] (60.38)	[illegible] (92.36)	[illegible] (85.84)	34.40 (80.76)	31.71 (74.49)	[illegible] (83.17)
ONt 823	27.93 (68.16)	25.27 (90.29)	23.90 (85.29)	22.45 (80.12)	20.33 (72.53)	23.98 (82.07)
ONt 8210	32.66 (73.42)	29.78 (93.12)	27.62 (86.40)	26.48 (82.86)	23.57 (73.76)	27.89 (84.04)
H 722	38.06 [illegible]	35.28 (90.76)	31.63 (86.43)	29.08 (74.84)	27.35 (70.39)	32.45 (79.36)
H 2653	[illegible]	[illegible] (89.52)	20.88 (83.38)	19.25 (76.84)	17.98 (71.77)	21.13 (80.38)
H 7038	[illegible] (65.62)	35.27 (96.41)	[illegible] (78.46)	28.03 (71.83)	24.76 (63.47)	31.54 (76.04)
FM 6203	32.98 (64.25)	29.71 (90.96)	24.85 (75.54)	21.65 (65.74)	19.25 (58.55)	25.73 (72.70)
HW 208 F	41.72 (75.64)	39.48 (94.68)	38.33 (91.75)	37.33 (89.55)	35.83 (85.95)	38.54 (90.54)
TH 318	29.21 (63.27)	26.15 (89.57)	23.92 (81.94)	22.67 (77.66)	19.75 (67.66)	24.34 (79.21)
Veepick	33.33 [illegible]	[illegible] (95.58)	27.92 (83.74)	24.40 (73.21)	21.37 (64.07)	27.46 (77.91)
Veepro	[illegible]	[illegible]	27.63 (81.75)	24.28 (71.82)	20.50 (60.58)	27.33 (76.00)
Veeking	[illegible]	[illegible]	31.62 (79.73)	28.87 (73.29)	24.25 (61.53)	31.91 (76.20)
Veemore	[illegible]	[illegible]	35.62 (79.56)	31.25 (70.22)	27.47 (61.72)	35.61 (74.99)
Veeroma	[illegible]	[illegible]	31.13 [illegible]	27.28 (70.41)	23.07 [illegible]	31.04 (75.11)
Rubyvee	[illegible]	[illegible]	[illegible]	19.35 (65.98)	16.17 [illegible]	22.57 (71.08)
UC 28	[illegible]	[illegible]	[illegible]	35.92 (71.37)	31.73 [illegible]	[illegible]
UC 82	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	31.77 (75.25)
E 6203	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] (75.62)
Processor 90	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] (74.22)
Roma	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
San Marzano	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Punjab Chhuhara	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] (74.07)
Labonitha	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HIR 674	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Pant T2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fresh Market 9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
DMM (EC 168250)	[illegible]	[illegible]	[illegible]	26.17 [illegible]	[illegible]	[illegible]
Kt 4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HS 101	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
AC 142	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Punjab Kesari	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Pusa Early Dwarf	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] (70.97)
Money Maker	[illegible]	[illegible]	[illegible]	[illegible]	33.88 (58.83)	[illegible]
Pusa Ruby	[illegible]	22.25 [illegible]	[illegible]	17.88 [illegible]	12.85 [illegible]	19.20 [illegible]
LE 206	48.11 [illegible]	42.25 [illegible]	[illegible]	31.25 [illegible]	27.80 [illegible]	[illegible] (72.05)
LE 214	[illegible] (53.98)	55.32 (71.11)	42.58 (54.72)	36.46 (46.94)	30.10 (38.70)	[illegible] (52.87)
Sakthi	[illegible] (59.03)	48.15 (90.74)	42.70 (80.15)	38.75 (72.82)	33.52 (57.09)	42.92 (75.20)
Maggi ketchup	18.05	15.68 (86.60)	[illegible] (76.72)	[illegible] (65.67)	[illegible] (57.86)	13.84 (71.72)
Stages (Mean)	39.91	35.59 (89.68)	31.69 (79.97)	28.37 (71.80)	24.96 (63.26)	

	Genotypes	Stages	G x S
CD (P = 0.05)	1.50	0.51	1.36
CD (P = 0.01)	1.98	0.67	4.42

Parenthesis indicate percentage retention

Market 9 recorded the highest content from 3rd month onwards. The lowest content at all stages was recorded by the Maggi ketchup (18.05 to 10.33 mg/100 g). The retention percentage varied from 89.48 to 63.26 over the period of storage. The mean per cent retention was the highest in HW 208 F (90.54) and the lowest in LE 214 (52.87).

2. Changes in sensory score

Sensory scores made in terms of consistency, colour, flavour and absence of defects and overall scores changed significantly with genotypes and duration of storage. The interaction effects were significant for consistency, absence of defects and overall scores (Table 33).

The score for consistency was reduced from the initial 17.58 to 15.91 in 12 months period (Table 34). The minimum consistency score throughout the period of storage was observed in LE 214 (10.60 to 7.40). Though HW 208 F did not change in consistency during storage, this was not reflected in scoring (23.40 to 22.80). Even then this genotype recorded the highest mean consistency score (23.20) followed by Maggi ketchup (21.[illegible]) [illegible] did not change in score (21.0).

The extent of reduction in score for colour seemed to be the highest (18.[illegible] to 1[illegible].72) with enhanced storage (Table 35). All the genotypes scored low with advanced storage but the extent of reduction was not much marked in St 87 (21.40 to 21.08), Ohio 8129 (23.80 to 23.00) and St 64 (23.40 to 23.08). The minimum score after 12 month was observed in HS 101 (9.80) but the mean score over the period of storage was the lowest in LE 214 (11.08).

Scores for flavour also showed a decreasing trend but it was less conspicuous than for colour (17.72 to 15.40). The mean score over the storage period was the highest for Ohio 832 (20.96) closely followed by Ohio 8129 (20.88) and H 722 (20.84). The lowest score was recorded in Pusa Ruby (10.60) (Table 36).

Table 33. Analyses of variance for sensory scores of ketchup during storage upto 12 months

Sources of variation	df	Mean squares				
		Consistency	Colour	Flavour	Absence of defects	Overall score
Genotypes (G)	42	316.58**	271.06**	226.61**	61.56**	2589.01**
Stages (S)	4	115.77**	209.94**	181.10**	47.41**	2036.38**
G x S	168	1.47**	0.84	0.78	2.61**	6.96*
Error	860	0.82	1.17	1.31	1.01	5.07

* Significant at P = 0.05

** Significant at P = 0.01

Table 38. Changes in score for consistency of ketchup during storage upto 12 months

Genotypes	Before storage	3 MAS	6 MAS	9 MAS	12 MAS	Genotypes (Mean)
Ohio 832	20.8	20.8	20.6	20.4	20.4	20.6
Ohio 7814	21.0	21.0	20.8	20.4	20.2	20.7
Ohio 8129	20.6	20.6	20.6	20.4	20.4	20.5
St 61	19.4	19.0	18.4	17.6	17.4	18.4
St 64	21.0	21.0	21.0	21.0	21.0	21.0
St 87	21.0	21.0	20.6	20.4	20.2	20.6
ONt 828	19.0	18.8	18.4	18.0	17.8	18.4
ONt 8210	18.4	18.4	17.4	16.6	16.2	17.4
H 722	21.0	21.0	20.8	20.6	20.4	20.8
H 2653	20.0	19.8	19.2	19.0	18.6	19.3
H 7038	18.2	17.8	16.4	15.6	15.2	16.6
FM 6203	[illegible]	19.2	19.0	18.6	18.4	18.9
HW 208-1	[illegible]	23.4	23.4	23.0	22.8	23.2
TH 318	[illegible]	18.8	18.0	17.2	16.8	18.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	21.2	21.4	[illegible]	20.6	20.4	20.9
[illegible]	[illegible]	13.2	[illegible]	10.2	10.0	11.9
[illegible]	[illegible]	17.4	17.2	16.8	16.6	17.1
[illegible]	[illegible]	21.2	[illegible]	20.8	20.8	21.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Pusa Early Dwarf	11.2	[illegible]	[illegible]	9.6	8.6	10.0
Money Maker	16.2	[illegible]	[illegible]	13.8	13.4	15.0
Pusa Ruby	10.8	10.6	10.2	8.6	8.6	9.20
LE 206	[illegible]	14.8	14.2	12.4	12.2	13.20
LE 214	10.6	10.2	8.8	7.8	7.4	8.96
Sakthi	12.4	12.0	11.2	9.8	9.6	11.00
Maggi ketchup	22.0	21.6	21.2	20.8	20.8	21.30
Stages (Mean)	17.58	17.11	16.73	16.12	15.91	

	Genotypes	Stages	G x S
	0.30	0.17	1.12
	0.66	0.23	1.48

MAS - Months after storage

Table 35. Changes in score for colour of ketchup during storage upto 12 months

Genotypes	Before storage	3 MAS	6 MAS	9 MAS	12 MAS	Genotypes (Mean)
Ohio 832	21.6	21.6	21.2	20.6	20.0	21.00
Ohio 7814	21.4	21.0	20.4	20.0	19.0	20.36
Ohio 8129	23.8	23.8	23.6	23.4	23.0	23.52
St 61	20.4	20.0	19.6	18.8	18.2	19.40
St 64	23.6	23.4	23.2	22.8	22.6	23.08
St 87	21.4	21.4	21.0	20.8	20.8	21.08
ONt 823	20.2	19.8	19.2	18.8	18.2	19.24
ONt 8210	14.4	14.0	13.4	12.6	12.0	13.28
H 722	21.8	21.0	20.6	19.8	19.0	20.44
H 2633	19.6	18.8	18.2	17.6	16.6	18.12
H 7038	18.8	18.4	18.0	17.6	17.0	17.96
FM 6203	22.2	21.2	20.8	20.0	19.2	20.68
HW 208 F	22.2	21.8	21.4	21.0	20.6	21.40
TH 318	18.2	17.6	17.2	16.8	16.4	17.24
Veepuk	[illegible]	15.0	14.0	12.6	12.0	13.80
Veepro	[illegible]	20.2	19.2	18.2	18.2	19.28
Veeking	[illegible]	17.8	17.2	16.0	15.6	17.04
Veemore	[illegible]	18.0	17.0	17.0	16.2	17.60
Veerona	[illegible]	20.2	20.2	20.2	19.6	20.16
Rubyvee	[illegible]	18.2	17.2	16.8	[illegible]	17.68
UC 28	[illegible]	[illegible]	[illegible]	15.2	[illegible]	[illegible]
UC 82	[illegible]	[illegible]	[illegible]	16.6	15.2	[illegible]
E 6203	[illegible]	[illegible]	[illegible]	20.2	[illegible]	[illegible]
Pro[illegible]	[illegible]	[illegible]	[illegible]	15.8	15.2	[illegible]
Roma	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
San Ma[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Punjab [illegible]	[illegible]	17.2	[illegible]	[illegible]	[illegible]	[illegible]
Labonita	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	18.36
HIR [illegible]	[illegible]	[illegible]	11.8	[illegible]	[illegible]	12.04
Pant T	[illegible]	[illegible]	[illegible]	17.6	[illegible]	17.92
Fresh Mar[illegible]	[illegible]	[illegible]	13.6	[illegible]	14.2	15.56
DMM [illegible]	[illegible]	[illegible]	[illegible]	12.8	[illegible]	[illegible]
Kt 4	11.4	11.2	[illegible]	12.2	11.8	12.76
HS 101	13.7	12.6	12.0	10.2	[illegible]	11.56
AC 142	[illegible]	[illegible]	[illegible]	13.4	13.6	14.60
Punjab Kesari	17.8	[illegible]	13.8	13.2	13.2	15.60
Pusa Early Dwarf	13.8	[illegible]	13.2	14.8	12.6	14.76
Money Maker	12.2	11.6	11.2	10.6	10.2	11.16
Pusa Ruby	11.6	12.4	12.4	12.0	11.2	12.28
LE 206	20.4	20.2	19.6	18.8	17.2	19.24
LE 210	12.4	11.8	11.0	10.2	10.0	11.08
Sakthi	11.6	11.2	12.8	12.0	11.0	12.52
Maggi ketchup	19.8	18.8	18.6	16.8	16.6	17.70
Stages (Mean)	18.24	17.70	17.16	16.50	15.72	

	Genotypes	Stages
CD (P = 0.05)	0.60	0.20
CD (P = 0.01)	0.79	0.27

Table 36. Changes in score for flavour of ketchup during storage upto 12 months

Genotypes	Before storage	3 MAS	6 MAS	9 MAS	12 MAS	Genotypes (Mean)
Ohio 832	21.6	21.4	21.0	20.6	20.2	20.96
Ohio 7814	21.2	20.8	20.2	19.4	18.0	19.92
Ohio 8129	21.0	21.0	20.8	20.8	20.8	20.88
St 61	17.0	16.4	16.2	16.0	14.8	16.08
St 64	21.0	21.0	20.4	19.8	19.6	20.36
St 87	20.2	20.2	19.4	19.4	18.8	19.60
ONT 828	19.2	[illegible]	17.8	17.2	16.2	17.76
ONT 8216	[illegible]	[illegible]	19.6	18.4	17.4	19.24
H 722	22.4	[illegible]	21.0	20.2	18.6	20.84
H 2653	[illegible]	16.2	15.6	15.4	13.4	15.52
H 7038	21.2	20.6	20.4	19.4	17.8	19.88
FM 6203	[illegible]	16.2	16.0	15.8	13.8	15.72
HW 208 1	[illegible]	[illegible]	[illegible]	20.2	19.6	20.48
TH 318	[illegible]	19.4	18.4	18.0	17.2	18.52
Veepick	[illegible]	15.2	15.2	14.6	14.0	14.96
Veepro	[illegible]	[illegible]	[illegible]	19.4	[illegible]	19.68
Veeking	[illegible]	[illegible]	[illegible]	16.2	15.6	17.08
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	21.2	[illegible]	21.36
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Pant T_2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fresh Market [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
DMAM (EC 108750)	[illegible]	15.2	15.2	15.2	[illegible]	[illegible]
Kt 4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HS 101	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
AC 142	[illegible]	[illegible]	[illegible]	15.8	[illegible]	15.92
Punjab Kesari	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Pusa Early Dwarf	12.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Money Maker	16.6	[illegible]	14.8	14.2	12.6	[illegible]
Pusa Ruby	[illegible]	11.2	10.8	10.4	9.2	[illegible]
LE 206	[illegible]	14.8	14.8	14.0	13.0	[illegible]
LE 214	11.6	11.6	11.6	10.6	9.8	[illegible]
Sakthi	13.6	13.0	13.0	12.6	11.4	12.72
Maggi ketchup	20.6	20.0	19.2	18.4	17.0	19.04
Stages (Mean)	17.72	17.42	17.00	16.45	15.40	

	Genotypes	Stages
CD (P 0.05)	0.63	0.22
CD (P 0.01)	0.83	0.28

MAS Months after storage

Influence of storage life on scores for absence of defects was much less marked (18.26 to 17.03) than other factors considered for scoring (Table 37). Maggi ketchup maintained the highest score throughout the period of storage followed by Ohio 832. The least score was recorded in LE 214 (14.20).

The overall score decreased from 71.80 before storage to 64.06, 12 months after storage. The extent of reduction varied with genotypes (Table 38). Ohio 8129 showed the least change in sensory score (85.40 to 84.80). It maintained the Grade I score upto six months (85.00). HW 208 F (84.60) and St 64 (84.20) fell beyond the limit for Grade I within six months and Maggi ketchup (82.80) within three months. The mean overall score during the period of storage was the highest for Ohio 8129 ([illegible]) and the least for LE 214 (45.20).

3. Micro-organisms causing spoilage in ketchup

a. Estimation of microflora

The ketchup bottles were stored under room conditions for one year. Three ketchup samples showed visible microbial infection, of which LE 214 and Sakthi after three months of storage and AC 142 after six months of storage. Isolation of micro-organisms showed that only fungal populations were present in the infected samples. The data on fungal population revealed that LE 214 had the highest count (7200/g) followed by Sakthi (5100/g) and AC 142 (3500/g).

b. Identification of microflora

The morphological characters of the isolated fungi were studied and identified as *Aspergillus flavus* and *Aspergillus fumigatus*.

Table 37. Changes in score for absence of defects of ketchup during storage upto 12 months

Genotypes	Before storage	3 MAS	6 MAS	9 MAS	12 MAS	Genotypes (Mean)
Ohio 832	20.2	20.2	20.2	20.2	19.6	20.1
Ohio 7814	18.4	18.4	18.2	18.0	18.0	18.2
Ohio 8129	20.0	20.0	20.0	20.0	19.6	19.9
St 61	18.2	18.2	18.2	18.2	18.2	18.2
St 69	19.8	19.8	19.6	19.6	19.6	19.7
St 87	18.0	18.0	17.8	17.8	17.8	17.9
ONt 828	19.2	19.2	19.2	19.2	19.2	19.2
ONt 8210	17.2	17.2	17.0	17.0	16.8	17.0
H 722	18.4	18.4	18.2	18.2	17.6	18.2
H 2653	18.6	18.6	18.6	18.4	18.2	18.5
H 7038	19.2	19.2	19.2	19.0	19.0	19.1
FM 6203	[illegible]	18.2	18.2	18.0	17.0	18.0
HW 208 1	[illegible]	19.4	19.2	19.0	19.0	19.2
TH 318	16.3	16.8	16.6	16.6	16.6	16.7
Veepick	17.2	16.8	16.8	16.8	16.4	16.8
Veepro	[illegible]	17.4	17.4	17.4	17.2	17.6
Verking	[illegible]	[illegible]	15.2	15.2	15.2	15.3
Veemore	[illegible]	[illegible]	13.2	13.6	15.6	14.5
Veeroma	[illegible]	[illegible]	18.4	18.4	17.0	18.2
Rubyvee	[illegible]	[illegible]	[illegible]	18.4	18.4	15.8
UC 28	[illegible]	[illegible]	17.2	17.2	17.2	17.4
UC 82	[illegible]	[illegible]	[illegible]	16.5	16.6	17.0
E 6203	[illegible]	[illegible]	[illegible]	17.6	[illegible]	18.0
Processor [illegible]	[illegible]	[illegible]	[illegible]	18.2	[illegible]	18.3
Roma	[illegible]	[illegible]	[illegible]	17.2	[illegible]	17.2
San Marzano	[illegible]	[illegible]	[illegible]	17.8	[illegible]	18.2
Punjab Chhuhara	[illegible]	[illegible]	17.6	17.2	16.8	17.6
Labonitha	[illegible]	18.2	17.8	17.6	[illegible]	[illegible]
HHR 676	[illegible]	16.8	16.6	16.6	16.6	[illegible]
Pant T_2	[illegible]	17.5	[illegible]	18.8	18.6	[illegible]
Fresh Market 9	[illegible]	17.6	17.6	17.4	17.6	17.6
DMM (EC 168759)	18.2	17.6	15.6	14.2	12.9	15.6
Kt 4	15.6	15.9	15.0	16.8	16.8	15.0
HS 101	16.6	16.4	16.2	16.2	16.2	16.3
AC 142	16.0	16.5	16.4	13.4	12.9	14.3
Punjab Kesari	18.0	18.0	17.8	17.8	17.8	17.9
Pusa Early Dwarf	17.8	17.8	17.8	17.8	17.8	17.8
Money Maker	16.8	16.8	16.8	16.8	16.6	16.7
Pusa Ruby	17.2	17.0	16.6	16.4	16.2	16.7
LE 206	19.6	19.0	18.8	18.6	18.6	18.9
LE 214	16.8	15.2	13.8	13.0	12.0	14.2
Sakthi	18.6	16.0	15.0	13.6	13.0	13.2
Moggi ketchup	22.6	22.4	21.2	21.2	20.0	21.3
Stages (Mean)	18.26	17.87	17.61	17.38	17.03	

	Genotypes	Stages	G x S
CD (P = 0.05)	0.56	0.19	1.26
CD (P = 0.01)	0.73	0.25	1.63

MAS - Months after storage

Table 38 . Changes in overall score of ketchup during storage upto 12 months

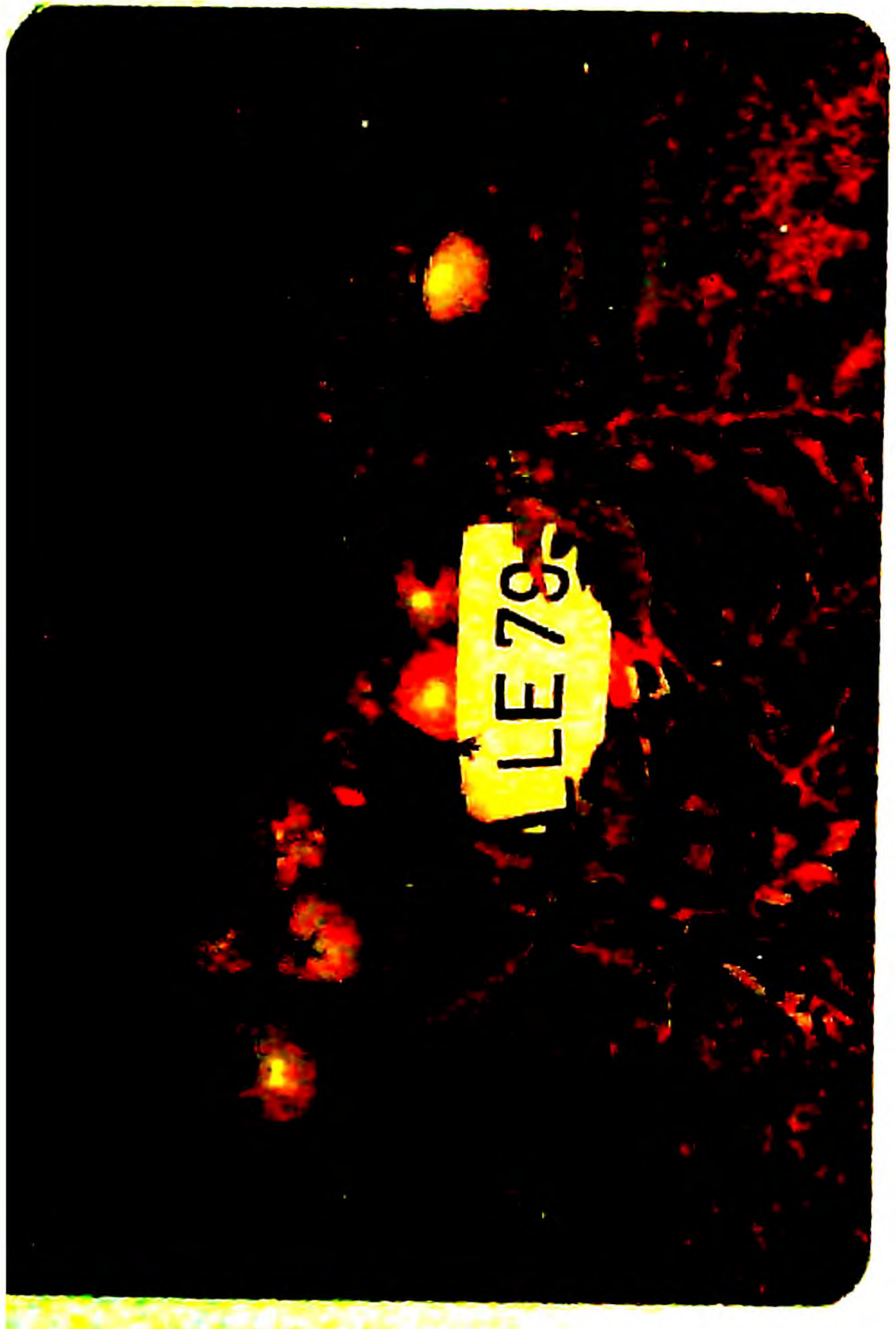
Genotypes	Before storage	3 MAS	6 MAS	9 MAS	12 MAS	Genotypes (Means)
Ohio 832	84.20	84.00	83.00	81.80	80.20	82.60
Ohio 7814	82.00	81.00	79.60	77.80	75.20	79.10
Ohio 8129	85.40	85.40	85.00	84.60	83.80	84.80
St 61	75.00	73.60	72.40	70.60	68.80	72.10
St 64	85.20	85.20	84.20	83.20	82.80	84.10
St 87	80.60	79.40	78.60	78.40	77.60	78.92
ONt 828	77.60	76.20	74.60	73.20	71.40	74.60
ONt 8210	70.40	70.00	67.40	64.60	[illegible]	67.00
H 722	83.60	82.40	80.60	78.80	74.60	80.00
H 2653	75.20	73.40	71.60	70.20	66.80	71.40
H 7038	77.40	76.00	74.00	71.60	69.00	73.60
FM 6203	77.00	74.80	74.00	72.40	68.40	73.30
HW 208 F	85.80	85.60	84.60	83.20	[illegible]	84.20
TH 318	74.00	72.60	70.20	[illegible]	[illegible]	[illegible]
Veepick	65.00	62.40	60.40	58.00	[illegible]	[illegible]
Veepro	81.20	79.40	77.20	[illegible]	[illegible]	[illegible]
Veeking	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Veemore	63.20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Veeroma	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rubyvee	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
UC 28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
UC 82	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
E 6203	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Processor 40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Roma	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
San Marzano	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Punjab Chhuhara	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Labonitha	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
IIHR 674	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Pant T_2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fresh Market 9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
DMM (EC 108759)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Kt 4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HS 101	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
AC 142	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Punjab Kesari	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Pusa Early Dwarf	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Money Maker	61.80	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Pusa Ruby	52.80	51.20	50.00	[illegible]	[illegible]	[illegible]
LE 206	70.40	68.80	67.40	[illegible]	[illegible]	[illegible]
LE 214	51.00	[illegible]	[illegible]	41.60	[illegible]	[illegible]
Sakthi	58.20	56.20	52.00	[illegible]	[illegible]	[illegible]
Maggi ketchup	85.00	82.80	80.20	77.20	[illegible]	[illegible]
Stages (Mean)	71.80	70.36	68.52	66.44	[illegible]	

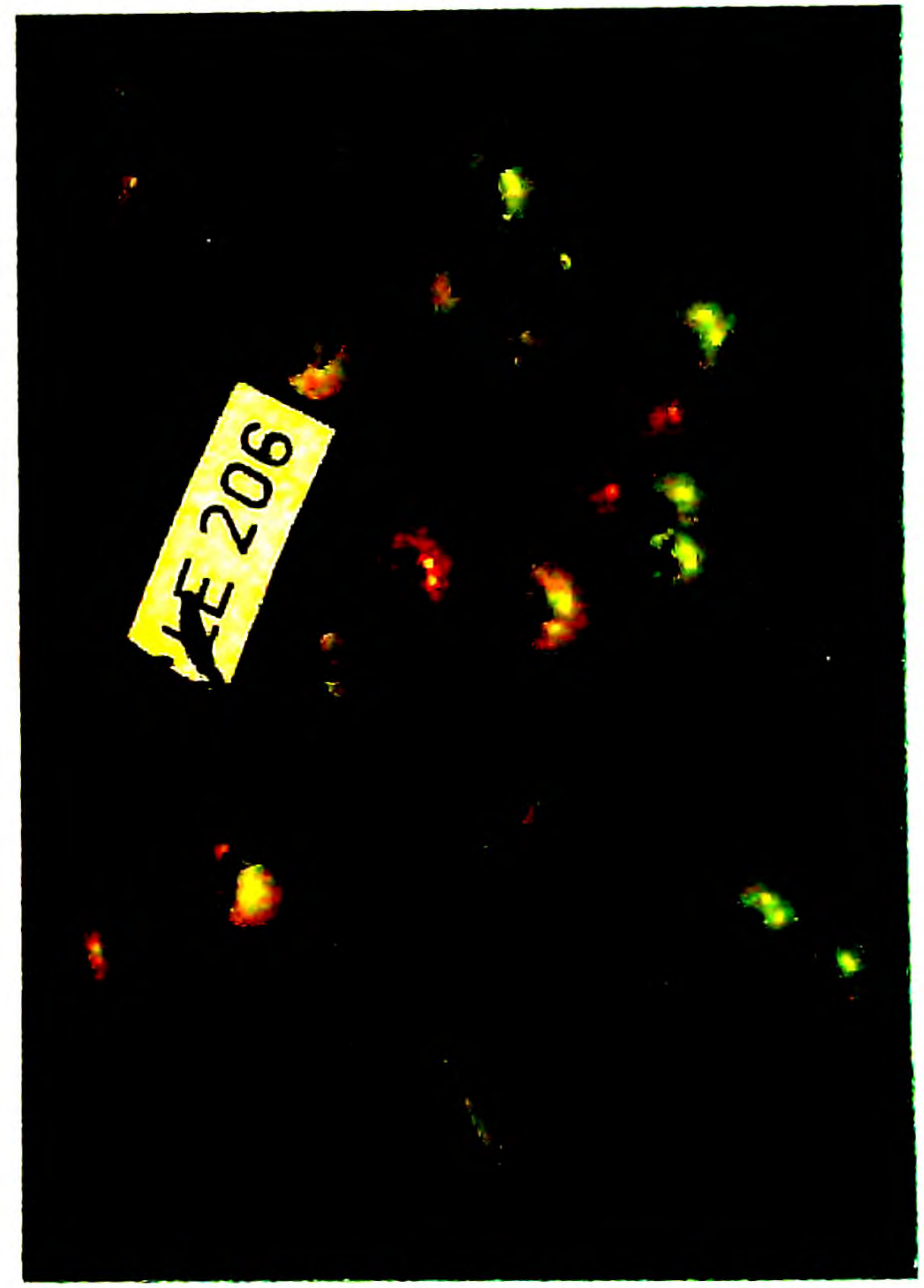
	Genotypes	Stages	G x S
CD (P = 0.05)	1.25	0.41	2.79
CD (P = 0.01)	1.64	0.56	3.67

MAS - Months after storage

Plate VII [illegible]

Plate VIII LE 206


LE 79


E 206

D. Transfer of processing characteristics to a bacterial wilt resistant genetic background

1. Combining ability and gene action

The analyses of variance revealed highly significant differences for all the characters studied among the 23 genotypes (Tables 39 to 41). The mean squares due to parents also differed significantly except for reducing sugar content. Highly significant differences were also observed for the variance component, 'parents vs hybrids' for all characters except reducing sugar, ascorbic acid, storage life and locules/fruit. Significant mean squares among lines and testers revealed wide range of variability among them. Mean squares due to line x tester interaction were significant for plant height, days to harvest, fruits/plant, fruit yield/plant, fruit weight, locules, TSS, total solids, insoluble solids, lycopene and ascorbic acid.

Based on line x tester analysis, general and specific combining ability effects were estimated (Tables 42, 43, 45, 46, 48, 49). Components of additive and non-additive variances and heritability were also worked out (Tables 44, 47, 50).

a. Fruit yield and its components

Highly significant positive gca effects indicated that TH 318 and LE 214 (11.71 and 4.41 respectively) were good general combiners for increased plant height. Ohio 8129 (-7.29), St 64 (-5.49) and Sakthi (-4.11) had significant negative gca effects suggesting that these genotypes are good general combiners as source(s) of genes for dwarfness. Significant sca effects for plant height were expressed in LE 206 x St 64 and LE 214 x HW 208 F. Heritability was the highest (0.64) for plant height suggesting improvement of the characters through selection. Preponderance of additive variance (6.07) was also observed for plant height.

Table 39. Analyses of variance for line x tester analysis including parents for fruit yield and its components in tomato

Sources of variation	df	Mean squares			
		Plant height (cm)	Days to harvest	Fruits/plant	Fruit yield/plant (g)
Genotypes	22	283.52**	191.26**	213.74**	222238.90**
Parents	7	181.07**	224.34**	441.34**	129654.29**
Hybrids	14	323.31**	127.52**	87.51**	229995.42**
Parents vs hybrids	1	443.56**	852.00**	387.68**	761744.02**
Lines	2	455.45**	166.88**	88.48**	826583.96**
Testers	4	829.15**	301.39**	113.21**	204183.01**
Line x Tester	8	37.36**	30.75**	74.41**	93754.50**
Error	92	7.47	5.55	6.87	5262.09

** Significant at P = 0.01

Table 40. Analyses of variance for line x tester analysis including parents for fruit characteristics in tomato

Sources of variation	df	Mean squares				
		Average fruit weight (g)	Fruit shape index	Locules/fruit	Pericarp thickness (mm)	Storage life (days)
Genotypes	22	1370.83**	0.045**	0.27**	2.61**	97.99**
Parents	7	2686.89**	0.094**	0.43**	4.68**	245.37**
Hybrids	14	718.35**	0.001	0.20**	1.65**	31.05**
Parents vs hybrids	1	1293.06**	0.306**	0.06	1.61**	3.54
Lines	2	1240.93**	0.0002	0.04	1.22**	72.41**
Testers	4	1315.79**	0.002	0.36**	4.77**	70.29**
Line x tester	8	288.98**	0.0007	0.16**	0.20	1.10
Error	92	16.81	0.001	0.02	0.13	3.16

** Significant at P = 0.01

Table 41. Analyses of variance for line x tester analysis including parents for fruit juice characteristics in tomato

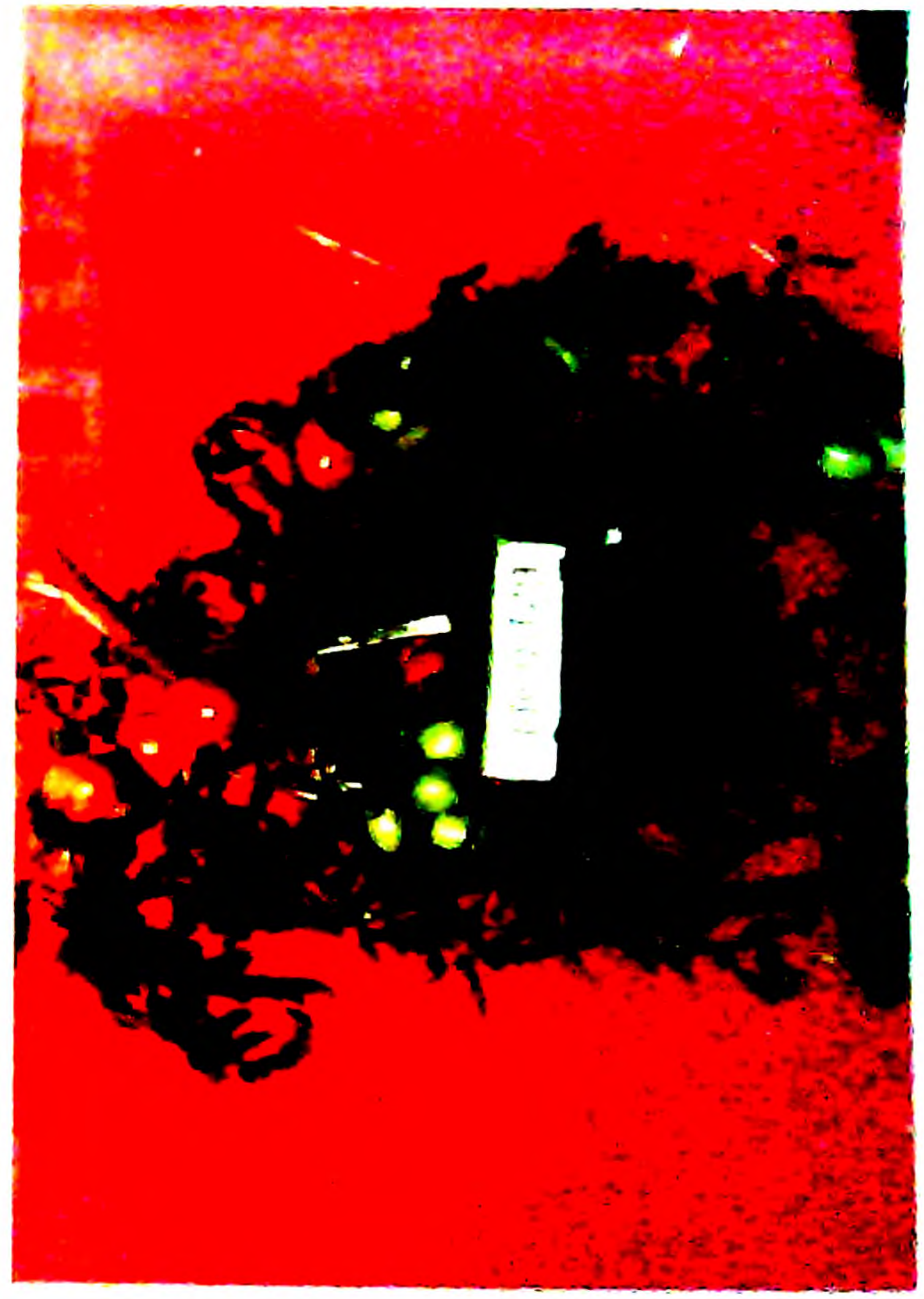
Sources of variation	df	Mean squares									
		Juice@ yield (%)	TSS@ (%)	Total solids (%)	Insoluble solids (%)	Reducing sugar (%)	Acidity (%)	pH@	Consistency (PPT)	Lycopene (mg/100 g)	Ascorbic acid (mg/100 g)
Genotypes	22	18.18**	1.28**	3.34**	0.109**	0.36**	0.009**	0.20**	0.005**	15.71**	85.58**
Parents	7	31.46**	1.18**	3.07**	0.280**	0.17	0.022**	0.30**	0.012**	6.10**	155.24**
Hybrids	14	11.71**	1.30**	2.23**	0.021**	0.47**	0.002	0.02	0.002**	18.53**	56.86**
Parents vs hybrids	1	15.69*	1.62**	20.60**	0.155**	0.25	0.013**	3.47**	0.005**	43.76**	0.03
Lines	2	4.44	2.09**	4.99**	0.009*	0.41	0.004	0.008	0.003**	29.91**	96.90**
Testers	5	35.40**	1.25**	4.23**	0.042**	1.36**	0.004*	0.034	0.004**	41.53**	127.28**
Line x tester	8	1.69	1.13**	0.55**	0.013**	0.03	0.001	0.007	0.00024	4.18**	11.64*
Error	46	3.30	0.08	0.12	0.002	0.10	0.001	0.009	0.00019	0.24	5.14

* and ** Significant at P = 0.05 and P = 0.01, respectively

@ Error df 92

Plate IX HW 208 1

Plate X Ohio 8129



Sakthi (-1.16), LE 206 (-1.80), Ohio 8129 (-1.84) and St 64 (-6.31) showed significant negative gca effects, for days to harvest, which favoured earliness. The positive gca effects expressed by LE 214 (2.96), Fresh Market 9 (5.29) and HW 208 F (3.03) indicated their lateness. Significantly negative sca effects were shown by LE 214 x Ohio 8129 (-3.56), Sakthi x TH 318 (-2.31), LE 206 x Fresh Market 9 (-2.13). High value of additive variance (8.21) and relatively high heritability (0.44) were observed for days to harvest.

The good general combiners for fruits/plant as indicated by significant gca effects were TH 318 (2.88), Ohio 8129 (1.88) and Sakthi (1.54). Fresh Market 9 which had only a few fruits had the lowest gca (-3.19). Highly significant positive sca effects were expressed by Sakthi x TH 318 ([illegible]) and LE 206 x Fresh Market 9 (3.59). A preponderance of non-additive variance (13.51) and a very low heritability (0.05) were observed for fruits/plant.

The parents which had a fairly high yield were good general combiners (Sakthi, TH 318, Fresh Market 9 and HW 208 F). Hybrids Sakthi x TH 318 (178.66), Sakthi x Fresh Market 9 (71.12), LE 206 x St 64 (113.22) and LE 206 x Ohio 8129 (121.99) showed significant positive sca effects. Non additive variance was more important for this character. Accordingly heritability was also moderate (0.33).

b. Fruit characteristics

Fresh Market 9, Sakthi and HW 208 F recorded significantly high positive gca effects for fruit weight (11.88, 8.00 and 7.01 respectively). Significant sca effects were observed in Sakthi x Fresh Market 9 (13.54), LE 206 x Ohio 8129 (5.36) and LE 206 x St 64 (5.05). Heritability was moderate (0.34) and non-additive variance (54.44) predominated over additive variance (36.41) for fruit weight.

Table 42. Estimates of general combining ability effects of lines and testers for fruit yield and its components in tomato

	Plant height (cm)	Days to harvest	Fruits/plant	Fruit yield/plant
Lines				
Sakthi	-4.11**	-1.16*	1.84**	209.66**
LE 206	-0.31	-1.80**	0.08	-95.11**
LE 214	4.41**	2.96**	-1.92**	-114.56**
SE (gi)	0.55	0.47	0.52	14.51
SE (gi-gj)	0.77	0.67	0.74	20.52
Testers				
St 64	-5.49**	-6.31**	1.08	-87.47**
Ohio 8129	-7.29**	-1.84**	1.88**	-158.11**
HW 208 F	0.31	3.03**	-2.65**	49.84**
TH 318	11.71**	-0.17	2.88**	106.83**
Fresh Market 9	0.77	5.29**	-3.19**	88.90**
SE (gi)	0.71	0.61	0.68	18.73
SE (gi-gj)	1.00	0.86	0.96	26.49

* and ** Significant at P = 0.05 and P = 0.01, respectively

Table 43. Estimates of specific combining ability effects for fruit yield and its components in tomato

	Plant height (cm)	Days to harvest	Fruits/plant	Fruit yield/ plant (g)
Sakthi x St 64	-[illegible].63	0.63	0.36	-94.08**
Sakthi x Ohio 8129	-[illegible].23	1.76	-0.44	-131.86**
Sakthi x HW 208 F	-[illegible].2[illegible]	-1.91	-2.31	-23.24
Sakthi x TH 318	-0.63	-2.31**	6.16**	178.06**
Sakthi x Fresh Market 9	1.71	1.83	-3.77**	71.12*
LE 206 x St 64	3.57**	0.47	0.92	118.22**
LE 206 x Ohio 8129	1.77	1.80	0.92	121.99**
LE 206 x HW 208 F	-3.03*	0.53	1.05	-14.27
LE 206 x TH 318	-1.63	-0.67	-6.48**	-221.35**
LE 206 x Fresh Market 9	-0.69	-2.13**	3.59**	-4.59
LE 214 x St 64	-2.95*	-1.09	-1.28	-24.15
LE 214 x Ohio 8129	-1.55	-3.56**	-0.48	9.88
LE 214 x HW 208 F	3.25**	1.37	1.25	37.51
LE 214 x TH 318	2.25	2.97**	0.32	43.29
LE 214 x Fresh Market 9	-1.01	0.31	0.19	-66.53*
SE (sij)	1.22	1.05	1.17	32.44
SE (sij-skl)	1.73	1.49	1.66	45.88

* and ** Significant at P = 0.05 and P = 0.01 respectively

Table 44. Components of additive and non-additive variances and heritability for fruit yield and its components in tomato

Variances	Plant height (cm)	Days to harvest	Fruits/plant	Fruit yield/plant (g)
Cov HS	6.07	2.05	0.28	2889.96
$\sigma^2 A$	24.26	8.21	1.11	11559.84
Cov FS	86.64	32.16	17.03	73915.69
$\sigma^2 D$	5.98	5.04	13.51	17698.48
Heritability	0.64	0.44	0.05	0.33

TH 318 was a good general combiner for fruit shape index as indicated by positive and significant gca effect (0.019). No hybrid exhibited significant sca effects. Non-additive variance was negative and heritability was very low (0.03). The general combining ability effects and specific combining ability effects for locules/fruit were not significant. Non-additive variance predominated over additive variance.

Significant gca effects indicated that St 64 (0.89) and LE 206 (0.26) were good general combiners for pericarp thickness. The specific combining ability effects were not significant. The high additive variance coupled with relatively high heritability (0.46) suggest selection for improvement.

Parents Ohio 8129 (2.03), LE 206 (1.65) and St 64 (1.36) showed significant positive gca for storage life. None of the hybrids expressed significant sca for storage life. The non-additive variance was negative (-0.1[illegible]) suggesting that keeping quality was solely controlled by additive gene effect (2.54). This was further substantiated by relatively high heritability ([illegible]).

c. Fruit juice characteristics

HW 208 F and Fresh Market 9 showed significantly high gca effects for juice yield. Maximum sca effect was expressed by LE 214 x TH 318 (0.64) followed by LE 206 x Ohio 8129 (0.60) but the sca effects were not significant. Juice yield was controlled by additive gene action. Heritability observed was moderate (0.21).

Estimates of general combining ability effects indicated that St 64 (0.48) and LE 206 (0.32) were good general combiners for TSS. The F_1 hybrids LE 206 x St 64 recorded the highest significant sca effect (0.95). Sakthi x TH 318 also recorded significant sca (0.31). Non-additive gene action was predominant (0.21) which was further substantiated by the very low heritability (0.05).

Table 45 Estimates of general combining ability effects of lines and testers for fruit characteristics in tomato

	Average fruit weight (g)	Fruit shape index	Locules/ fruit	Pericarp thickness (mm)	Storage life (days)
Lines					
Sakthi	8.00**	0.003	0.01	-0.13	0.09
LE 206	-5.28**	-0.0004	0.03	0.26**	1.65**
LE 214	-2.72**	-0.002	0.05	-0.12	-1.75**
SE (gi)	0.82	0.006	0.03	0.07	0.36
SE (gi-gj)	1.16	0.009	0.04	0.12	0.50
Testers					
Sr 64	-6.67**	-0.009	-0.20	0.89**	1.36**
Ohio 8129	-10.66**	0.005	-0.07	-0.55**	2.03**
HW 208 F	7.01**	-0.009	0.19	-0.40**	0.09
TH 318	-1.36	0.019*	-0.05	0.09	-3.57**
Fresh Market 9	11.[illegible]**	-0.006	0.12	-0.03	0.09
SE (gi)	[illegible]	0.008	0.04	0.09	0.46
SE (gi-gj)	[illegible]	0.011	0.06	0.13	0.65

* and ** Significant at P < 0.05 and P < 0.01 respectively

Table 46 . Estimates of specific combining ability effects for fruit characteristics in tomato

	Average fruit weight (g)	Fruit shape index	Locules/ fruit	Pericarp thickness (mm)	Storage life (days)
Sakthi x St 64	[illegible]	[illegible]	0.14	0.05	-0.16
Sakthi x Ohio 8129	[illegible]	-0.01	0.10	0.13	-0.23
Sakthi x HW 208 F	[illegible]	0.003	-0.04	-0.02	-0.29
Sakthi x TH 318	-4.46*	0.004	-0.01	0.10	-0.03
Sakthi x Fresh Market 9	13.54**	0.01	0.02	-0.00	0.71
LE 206 x St 64	5.25**	0.01	-0.23**	-0.13	-0.12
LE 206 x Ohio 8129	5.36**	-0.01	0.33**	0.05	0.61
LE 206 x HW 208 F	-2.92	-0.01	-0.02	-0.09	0.15
LE 206 x TH 318	1.36	-0.003	-0.03	-0.16	0.01
LE 206 x Fresh Market 9	-5.84**	0.01	-0.05	0.32	-0.65
LE 214 x St 64	2.91	-0.0009	0.09	0.08	0.28
LE 214 x Ohio 8129	0.83	0.01	-0.22**	0.08	-0.39
LE 214 x HW 208 F	0.14	0.01	0.06	0.11	0.15
LE 214 x TH 318	3.15	-0.0009	0.04	0.05	0.01
LE 214 x Fresh Market 9	-4.70*	0.02	0.03	-0.32	-0.05
SE (sij)	1.83	0.014	0.07	0.16	0.80
SE (sij-skl)	2.59	0.020	0.10	0.23	1.12

* and ** Significant at P = 0.05 and P = 0.01 respectively

Table 47. Components of additive and non-additive variances and heritability with respect to fruit characteristics in tomato

Variances	Average fruit weight (g)	Fruit shape index	Locules/fruit	Pericarp thickness (mm)	Storage life (days)
Cov HS	9.11	0.00001	0.001	0.031	0.64
$\sigma^2 A$	36.41	0.00003	0.003	0.123	2.54
Cov FS	186.35	0.00001	0.033	0.386	8.95
$\sigma^2 D$	54.44	-0.00005	0.028	0.013	-0.41
Heritability	0.34	0.03	0.06	0.46	0.46

Among parents, which showed significant gca effects, HW 208 F (0.71) was the best general combiner for total solids. St 64 (0.48), Sakthi (0.43) and LE 206 (0.22) were the other good general combiners. Significant sca effects were estimated in LE 206 x Ohio 8129 (0.58) and Sakthi x TH 318 (0.50). Additive gene action predominated as indicated by high additive variance (0.24) and relatively high heritability (0.48).

The good general combiners for insoluble solids were HW 208 F, Ohio 8129 and St 64 as indicated by the significantly high gca effects (0.07, 0.05 and 0.03 respectively). The sca effects were significant for Sakthi x HW 208 F (0.07) and LE 206 x Ohio 8129 (0.07). The magnitude of non-additive variance was more (0.004) when compared to additive component ([illegible]). This resulted in relatively low heritability (0.14).

The [illegible] parents which exhibited significantly positive gca effects for [illegible] were Ohio 8129 (0.41) and St 64 (0.23). The sca effects [illegible] significant but LE 214 x Fresh Market 9 showed relatively [illegible] (0.19). The additive genetic variance was more (0.06) when compared [illegible] non additive variance (-0.02) and the heritability was only [illegible] ([illegible]).

Significantly positive gca effects for acidity were observed for TH 318 ([illegible]) and Sakthi (0.018) but none of the crosses showed significant sca effects. Additive variance was more when compared to non additive variance.

The best combiner for pH was HW 208 F as indicated by the significant gca effect (0.057). The positive gca effects expressed by Ohio 8129 (0.034), Fresh Market 9 (0.001) and LE 214 (0.021) were not significant. The sca effects though positive were not significant. Additive variance predominated over non-additive variance.

HW 208 F and Ohio 8129 were good general combiners (0.026 and 0.014 respectively) for consistency. Variance due to specific combining

Table 41 Estimates of general combining ability effects of lines and testers for fruit juice characteristics in tomato

	Juice yield (%)	TSS (%)	Total sugars (%)	[illegible]	Reducing sugars (%)	[illegible]	[illegible]	Consistency (PPT)	Lycopene (mg/100 g)	Ascorbic acid (mg/100 g)
Lines										
Sulcata	0.44	-0.59	[illegible]**	[illegible]	[illegible]	[illegible]*	[illegible]	0.009	-0.36**	-1.26**
LE 266	-0.40	0.32**	0.22*	[illegible]	-0.19*	[illegible]	-0.011	0.007	1.56**	-1.66**
LE 214	-0.04	-0.23**	[illegible]**	-0.027*	[illegible]	-0.011	0.021	-0.016*	1.20**	2.93**
SE (gi)	0.36	0.06	0.09	0.012	0.08	0.007	0.020	0.004	0.13	0.59
SE (gi-gj)	0.51	0.08	0.13	0.017	0.12	0.009	0.028	0.005	0.18	0.83
Testers										
Sel 6a	0.30	0.48**	0.48**	0.033**	0.23*	-0.001	-0.033	-0.002	2.24**	1.13
Ohio 8129	-2.20**	-0.19**	0.11	0.047**	0.41**	-0.015	0.034	0.014**	2.41**	-4.90**
HW 208 F	1.40**	-0.13**	0.71**	0.068**	0.01	0.001	0.057*	0.026**	-1.02**	4.13**
TH 318	-1.00*	0.06	-0.26*	-0.080**	-0.03	0.035**	-0.059*	-0.016**	-1.75**	-2.83**
Fresh Market 9	1.00*	-0.17*	-1.03**	-0.071	-0.62**	-0.020*	0.001	-0.023**	-1.88**	2.47
SE (gi)	0.47	0.07	0.11	0.015	0.11	0.009	0.025	0.005	0.16	0.76
SE (gi-gj)	0.66	0.10	0.16	0.021	0.15	0.012	0.036	0.006	0.23	1.07

* and ** Significant at P = 0.05 and P = 0.01 respectively

Table 64. Estimates of specific combining ability effects for fruit juice characteristics in tomato

	Juice yield (%)	TSS	Total solids (%)	Insoluble solids (%)	Reducing sugar (%)	Acidity (%)	pH	Consistency (PPT)	Lycopene (mg/100 g)	Ascorbic acid (mg/100 g)
Sakthi x St 4	-0.24	-0.51**	-0.25	-0.03	-0.00	0.003	-0.02	-0.004	-0.53	01.26
Sakthi x Ohio 8129	0.36	0.06	-0.20	-0.02	-0.10	0.015	0.02	-0.003	0.02	-0.12
Sakthi x HW 208 F	0.36	0.07	0.14	0.07*	-0.03	-0.004	0.04	0.011	0.32	0.21
Sakthi x TH 318	-0.44	0.31*	0.30*	-0.002	0.04	-0.012	0.01	-0.003	0.07	-0.53
Sakthi x Fresh Market 9	-0.04	0.08	-0.16	-0.03	0.09	-0.006	-0.05	0.000	0.12	-0.81
LE 206 x St 64	-0.20	0.95**	0.32	0.05	0.05	0.020	0.03	0.004	1.31**	-1.85
LE 206 x Ohio 8129	0.60	-0.26*	0.58**	0.07*	0.05	-0.021	-0.02	0.009	1.41**	0.92
LE 206 x HW 208 F	0.00	-0.25	-0.25	-0.11**	-0.06	-0.010	-0.01	-0.0002	-0.66*	-1.24
LE 206 x TH 318	-0.20	-0.20	-0.39	-0.01	0.04	0.002	-0.02	-0.008	-0.98**	0.37
LE 206 x Fresh Market 9	-0.20	-0.24	-0.25	-0.01	-0.19	0.011	0.01	-0.005	1.08**	-1.91
LE 214 x St 64	0.44	-0.43**	-0.03	-0.03	-0.04	-0.027	-0.02	0.0002	-0.78**	-3.12
LE 214 x Ohio 8129	-0.96	0.20	-0.38	-0.06	0.05	0.007	0.01	-0.005	-1.43**	-0.80
LE 214 x HW 208 F	-0.36	0.19	0.12	0.04	-0.03	0.014	-0.04	-0.011	0.35	1.03
LE 214 x TH 318	0.64	-0.11	-0.11	0.01	-0.08	0.010	0.01	0.011	0.91**	0.17
LE 214 x Fresh Market 9	0.24	0.16	0.40	0.04	0.10	-0.004	0.04	0.005	0.96**	2.72
SE (sij)	0.81	0.13	0.20	0.03	0.19	0.015	0.04	0.008	0.28	1.31
SE (sij-skl)	[illegible]	0.18	0.28	0.04	0.26	0.021	0.06	0.011	0.40	1.85

Table 50. Components of additive and non-additive variances and heritability with respect to fruit juice characteristics in tomato

Variances	Juice yield (%)	TSS (%)	Total solids (%)	Insoluble solids (%)	Reducing sugar (%)	Acidity (%)	pH	Consistency (PPT)	Lycopene (mg/100 g)	Ascorbic acid (mg/100g)
Cov HS	0.21	0.004	0.06	0.0003	0.02	0.00005	0.0002	0.00005	0.51	1.60
$\sigma^2 A$	0.85	0.015	0.24	0.001	0.06	0.00018	0.0007	0.00019	2.03	6.40
Cov FS	2.11	0.232	1.05	0.006	0.17	0.00075	0.0014	0.00069	8.32	24.49
$\sigma^2 D$	-0.32	0.210	0.14	0.004	-0.02	0.00010	-0.0005	0.00002	1.31	2.17
Heritability	0.21	0.05	0.45	0.14	0.37	0.19	0.07	0.48	0.57	0.47

ability effects for consistency was very low. Non-additive variance was negligible and heritability observed was moderately high.

The parents which recorded high lycopene content, St 64, Ohio 8129 and LE 206, also showed significantly high gca effects (2.41, 2.24 and 1.56 respectively). All the other parents had negative gca effects. LE 206 x Ohio 8129 and LE 206 x St 64 exhibited significantly high sca effects (1.41 and 1.31 respectively). LE 214 x Fresh Market 9 (0.96) and LE 214 x TH 318 (0.91) had also significant sca effects. A high magnitude of additive variance (2.03) coupled with high heritability (0.57) was observed for lycopene content.

Significantly high gca effects were observed in HW 208 F (4.13) and LE 214 (2.93) for ascorbic acid. LE 214 also had high <u>per se</u> performance ([illegible] mg/100 g) among 64 genotypes. Positive sca effect though not significant was recorded in LE 214 x Fresh Masrket 9 (2.72), LE 206 x [illegible] (1.85) and Sakthi x St 64 (1.26). Additive genetic variance ([illegible]) was more and the heritability was moderately high (0.47).

2. Heterosis

Sakthi, LE 206 and LE 214 were crossed with selected male lines, St 64, Ohio 8129, HW 208 F, TH 318 and Fresh Market 9. Heterosis over better parent (heterobeltiosis) and midparent (relative heterosis) were estimated and presented along with the mean performance of parents (Tables 51 to 59).

a. Fruit yield and its components

The estimate of heterobeltiosis and relative heterosis ranged from -21.50% to 9.93% and -15.35% to 14.39% respectively. Three hybrids with TH 318 as male and Sakthi, LE 206 and LE 214 as females showed significant heterobeltiosis (4.62%, 8.21% and 9.93% respectively). The tallest hybrid (LE 214 x TH 318) had a height of 93 cm. All the hybrids were late to harvest. The heterobeltiosis ranged from 7.30% to 21.37% whereas relative heterosis ranged from 2.14% to 14.37% (Table 51).

The hybrid Sakthi x TH 318 produced more fruits (32.40). Relative heterosis was positive and significant (9.83%), though heterobeltiosis was negative (-5.26%). The hybrids Sakthi x Fresh Market 9 (1.15 kg) and Sakthi x TH 318 (1.28 kg) yielded more than the better parents but the heterotic effects were not significant (8.48% and 7.04% respectively). Significant relative heterosis was observed in these hybrids (9.20% and 13.24%) (Table 52).

b. Fruit characteristics

Significant relative heterosis was observed in Sakthi x Fresh Market 9 and Sakthi x HW 208 F (18.73% and 10.90% respectively) for fruit weight. The *per se* performance of hybrids were 70.97 g and 55.62 g respectively. The female parents were characterised by round fruits with shape index <1 and male parents had fruits with shape index >1. The hybrids produced fruits with round shape as indicated by index value 1. Consequently the estimate over better parent (-27.05 to -13.46%) and mid parent (-15.63 to -2.73%) were negative (Table 53).

LE 206 x Ohio 8129 (55.56%) and LE 214 x St 64 (6.67%) showed significant positive heterobeltiosis for locules/fruit. All other hybrids had a fewer locules compared to the better parent, as indicated by the negative estimate of heterobeltiosis (-33.33% to -8.00%). The relative heterosis ranged from -22.58% to 78.57%. The hybrids Sakthi x LE 206 and LE 214 x St 64 had increased pericarp thickness (6.08 mm, 6.29 mm and 6.12 mm respectively) as indicated by the significant relative heterosis. (16.70%, 10.45% and 10.76% respectively). Sakthi x Fresh Market 9, Sakthi x HW 208 F, Sakthi x TH 318 and LE 206 x Fresh Market 9 exceeded their midparental values but the increases were not significant. Storage life of fruits from hybrids were enhanced (13.20 to 22.80 days)

Table 51. Mean performance of parental lines and F_1 hybrids and extent of heterosis in tomato for plant height and days to harvest

Parents/F_1 hybrids	Plant height (cm)			Days to harvest		
	Mean	HB (%)	RH (%)	Mean	HB (%)	RH (%)
Parents						
Sakthi	68.6			93.6		
LE 206	71.0			93.2		
LE 214	84.6			97.4		
St 64	82.2			100.8		
Ohio 8129	79.2			108.6		
HW 208 F	84.6			110.6		
TH 318	78.0			105.4		
Fresh Market 9	81.8			105.8		
F_1 hybrids						
Sakthi x St 64	64.4	-21.56	-14.59	100.8	7.69	3.70
Sakthi x Ohio 8129	63.0	-20.45	-14.75	106.4	13.68	5.24
Sakthi x HW 208 F	70.6	-16.55	-7.83	107.6	14.96	5.39
Sakthi x TH 318	81.6	4.62*	11.32**	104.0	11.11	4.52
Sakthi x Fresh Market 9	73.0	-10.76	-4.70	113.6	21.37	13.94
LE 206 x St 64	72.4	-11.92	-5.48	100.0	7.30	3.09
LE 206 x Ohio 8129	68.8	-13.13	-8.39	105.8	13.52	4.86
LE 206 x HW 208 F	71.6	-15.17	-7.97	109.4	17.38	7.36
LE 206 x TH 318	84.4	8.21**	13.29**	105.0	12.66	5.74
LE 206 x Fresh Market 9	74.4	-9.05	-2.62	109.0	16.95	9.55
LE 214 x St 64	70.6	-16.55	-15.35	103.2	5.95	4.14
LE 214 x Ohio 8129	70.2	-17.02	-14.29	105 2	8.01	2.14
LE 214 x HW 208 F	82.6	-2.36	-2.36	115.0	18.07	10.58
LE 214 x TH 318	93.0	9.93**	14.39**	113.4	16.43	11.83
LE 214 x Fresh Market 9	78.8	-6.86	-5.29	116.2	19.30	14.37
SEm	1.22			1.05		
* CD (P = 0.05)		3.43	2.97		2.96	2.56
** CD (P = 0.01)		4.55	3.94		3.92	3.39

Table 52. Mean performance of parental lines and F_1 hybrids and extent of heterosis in tomato for fruits/plant and fruit yield/plant

Parents/F_1 hybrids	Fruits/plant			Fruit yield/plant (g)		
	Mean	HB (%)	RH (%)	Mean	HB (%)	RH (%)
Parents						
Sakthi	34.2			1065.18		
LE 206	41.2			880.66		
LE 214	27.2			691.20		
St 64	23.6			887.75		
Ohio 8129	24.8			835.89		
HW 208 F	15.2			1045.40		
TH 318	24.8			1196.18		
Fresh Market 9	12.0			1051.08		
F_1 hybrids						
Sakthi x St 64	24.8	-27.49	-14.19	813.90	-23.59**	-16.65**
Sakthi x Ohio 8129	24.8	-27.49	-15.93	705.48	-33.77**	-25.78**
Sakthi x HW 208 F	18.4	-46.20	-25.51	1022.05	-4.05	-3.15
Sakthi x TH 318	32.4	-5.26	9.83*	1280.34	7.04	13.24**
Sakthi x Fresh Market 9	16.4	-52.05	-29.00	1155.47	8.48	9.20*
LE 206 x St 64	23.6	-42.72	-27.16	721.43	-18.74**	-18.41**
LE 206 x Ohio 8129	24.4	-40.78	-26.06	654.56	-25.67**	-23.74**
LE 206 x HW 208 F	20.0	-51.46	-29.08	726.25	-30.53**	-24.59**
LE 206 x TH 318	18.0	-56.31	-45.45	576.17	-51.83**	-44.51**
LE 206 x Fresh Market 9	22.0	-46.60	-17.29	775.00	-26.27**	-19.76**
LE 214 x St 64	19.4	-28.68	-23.62	559.61	-36.96**	-29.12**
LE 214 x Ohio 8129	21.0	-22.79	-19.63	523.00	-37.43**	-31.50**
LE 214 x HW 208 F	18.2	-33.09	-14.15	758.58	-27.44**	-12.64**
LE 214 x TH 318	22.8	-16.18	-12.31	821.35	-31.34**	-12.96**
LE 214 x Fresh Market 9	16.6	-38.97	-15.31	693.60	-34.01**	-20.38**
SEm	1.17			32.44		
* CD (P = 0.05)		3.29	2.85		91.07	78.91
** CD (P = 0.01)		4.36	3.78		120.66	104.53

Table 53. Mean performance of parental lines and F_1 hybrids and extent of heterosis in tomato for average fruit weight and fruit shape index

Parents/F_1 hybrids	Average fruit weight (g)			Fruit shape index		
	Mean	HB (%)	RH (%)	Mean	HB (%)	RH (%)
Parents						
Sakthi	31.17			0.89		
LE 206	21.40			0.79		
LE 214	25.86			0.88		
St 64	37.78			1.05		
Ohio 8129	34.16			1.22		
HW 208 F	69.14			1.03		
TH 318	48.81			1.10		
Fresh Market 9	88.38			1.04		
F_1 hybrids						
Sakthi x St 64	32.91	-12.89	-4.54	0.87	-17.14**	-10.31**
Sakthi x Ohio 8129	28.70	-15.98	-12.14	0.89	-27.05**	-15.64**
Sakthi x HW 208 F	55.62	-19.55	10.90*	0.89	-13.59**	-7.29**
Sakthi x TH 318	39.53	-19.01	-1.15	0.92	-16.36**	-7.54**
Sakthi x Fresh Market 9	70.97	-19.70	18.73**	0.90	-13.46**	-6.74**
LE 206 x St 64	30.64	-18.90	3.55	0.89	-15.24**	-3.26**
LE 206 x Ohio 8129	26.96	-21.08	-2.95	0.89	-27.05**	-11.44**
LE 206 x HW 208 F	36.35	-47.43	-19.70	0.87	-15.53**	-4.40**
LE 206 x TH 318	32.06	-34.32	-8.67	0.91	-17.27**	-3.70*
LE 206 x Fresh Market 9	35.30	-60.06	-35.69	0.89	-14.42**	-2.73
LE 214 x St 64	29.07	-23.05	-8.64	0.88	-16.19**	-8.81**
LE 214 x Ohio 8129	25.00	-26.81	-16.69	0.90	-26.23**	-14.29**
LE 214 x HW 208 F	41.70	-39.69	-12.21	0.89	-13.59**	-6.81**
LE 214 x TH 318	36.37	-25.49	-2.58	0.91	-17.27**	-8.08**
LE 214 x Fresh Market 9	42.01	-52.47	-26.45	0.86	-17.31**	-10.42**
SEm	1.83			0.01		
* CD (P = 0.05)		5.15	4.46		0.04	0.03
** CD (P = 0.01)		6.82	5.91		0.05	0.03

Plate XI F_1 hybrid Sakthi x HW 208 F


SAKTHI x HW 208 F

when compared to the female parents (9.20 to 15.20 days) which had comparatively a low keeping quality. But the increase when worked out over better parent turned to be negative except in one hybrid (LE 206 x Fresh Market 9 = 1.03%). Hybrids of Sakthi, LE 206 and LE 214 with Fresh Market 9 expressed significant relative heterosis (31.08%, 12.00% and 17.48% respectively) (Table 54).

The female parents Sakthi and LE 214 had fruit cracking (27.32% and 8.71% respectively). Among the male parents, Fresh Market 9 also showed very low cracking (4.14%). All other male parents and LE 206 among female parents did not crack. Irrespective of the female and male parents involved in the crosses, the hybrids were completely free from cracking.

c. Fruit [illegible] characteristics

The [illegible] parents had more juice yield but none of the crosses expressed [illegible] heterobeltiosis (-2.11% to 1.23%). Relative heterosis ranged from [illegible] to 3.51%. Sakthi x HW 208 F and LE 214 x HW 208 F showed significant relative heterosis (2.43%). LE 206 x St 64 had the highest TSS (7.67%). Heterobeltiosis (21.95%) and relative heterosis (32.83%) were significant and the highest for the hybrid. Sakthi x TH 318 (8.02%) and LE 214 x Fresh Market 9 (9.17%) also had significant positive relative heterosis (Table 55).

More number of hybrids expressed heterobeltiosis and relative heterosis for total solids and the estimate ranged from -10.86% to 28.49% and 3.41% to 34.64% respectively. Sakthi x HW 208 F had the maximum total solids (9.18%) but the estimate of heterobeltiosis was not the highest (11.95%) due to high *per se* performance of HW 208 F. The maximum heterobeltiosis (28.49%) and relative heterosis (34.64%) were expressed by Sakthi x TH 318. All hybrids except LE 214 x Ohio 8129 exhibited significant relative heterosis. All the F_1 hybrids showed increased insoluble solids (0.66% to 0.91%) over female parents which were relatively

Table 56. Mean performance of parental lines and F[illegible] hybrids and extent of heterosis in tomato for [illegible]/fruit, pericarp thickness and storage life

Parents/F_1 hybrids	[illegible] Mean	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Storage life (days) Mean	HB (%)	RH (%)
Parents									
[illegible]	[illegible]			[illegible]			15.2		
LE 206	[illegible]			[illegible]			15.6		
LE 214	[illegible]			[illegible]			9.2		
Sr 64	[illegible]			[illegible]			26.2		
Ohio 8129	[illegible]			[illegible]			28.6		
HW 208 F	[illegible]			[illegible]			22.8		
TH 318	[illegible]			[illegible]			19.0		
Fresh Market 9	[illegible]			[illegible]			19.4		
F_1 hybrids									
[illegible] x Sr 64	[illegible]	[illegible]**	[illegible]**	[illegible]	[illegible]	[illegible]**	19.8	-24.43**	8.79
[illegible] x Ohio 8129	[illegible]	[illegible]**	[illegible]**	[illegible]	[illegible]	-12.38	20.4	-28.67**	5.15
[illegible] x HW 208 F	[illegible]	[illegible]**	[illegible]	[illegible]	[illegible]	[illegible]	18.4	-19.30**	11.52
[illegible] x TH 318	[illegible]	[illegible]**	[illegible]**	[illegible]	[illegible]	3.29	15.0	-26.67**	2.74
[illegible] x Fresh Market 9	[illegible]	[illegible]**	[illegible]	[illegible]	[illegible]	1.70	19.4	—	31.08**
LE 206 x Sr 64	[illegible]	[illegible]**	[illegible]**	[illegible]	[illegible]	[illegible]**	21.4	-18.32**	2.39
LE 206 x Ohio 8129	[illegible]	[illegible]**	[illegible]**	[illegible]	[illegible]	-9.96	22.8	-20.28**	3.17
LE 206 x HW 208 F	[illegible]	[illegible]**	[illegible]**	[illegible]	[illegible]	-3.18	20.4	-10.53**	6.25
LE 206 x TH 318	[illegible]	[illegible]**	[illegible]**	[illegible]	[illegible]	[illegible]	16.60	-12.63*	-4.05
LE 206 x Fresh Market 9	[illegible]	[illegible]**	[illegible]	[illegible]	[illegible]	5.63	19.6	1.03	12.00*
LE 214 x Sr 64	3.2	[illegible]*	[illegible]**	[illegible]	[illegible]	10.76**	18.4	-29.77**	3.95
LE 214 x Ohio 8129	[illegible]	[illegible]**	[illegible]	[illegible]	[illegible]	13.41	18.40	-35.66**	-2.65
LE 214 x HW 208 F	[illegible]	[illegible]	[illegible]	[illegible]	11.82	[illegible]	17.00	-25.44**	6.25
LE 214 x TH 318	[illegible]	[illegible]**	[illegible]	[illegible]	[illegible]	-3.38	13.20	-30.53**	-6.38
LE 214 x Fresh Market 9	4.2	[illegible]**	[illegible]*	[illegible]	21.70	-10.11	16.80	-13.40*	17.48*
SEm	0.07			[illegible]			0.80		
* CD (P = 0.05)		[illegible]	0.16		[illegible]	0.39		2.23	1.93
** CD (P = 0.01)		[illegible]	[illegible]		0.60	0.52		2.96	2.56

Table 55. Mean performance of parental lines and F_1 hybrids and extent of heterosis in tomato for juice yield and TSS

Parents/F_1 hybrids	Juice yield (%)			TSS (%)		
	Mean	HB (%)	RH (%)	Mean	HB (%)	RH (%)
Parents						
Sakthi	79.8			5.60		
LE 206	80.4			5.74		
LE 214	80.4			4.90		
St 64	85.4			4.80		
Ohio 8129	81.0			5.00		
HW 208 F	85.6			5.04		
TH 318	83.2			4.62		
Fresh Market 9	85.2			4.26		
F_1 hybrids						
Sakthi x St 64	84.4	-1.17	2.18	5.12	-8.57**	-1.54
Sakthi x Ohio 8129	82.0	1.23	1.99	5.02	-10.36**	-5.28
Sakthi x HW 208 F	85.6	--	3.51**	5.04	-10.10**	-5.26
Sakthi x TH 318	82.4	0.96	1.10	5.52	-1.43	-8.02**
Sakthi x Fresh Market 9	84.8	0.47	2.79*	5.06	-9.64**	2.64
LE 206 x St 64	83.6	2.11	0.84	7.00	21.95**	32.83**
LE 206 x Ohio 8129	81.4	0.49	0.82	5.12	-10.80**	-4.66
LE 206 x HW 208 F	84.4	-1.40	1.69	5.14	-10.45**	-4.64
LE 206 x TH 318	81.8	-1.68	--	5.42	-5.57	4.63
LE 206 x Fresh Market 9	83.8	1.64	1.21	5.16	-10.10*	3.20
LE 214 x St 64	84.6	-0.94	2.05	5.06	3.27	4.33
LE 214 x Ohio 8129	80.2	-0.99	-0.62	5.02	0.40	1.41
LE 214 x HW 208 F	84.4	-1.40	2.43*	5.02	-0.40	1.01
LE 214 x TH 318	83.0	-0.24	1.47	4.96	1.22	4.20
LE 214 x Fresh Market 9	84.6	-0.70	2.17	5.00	2.04	9.17**
SEm	0.81			0.12		
* CD (P = 0.05)		2.28	1.97		0.35	0.30
** CD (P = 0.01)		3.02	2.62		0.46	0.40

Plate XII F_1 hybrid LE 206 x Ohio 8129

Plate XIII F_1 hybrid LE 206 x St 64


LE 206- OHIO 8129


LE 206 x SLC4

low in insoluble solids (0.45% to 0.62%). No hybrids exceeded the better parent (-43.65% to -11.54%). Though four hybrids exhibited positive relative heterosis, only LE 214 x Fresh Market 9 expressed significant heterosis (12.20%) (Table 56).

Significant positive heterobeltiosis was expressed by LE 206 x Ohio 8129 for reducing sugar (19.88%). Positive heterobeltiosis (1.92% to 14.37%) expressed by other hybrids were not significant. LE 206 x St 64 (18.29%), LE 206 x Ohio 8129 (20.62%) and LE 214 x Ohio 8129 (14.90%) had significant relative heterosis. The female parents which were soft fruited had more acidity (0.51% to 0.58%) than firm fruited male parents (0.3[illegible] to [illegible]). All the hybrids showed negative heterobeltiosis (-20.37% to [illegible]). The relative heterosis ranged from -4.44% to 8.51%. The positive relative heterosis expressed by ten hybrids were not significant (Table 57).

The hybrids produced fruits with a low pH. The estimate of heterobeltiosis ([illegible].41% to -2.53%) and relative heterosis (-11.32% to -2.24%) were all negative. All the hybrids had more pulp consitency (0.23 to 0.31) than the female parents which were relatively low in consistency (0.16 to 0.21). The hybrids Sakthi x LE 206 and LE 214 x Fresh Market 9 expressed significant positive heterobeltiosis (19.05%, 14.29% and 9.52% respectively). The relative heterosis ranged from 2.04% to 24.32% and nine out of fifteen crosses exhibited significant relative heterosis (Table 58).

The magnitude of heterosis was the highest for lycopene content as expressed by heterobeltiosis (-20.54% to 78.09%) and relative heterosis (2.56% to 107.29%). In four out of six crosses, involving St 64 and Ohio 8129 as male parents, significantly higher heterobeltiosis was observed. LE 206 x St 64 (78.09%) and LE 206 x Ohio 8129 (107.29%) expressed maximum heterobeltiosis and relative heterosis respectively. These hybrids had 11.38 mg and 11.66 mg/100 g lycopene respectively. The

Table 56. Mean performance of parental lines and F_1 hybrids and extent of heterosis in tomato for total solids and insoluble solids

Parents/F_1 hybrids	Total solids (%)			Insoluble solids (%)		
	Mean	HB (%)	RH (%)	Mean	HB (%)	RH (%)
Parents						
Sakthi	6.06			0.54		
LE 206	6.56			0.62		
LE 214	5.67			0.45		
St 64	7.54			1.13		
Ohio 8129	7.83			1.16		
HW 208 F	8.20			1.26		
TH 318	6.67			0.84		
Fresh Market 9	5.50			0.78		
F_1 hybrids						
Sakthi x St 64	8.53	13.13**	25.44**	0.78	-30.97	-6.59
Sakthi x Ohio 8129	8.24	5.24	18.65**	0.80	-31.03	-5.88
Sakthi x HW 208 F	9.18	11.95**	28.75**	0.91	-27.78	1.11
Sakthi x TH 318	8.57	28.49**	34.64**	0.69	-17.86	--
Sakthi x Fresh Market 9	7.14	17.82**	23.53**	0.67	-14.10	1.52
LE 206 x St 64	8.91	18.17**	26.38**	0.84	-25.66	-6.00
LE 206 x Ohio 8129	8.82	12.64**	22.59**	0.88	-24.14	-1.12
LE 206 x HW 208 F	8.58	4.63	16.26**	0.71	-43.65	-24.47
LE 206 x TH 318	7.47	11.99**	12.93**	0.67	-20.24	-8.22
LE 206 x Fresh Market 9	6.84	4.27	13.43**	0.68	-12.82	-2.86
LE 214 x St 64	7.69	1.99	16.43**	0.73	-35.40	-7.59
LE 214 x Ohio 8129	6.98	-10.86	3.41	0.71	-38.79	-11.80
LE 214 x HW 208 F	8.07	-1.59	16.37**	0.83	-34.13	-2.92
LE 214 x TH 318	6.87	3.00	11.35**	0.66	-21.43	2.33
LE 214 x Fresh Market 9	6.62	16.75**	18.53**	0.69	-11.54	12.20*
SEm	0.20			0.026		
* CD (P 0.05)		0.56	0.49		0.07	0.06
** CD (P 0.01)		0.75	0.65		0.10	0.08

Table 57. Mean performance of parental lines and F_1 hybrids and extent of heterosis in tomato for reducing sugar and acidity

Parents/F_1 hybrids	Reducing sugars (%)			Acidity (%)		
	Mean	HB (%)	RH (%)	Mean	HB (%)	RH (%)
Parents						
Sakthi	3.56			0.58		
LE 206	3.27			0.54		
LE 214	3.12			0.51		
St 64	3.02			0.40		
Ohio 8129	3.23			0.36		
HW 208 F	3.11			0.40		
TH 318	3.18			0.43		
Fresh Market 9	2.72			0.35		
F_1 hybrids						
Sakthi x St 64	3.39	-4.78	3.04	0.50	-13.79	2.04
Sakthi x Ohio 8129	3.48	-2.25	2.50	0.49	-15.52	4.26
Sakthi x HW 208 F	3.15	-11.52	-5.55	0.49	-15.52	--
Sakthi x TH 318	3.19	-10.39	-5.34	0.52	-10.34	2.97
Sakthi x Fresh Market 9	2.64	-25.84**	-15.92*	0.47	-18.97	1.08
LE 206 x St 64	3.74	14.37	18.92*	0.49	9.26	4.26
LE 206 x Ohio 8129	3.92	19.88*	20.62**	0.43	-20.37	-4.44
LE 206 x HW 208 F	3.54	8.26	10.97	0.46	-14.81	-2.13
LE 206 x TH 318	3.48	6.42	7.91	0.51	-5.56	5.15
LE 206 x Fresh Market 9	2.66	18.65*	11.19	0.46	-14.81	3.37
LE 214 x St 64	3.37	8.01	9.77	0.44	-13.73	-3.30
LE 214 x Ohio 8129	3.65	13.00	14.96*	0.46	-9.80	--
LE 214 x HW 208 F	3.18	1.92	2.09	0.48	-5.88	5.49
LE 214 x TH 318	3.08	-3.14	-2.22	0.51	--	8.51
LE 214 x Fresh Market 9	2.67	-14.42	-8.56	0.44	-13.73	2.33
SEm	0.01			0.015		
* CD (P = 0.05)		0.53	0.46		0.04	0.04
** CD (P = 0.01)		0.71	0.61		0.06	0.06

Table 58. Mean performance of parental lines and F_1 hybrids and extent of heterosis in tomato for pH and consistency

Parents/F_1 hybrids	pH			Consistency (PPT)		
	Mean	HB (%)	RH (%)	Mean	HB (%)	RH (%)
Parents						
Sakthi	4.06			0.21		
LE 206	3.94			0.18		
LE 214	4.06			0.16		
St 64	4.42			0.28		
Ohio 8129	4.50			0.32		
HW 208 F	4.34			0.33		
TH 318	4.51			0.28		
Fresh Market 9	3.96			0.21		
F_1 hybrids						
Sakthi x St 64	3.80	-14.03	-10.38**	0.27	-3.57	10.20**
Sakthi x Ohio 8129	3.90	-13.33**	-8.88**	0.28	-12.5	5.66
Sakthi x HW 208 F	3.95	-8.99**	-5.95**	0.31	-6.06	14.81**
Sakthi x TH 318	3.80	-15.74**	-11.32**	0.25	-10.71	2.04
Sakthi x Fresh Market 9	3.80	-6.40**	-5.24**	0.25	19.05**	19.05**
LE 206 x St 64	3.85	-12.90**	-7.89**	0.27	-3.57	17.39**
LE 206 x Ohio 8129	3.86	-14.22**	-6.76**	0.29	-9.38	16.00**
LE 206 x HW 208 F	3.90	-10.14**	-5.80**	0.30	-9.09	17.65**
LE 206 x TH 318	3.77	-16.41**	-10.77**	0.25	-10.71	8.70
LE 206 x Fresh Market 9	3.86	-2.53	-2.28	0.24	14.29*	23.08**
LE 214 x St 64	3.83	-13.35**	-9.67**	0.25	-10.71	13.64**
LE 214 x Ohio 8129	3.92	-12.89**	-8.47**	0.26	-18.75	8.33
LE 214 x HW 208 F	3.90	-10.14**	-7.14**	0.26	-21.21	6.12
LE 214 x TH 318	3.83	-15.08**	-10.62**	0.24	-14.29	9.09
LE 214 x Fresh Market 9	3.92	-3.45*	-2.24	0.23	9.52*	24.32**
SEm	0.043			0.008		
* CD (P = 0.05)		0.12	0.11		0.02	0.02
** CD (P = 0.01)		0.16	0.14		0.03	0.03

estimate of relative heterosis for ascorbic acid content ranged from -26.66% to 16.45%. Sakthi x St 64, Sakthi x HW 208 F and LE 206 x St 64 expressed significant relative heterosis (16.45%, 14.90% and 15.57% respectively). The positive heterobeltiosis expressed by Sakthi x HW 208 F (10.39%), Sakthi x St 64 (2.41%) and LE 206 x St 64 (0.49%) were not significant (Table 59).

3. Evaluation of F_1 hybrids for ketchup and paste

a. Ketchup

Var[illegible] due to tomato genotypes were significant for ketchup yield and [illegible] [illegible]ical composition and sensory scores. Mean square due to par[illegible] [illegible] hybrids were significant, for all characters except consiste[illegible] [illegible]res for consistency and colour (Tables 60 & 61).

[illegible] HW 208 F had the maximum ketchup recovery (40.33%) but it [illegible] differ significantly from HW 208 F (39.13%), the better parent. LE [illegible] St 64 (38.33%), Sakthi x St 64 (38.00%), LE 206 x Ohio 8129 [illegible] and Sakthi x Ohio 8129 (37.50%) also had increased ketchup [illegible] over the parents. None of the F_1 hybrids exceeded the standard parent HW 208 F (0.52) in consistency. Sakthi x HW 208 F recorded the highest consistency (0.48) among the F_1s. The hybrids LE 206 x Ohio 8129 (28.75 mg/100 g), LE 206 x St 64 (27.67 mg/100 g), Sakthi x Ohio 8129 (21.63 mg/100 g) and Sakthi x St 64 (18.26 mg/100 g) had comparatively higher lycopene content than rest of the F_1 hybrids and parents. All the hybrids were above the minimum limit for acidity in ketchup (1.20%). The lowest acidity was recorded in LE 206 x Ohio 8129 (1.67%) and the highest in Sakthi x TH 318 (2.02%) (Table 62).

Sakthi x HW 208 F recorded the maximum overall score (82.20) and also component factors, consistency (22.00), flavour (20.20) and absence of defects. LE 206 x Ohio 8129 scored the maximum for colour (24.20), closely followed by LE 206 x St 64 (23.80) and Sakthi x Ohio 8129 (23.60).

Table 59 . Mean performance of parental lines and F_1 hybrids and extent of heterosis in tomato for lycopene and ascorbic acid

Parents/F_1 hybrids	Lycopene (mg/100 g)			Ascorbic acid (mg/100 g)		
	Mean	HB (%)	RH (%)	Mean	HB (%)	RH (%)
Parents						
Sakthi	2.94			24.06		
LE 206	4.70			24.71		
LE 214	3.05			38.88		
St 64	6.39			18.26		
Ohio 8129	6.55			17.60		
HW 208 F	5.55			22.17		
TH 318	3.91			16.27		
Fresh Market 9	3.79			26.22		
F_1 hybrids						
Sakthi x St 64	7.63	19.41**	63.56**	24.64	2.41	16.45*
Sakthi x Ohio 8129	8.36	27.63**	76.19**	17.20	-28.51**	-17.43*
Sakthi x HW 208 F	5.22	-5.95	22.97*	26.56	10.39	14.90*
Sakthi x TH 318	4.25	8.70	24.09*	18.84	-21.70**	-6.57
Sakthi x Fresh Market 9	4.16	9.76	23.63*	23.87	-8.96	-5.05
LE 206 x St 64	11.38	78.09**	105.23**	24.83	0.49	15.57*
LE 206 x Ohio 8129	11.66	78.02**	107.29**	17.85	-27.76**	-15.62
LE 206 x HW 208 F	6.15	10.81	20.00**	24.71	--	5.42
LE 206 x TH 318	5.12	8.94	18.93*	19.34	-21.73**	5.61
LE 206 x Fresh Market 9	4.88	3.83	14.96*	22.38	-14.65**	-12.11
LE 214 x St 64	6.54	2.35	38.56**	24.45	-37.11**	-14.42
LE 214 x Ohio 8129	6.07	-7.33	26.46**	20.71	-46.73**	-26.66
LE 214 x HW 208 F	4.41	-20.54**	2.56	31.57	-18.80**	3.42
LE 214 x TH 318	4.24	8.44	21.84*	23.72	-38.99**	-13.98
LE 214 x Fresh Market 9	4.16	9.76	21.64*	31.59	-18.75**	-2.95
SEm	0.28			1.11		
* CD (P = 0.05)		0.81	0.70		3.72	3.22
** CD (P = 0.01)		1.08	0.93		4.97	4.31

Table 60. Analyses of variance for ketchup yield and its chemical composition (F_1 hybrids)

Sources of variation	df	Mean squares			
		Ketchup recovery (%)	Consistency (PPT)	Lycopene (mg/100 g)	Total acidity (%)
Genotypes	13	40.48**	0.010**	141.56**	0.24**
Parents	6	53.10**	0.018**	55.22**	0.25**
Hybrids	6	12.30**	0.004**	182.73**	0.05**
Parents vs hybrids	1	133.82**	0.0005	412.54**	1.28**
Error	28	0.58	0.0004	0.12	0.01

** Significant at P = 0.01

Table 61. Analyses of variance for sensory scores of ketchup (F_1 hybrids)

Sources of variation	df	Mean squares				
		Consistency	Colour	Flavour	Absence of defects	Overall scores
Genotypes	13	43.43**	4[illegible].91**	59.07**	12.19**	448.11**
Parents	6	71.78**	51.91**	68.27**	7.05**	570.52**
Hybrids	6	22.16**	36.43**	55.11**	13.65**	399.03**
Parents vs hybrids	1	0.91	1.73	27.66**	34.30**	8.25**
Error	56	0.59	0.91	0.45	0.51	2.50

** Significant at P = 0.01

Table 62. Ketchup yield and its chemical composition (F_1 hybrids)

Genotypes	Ketchup yield (%)	Consistency (PPT)	Lycopene (mg/100 g)	Total acidity (%)
Sakthi	29.55	0.37	5.98	2.48
LE 206	27.59	0.31	12.71	2.54
St 64	36.30	0.48	16.62	1.97
Ohio 8129	36.93	0.50	17.50	1.86
HW 208 F	39.13	0.52	13.58	1.86
TH 318	35.17	0.43	10.62	2.28
Fresh Market 9	32.00	0.37	7.77	1.99
Sakthi x St 64	38.00	0.42	18.26	1.73
Sakthi x Ohio 8129	37.50	0.42	21.03	1.73
Sakthi x HW 208 F	40.33	0.48	12.50	1.77
Sakthi x TH 318	35.67	0.38	10.35	2.02
Sakthi x Fresh Market 9	34.00	0.37	10.12	1.72
LE 206 x St 64	38.33	0.42	27.67	1.90
LE 206 x Ohio 8129	37.83	0.44	28.75	1.67
CD (P = 0.05)	1.28	0.03	0.58	0.19
CD (P = 0.01)	1.72	0.05	0.79	0.26

Among the hybrids, Sakthi x HW 208 F, Sakthi x Ohio 8129, Sakthi x St 64, LE 206 x St 64 and LE 206 x Ohio 8129 scored Grade II standard. This was an improvement over Sakthi and LE 206 which scored only 58.20 and 70.40 respectively of overall score (Table 63).

b. Paste

The analyses of variance indicated significant differences among genotypes for paste yield, its components and sensory scores. Mean squares due to hybrids also differed significantly except paste yield and overall score (Table 64).

Sakthi x HW 208 F recorded the maximum paste recovery (25.08%) but it did not differ significantly from hybrids Sakthi x Ohio 8129, LE 206 x St 64, LE 206 x Ohio 8129 and parents Ohio 8129 and HW 208 F.

For consistency, Sakthi x HW 208 F was the highest (0.71) but it was significantly lower than the top parent HW 208 F. LE 206 x Ohio 8129 recorded the highest lycopene in the paste (42.44 mg/100 g) followed by LE 206 x St 64 (40.17 mg/100 g) and Sakthi x Ohio 8129 (29.75 mg/100 g). LE 206 x Ohio 8129 recorded the lowest acidity in the paste ([illegible]) among the hybrids (Table 65).

LE 206 x Ohio 8129 had the highest score for colour (58.80) and Sakthi x HW 208 F for absence of defects (32.20). The paste from the hybrids confirmed to Grade II standard and this was an improvement over parents LE 206 and Sakthi (overall score 66.80 and 57.20 respectively) (Table 66).

4. Evaluation for bacterial wilt resistance

Incidences of bacterial wilt in tomatoes grown in a wilt sick plot were recorded (Table 67). Except Sakthi, LE 214 and LE 206, all the

Table 63 . Sensory scores of ketchup (F_1 hybrids)

Genotypes	Consistency (25)	Colour (25)	Flavour (25)	Absence of defects (25)	Overall scores (100)	Grade
Sakthi	12.4	13.6	13.6	18.6	58.2	
LE 206	15.0	20.4	15.4	19.6	70.4	
St 64	21.0	23.4	21.0	19.8	85.2	I
Ohio 8129	20.6	23.8	21.0	20.0	85.4	I
HW 208 F	23.4	22.0	21.0	19.4	85.8	I
TH 318	19.4	18.2	19.6	16.8	74.0	
Fresh Market 9	17.4	17.2	15.4	17.8	67.8	
Sakthi x St 64	18.0	22.0	17.8	18.6	76.4	II
Sakthi x Ohio 8129	18.4	23.6	18.0	18.2	78.2	II
Sakthi x HW 208 F	22.0	20.8	20.2	19.2	82.2	II
Sakthi x TH 318	17.0	17.8	16.0	14.6	65.4	
Sakthi x Fresh Market 9	15.0	15.2	12.8	15.8	58.8	
LE 206 x St 64	18.4	23.8	20.0	17.6	79.8	II
LE 206 x Ohio 8129	18.8	24.2	20.0	18.2	81.2	II
CD (P = 0.05)	0.98	0.85	1.21	0.91	2.00	
CD (P = 0.01)	1.30	1.13	1.61	1.21	2.67	

Table 64. Analyses of variance for [illegible], chemical composition and sensory scores (F_1 hybrids)

Sources of variation	df	Mean squares						
		Paste recovery (%)	Consistency (PPT)	Lycopene (mg/100 g)	Total acidity (%)	Colour* (score)	Absence of defects (score)	Overall* (score)
Genotypes	8	67.54**	0.[illegible]5**	342.07**	1.15**	422.75**	88.22**	546.44**
Parents	4	98.31**	0.[illegible]8*	116.25**	2.16**	558.80**	96.24**	1008.74**
Hybrids	3	0.78	0.[illegible]2	358.13**	0.03**	101.93**	66.85**	3.79
Parents vs hybrids	1	144.73**	0.[illegible]03**	1197.16**	0.48**	841.01**	120.27**	325.22**
Error	18	0.52	0.[illegible]1	1.38	0.005	2.59	1.48	4.75

** Significant at P = [illegible]

* df for error 36

Table 65. Paste yield and its chemical composition (F_1 hybrids)

Genotypes	Paste yield (%)	Consistency (PPT)	Lycopene (mg/100 g)	Acidity (%)
Sakthi	13.70	0.47	10.08	3.16
LE 206	13.68	0.46	17.62	2.70
St 64	23.40	0.77	24.79	1.45
Ohio 8129	24.17	0.75	25.37	1.32
HA 208 F	24.75	0.81	18.82	1.47
Sakthi x Ohio 8129	23.90	0.64	29.75	1.85
Sakthi x HA 208 F	25.08	0.71	18.60	1.74
LE 206 x St 64	24.58	0.67	40.17	1.81
LE 206 x Ohio 8129	24.83	0.68	42.44	1.61
CD (P = 0.05)	1.23	0.04	2.01	0.12
CD (P = 0.01)	1.69	0.05	2.76	0.16

Table 66. Sensory scores of paste (F_1 hybrids)

Genotypes	Colour (60)	Absence of defects (40)	Overall score (100)	Grade
Sakthi	30.80	26.40	57.2	
LE 206	42.40	24.40	66.8	
St 64	55.20	32.40	87.6	I
Ohio 8129	56.20	32.40	88.6	I
HW 208 F	50.40	34.60	85.0	I
Sakthi x Ohio 8129	57.20	25.40	82.6	II
Sakthi x HW 208 F	49.00	32.20	81.2	II
LE 206 x St 64	57.80	25.00	82.8	II
LE 206 x Ohio 8129	58.80	24.40	83.2	II
CD (P = 0.05)	2.06	1.56	2.80	
CD (P = 0.01)	2.77	2.09	3.76	

Table 67 . Reaction of tomato genotypes to bacterial wilt

Genotypes	Bacterial wilt incidence			Genotypes	Bacterial wilt incidence		
	30 DAT (%)	60 DAT (%)	Total (%)		30 DAT (%)	60 DAT (%)	Total (%)
Ohio 832	85	15	100	Pant T_2	60	40	100
Ohio 7814	70	30	100	Fire Ball	35	65	100
Ohio 8129	100		100	Fresh Market 9	30	70	100
St 61	90	10	100	DMM (EC 108759)	60	40	100
St 64	100	--	100	EC 129968	40	60	100
St 87	70	30	100	EC 104162/P_2-1	80	20	100
ONt 823	40	60	100	EC 54645	85	15	100
ONt 3210	90	10	100	EC 50366-1-1	75	25	100
H 2653	80	20	100	EC 129599	55	45	100
H 7033	45	55	100	EC 128965	65	35	100
FM 6203	75	25	100	EC 129355	100	--	100
HW 208-1	75	25	100	EC 101652	35	65	100
TH 318	100	--	100	Kt 1	60	40	100
Veepick	75	25	100	Kt 2	50	50	100
Veepro	65	35	100	Kt 3	60	40	100
Veekini	40	60	100	Kt 4	40	60	100
Veemore	65	35	100	HS 101	90	10	100
Veeroma	45	55	100	HS 102	85	15	100
Rubyvee	50	50	100	AC 142	60	40	100
HC 28	100		100	AC 238	40	60	100
HC 82	65	35	100	AC 2301	40	60	100
E 6203	75	25	100	S 12	50	50	100
Processor 80	20	80	100	Sweet 72	50	50	100
Roma	80	20	100	Punjab Kesari	65	35	100
San Marzano	100	--	100	Pusa Early Dwarf	25	75	100
Heinz 1350	60	40	100	Money Maker	60	40	100
Sioux	65	35	100	Marutham	95	5	100
Punjab Chhuhara	60	40	100	Pusa Ruby	80	20	100
Labonitha	40	60	100	LE 206	20	25	45 MS
IHR 674	65	35	100	LE 214	10	20	30 MR
Sel 11	65	35	100	Sakthi	10	15	25 MR

DAT - Days after transplanting
R - Resistant 20% plants wilted
MR - Moderately resistant - 20 to 40% plants wilted
MS - Moderately susceptible - 40 to 60% plants wilted
S - Susceptible - 60% plants wilted

Plate XIV F_2 Segregant having uniform fruits

Plate XV F_2 Segregant having elongated fruits remaining 61 genotypes were highly susceptible to wilt. Among the genotypes which survived, the lowest percentage of wilt was recorded in Sakthi (25%) followed by LE 214 (30%) which were scored as moderately resistant. LE 206 recorded 45% wilt incidence and was scored as moderately susceptible.

Similarly, the parents, F_1 hybrids and F_2 segregants were also evaluated for wilt incidence. The male parents and F_1 hybrids were highly susceptible and none of the plants survived beyond 60 DAP. The wilt incidence recorded in Sakthi and LE 206 were 23% and 43% respectively. The F_2's in crosses with Sakthi segregated in a 3:1 ratio ($P = 0.7$ to 0.5) indicating that resistance to bacterial wilt in Sakthi is inherited monogenically and is controlled by a single recessive gene (Table 68). In crosses with LE 206 F_2's segregated in a 13:3 ratio ($P = 0.9$ to 0.8) indicating that the gene system operating in LE 206 is digenic with supplementary gene interaction (Table 69).

Table 68. Inheritance of resistance to bacterial wilt in Sakthi

Generations	Number of plants			Expected number considering expressivity		Expected genetic ratio *		X^2	Probability
	Total	Resistant	Susceptible	R	S	R	S		
Sakthi	30	23	[illegible]						
Ohio 8129	30	--	30						
F_1	30	–	30						
F_2	150	24	126	29	121	0.77:3.23		0.226	0.7-0.5
HW 208 F	30	–	30						
F_1	30	–	30						
F_2	150	22	128	29	121	0.77:3.23		0.235	0.7-0.5
TH 318	30	–	30						
F_1	30	–	30						
F_2	150	28	122	29	121	0.77:3.23		0.206	0.7-0.5
Fresh Market 9	30	–	30						
F_1	30	--	30						
F_2	150	31	119	29	121	0.77:3.23		0.193	0.7-0.5

* The expected ratio is derived from classical ratios considering expressivity

Table 69. Inheritance of resistance to bacterial wilt in LE 206

Generations	Number of plants			Expected number considering expressivity		*Expected genetic ratio	X^2	Probability
	Total	Resistant	Susceptible	R	S	R S		
LE 206	30	17	13					
St 64	30	--	30					
F_1	30	—	30					
F_2	150	14	136	24	126	2.57:13.43	0.023	0.90-0.80
Ohio 8129	30	—	30					
F_1	30	—	30					
F_2	150	12	138	24	126	2.57:13.43	0.022	0.90-0.80

*The expected ratio is derived from classical ratios considering expressivity

Discussion

DISCUSSION

The results of the investigations on processing characteristics in tomato and their expression in a bacterial wilt resistant genetic background are discussed in this section.

A. Evaluation of tomato genotypes for processing characteristics

1. Variability, heritability and genetic advance

The 64 tomato genotypes exhibited considerable variation for fruit yield and its components, fruit characteristics and fruit juice characteristics. The observed variation is quite rational in a population from diversified geographical areas bred for specific management and end uses.

a. Fruit yield and its components

AC 23[illegible] was the earliest to flower (57.80 days) and to harvest (91.20 days). Pusa Early Dwarf could be harvested early during the second season (87.40 days). FM 6203 (110.40 days) and HW 208 F (109.40 days) were the late maturing genotypes during the first and second seasons, respectively. Index to earliness which is an indication of economic earliness showed that LE 206 was the earliest (S_1 = 1.32 and S_2 = 1.41). The known processing tomatoes were late indicated by low index values (0.01 to 0.08). The general lateness associated with gene 'hp' which is increasingly used in the newer processing tomatoes for better red colour (Sayama and Tigchelaar, 1985) substantiates the observed lateness at least in some genotypes. Sioux produced only a fewer fruits (S_1 = 6.00 and S_2 = 5.4) while AC 142, maximum number of fruits (S_1 = 52.40 and S_2 = 59.00). EC 129355 recorded the highest yield (S_1 = 1258.98 g and S_2 = 1315.49 g) in two seasons (S_1 and S_2).

Index to earliness recorded maximum variability (pcv-S_1 = 106.51 and S_2 = 104.05; gcv-S_1 = 70.85 and S_2 = 71.27) followed by fruits/plant (pcv-S_1 = 53.85 and S_2 = 49.50; gcv-S_1 = 37.93 and S_2 = 35.12), among the components of yield. The genetic advance as % of mean was the highest (S_1 = 97.10 and S_2 = 90.57) for index to earliness followed by fruits/plant (S_1 = 55.03 and S_2 = 51.25). High coefficient of variation for early yield and fruits/plant were reported by Nandpuri et al. (1973) and Dudi et al. (1983). High genetic advance as % of mean for these characters were also reported by Nandpuri et al. (1973).

b. Fruit characteristics

[illegible] which produced a fewer fruits had the biggest fruits. AC 142 and AC 238 which produced small fruits had the maximum number of fruits. Negative relationship of fruit weight with fruit number was established earlier (Kolhe, 1970; Rattan et al., 1983) showing that with increase in fruit number, there would be decrease in fruit weight.

Wide variations were observed in fruit shape as indicated by fruit shape index (0.70 to 2.02). Veepick recorded the highest index value (S_1 = 2.01 and S_2 = 1.88). The lowest index value was recorded for AC 2361 (S_1 = 0.71 and S_2 = 0.70) which has an oblate shape. The fruit shape indices observed for the genotypes fall within the range reported by Roy and Choudhary (1972) and Rao and Choudhary (1981) except for Veepick, characterised by the long oval shaped fruits (Plate I). Few genotypes possessed jointless pedicel which is an essential prerequisite for mechanical harvesting (Plate II).

Heinz 1350 recorded the highest number of locules followed by Veemore, AC 238 and Kt 3. Labonitha, Punjab Chhuhara, Roma, DMM, UC 82, Sel 11, H 722, Ohio 8129 and St 61 had low locule number (2.00). This is in agreement with the reports of Roy and Choudhary (1972) that round or oblate fruits have more number of locules and oblong or oval fruits low number of locules.

Pericarp thickness ranged from 2.70 mm to 7.58 mm. The higher limit falls outside the reported range of Roy et al. (1970), Roy and Choudhary (1972), Rao and Choudhary (1981), Dudi et al. (1983) and Tikoo (1987). The high pericarp thickness observed in the genotypes can be substantiated by the oblong or oval fruit shape (Roy et al., 1970; Roy and Choudhary, 1972) and the machine harvest types with very firm fruits with high flesh thickness resulted from the greater amounts of cell walls in the fruit (Stevens and Paulson, 1976; Ramadan, 1982).

Among the 64 genotypes, 30 genotypes were crack resistant. These genotypes were firm fruited also. This observation corroborates the view of Ramadan (1982) that the firm fruited cultivars had a high level of crack resistance. The firmness was related to skin toughness of the firm cultivars as there is a positive relationship between skin puncture resistance and crack resistance. Contradictory to the above, a few of the reportedly crack resistant genotypes ([illegible], [illegible], UC 28, UC 82) showed occasional cracking. This has to be justified by the environmental control rather than genetic factors for crack resistance suggested by Narayanankutty (19[illegible]).

Wide variation in the storage life of fruits was observed (4.60 to 34.00 days). H 722 (33.20 days) and St 67 (34.00 days) were the least perishable during the first and second seasons respectively. The soft fruits (LE 214, DMM) had a low storage life and extremely firm fruits (H 722, St 67, Ohio 832) relatively high storage life. The prolonged shelf life of genotypes having hp og^c genes (high pigment crimson) in the firm fruited cultivars was reported (Lampe and Watada, 1971). This observation was further explained by Ramadan (1982) that rate of fruit ripeness of firm fruit was not different from softer cultivars but since the initial firmness was much greater they remained in a usable condition for a much longer time and further noted that the process of ripening was not different in soft cultivars.

Among the fruit characters, cracking recorded the highest variability (pcv-S_1 = 82.20 and S_2 = 85.00) and genetic advance as % of mean (S_1 = 200.17 and S_2 = 108.68). The heritability was only moderate (S_1 = 0.59 and S_2 = 0.62). The observed heritability is in conformity with the reports of Alvarez (1984) and Lancaster and Morelock (1984). Average fruit weight also showed high pcv (S_1 = 58.94 and S_2 = 58.98) and gcv (S_1 = 45.84 and S_2 = 47.00). Similar observations were made by Dudi et al. (1983). Heritability for fruit shape index was high (0.95) during the first season. High heritability for fruit shape was also reported by Mochizuki et al. (1986). In line with the report of Dudi et al. (1983), pcv, gcv and genetic advance for pericarp thickness were low.

c. Fruit juice characteristics

Juice yield (%) ranged from 66.49% to 87.20%. St 64 (87.20%) during first season and HW 208 F (85.2[illegible]%) during second season recorded maximum juice yield. But the juice yield when worked out on an area basis showed that TH 318 recorded the highest yield.

Total soluble solids ranged from 3.[illegible]% to 6.80%. Veeroma recorded the highest TSS (S_1 = 6.60 and S_2 = 6.8[illegible]) during both seasons. ON[illegible] 8219 (3.[illegible]%) and Pusa Ruby (3.7[illegible]%) recorded the lowest TSS during first and second seasons respectively. Firm fruited genotypes recorded low TSS since more dry matter was partitioned into insoluble solids (Stevens et al., 1977).

Total solids ranged from 4.49% to 8.03% and 4.73% to 8.30% in first and second seasons respectively. However, seasonal difference in total solids was reported by Mohr (1987). HW 208 F recorded maximum total solids (8.30%) followed by Ohio 8129 (7.87%) and Veeroma (7.79%). Variations in the solids content in different parts of the fruit which was higher in the pericarp than in the locular tissue were reported (Davies and Kempton, 1975; Zhou and Xu, 1984).

HW 208 F recorded the maximum (S_1 = 1.21% and S_2 = 1.28%) insoluble solids. Insoluble solids appeared to be cultivar dependent and this explained the low variations in insoluble solids between seasons (Mohr, 1987). Total solids:insoluble solids ratio ranged from 6.06 (H 722) to 16.16 (EC 50366-1-1). Goose and Binstead (1973) opined that a ratio not exceeding 8:1 of total solids to insoluble solids gave a product of satisfactory consistency. The low ratio observed (6.06) can be substantiated by the more dry matter being partitioned into cell wall components in the firm fruited cultivars (Stevens et al., 1977).

The reducing sugar content ranged from 2.28% to 4.55% with the highest in Labonitha (4.47%) and EC 128965 (4.55%) during first and second seasons respectively. The low reducing sugar content in Processor 40, St 87, St 61, Veeking and HC 28 can be explained by the more soluble solids in the locules than in the pericarp (Brecht et al., 1976) and reduced locular tissue in firm fruits resulting in a reduction in reducing sugar. Stevens (1976) also found that in firm fruited cultivars more dry matter was partitioned into insoluble solids at the expense of reducing sugars.

Pusa Early Dwarf recorded the highest acidity. The range in acidity observed was from 0.28% to 0.74%. Mostly the genotypes which had high pericarp thickness possessed low acidity (Veeking-S_1 = 0.28% and S_2 = 0.35%, Ohio 832 - S_1 = 0.29% and S_2 = 0.34%, St 87 - S_1 = 0.30% and S_2 = 0.35% and HC 28 - S_1 = 0.30% and S_2 = 0.34%). The locular tissues are more acidic and the reduced locular area in firm fruited cultivars resulted in a reduction in acidity of firm fruits (Brecht et al., 1976; Stevens et al., 1977).

The pH of fruit ranged from 3.84 to 4.82. Though there was decrease in pH corresponding to increase in acidity, the magnitude of reduction varied with genotypes. This can be substantiated by the reduction in phosphate buffers in genotypes which increase the pH but the titrable acidity was not changed (Paulson and Stevens, 1974).

HW 208 F (S_1 = 34.84% and S_2 = 33.66%), H 722 (S_1 = 33.58% and S_2 = 32.40%) and St 87 (S_1 = 33.42% and S_2 = 32.14%) recorded high content of pulp. The genotypes which had more pulp content were firm fruited having high pericarp thickness, low loculed and elongate in shape. The pulp content ranged from 14.31% to 33.66%. This variation can be explained by the differences in firmness, total solids, soluble solids and insoluble solids. The genotypes which had high pulp content and insoluble solids showed high consistency also. This is in conformity with Stevens and Paulson (1976) who observed that the firm fruited cultivars which had high insoluble solids resulted in high consistency. The presence of 'hp' gene can also enhance the consistency (Sayama and Tigchelaar, 1985). Most of the fruits showed uniform ripening also (Plate III).

Lycopene content ranged from 2.31 mg to 6.62 mg/100 g. Ohio 5129 ([illegible] mg/100 g) and E 6203 (6.62 mg/100 g) were the high lycopene genotypes in first and second seasons, respectively. The observed range is in conformity with the reports of Madaiah et al. (1986), Setty et al. ([illegible]) and Bajaj et al. (1988).

The β carotene content ranged from 204.03 μg to 580.37 μg/100 g. St 87 recorded the lowest β carotene (204.03 μg/100 g) in the first season. Though not the lowest, Ohio 832 (S_1 = 223.60 μg/100 g and S_2 = [illegible] μg/100 g) and Rubyvee (S_1 = 140.4 μg/100 g and S_2 = 263.17 μg/100 g) which possess 'og^c' gene also showed low content substantiating that crimson (og^c) gene conditioned an increase in ratio of lycopene to β carotene resulting in brighter red colour. The observed colour differences resulted from reduction in β carotene and corresponding increase in lycopene content. High lycopene and high β carotene in fruits have to be viewed as the combined effect of 'hp' and 'og^c' genes (Sayama and Tigchelaar, 1985).

LE 214 recorded the highest ascorbic acid content (40.93 mg/100 g). St 61 (S_1 = 10.65 and S_2 = 10.60 mg), Ohio 832 (S_1 = 11.49 mg and S_2 = 12.22 mg) and ONt 828 (S_1 = 12.47 mg and S_2 = 14.31 mg) had low contents of ascorbic acid

Insoluble solids showed high heritability (0.93) among fruit juice characteristics. The high heritability observed for insoluble solids substantiates Stevens (1976). Moderately high heritability for acidity (S_1 = 0.65 and S_2 = 0.67) and pH (S_1 = 0.79 and S_2 = 0.63) are in line with Monma and Kamimura (1982). Lycopene (S_1 = 0.71 and S_2 = 0.88) and β carotene (S_1 = 0.84 and S_2 = 0.76) showed moderately high heritability and did not agree with the moderate heritability reported by Agble (1977) and Bhutani and Kalloo (1983).

2. Somatic analyses for fruit shape index and quality parameters

In selection of processing tomatoes, a special mention is often made on preference of elongated fruits with shape index >1. Since fruit shape index is easy to be judged visually, the interrelationships of quality components, if understood, can make the selection more worthwhile. Positive association of fruit shape index existed with consistency, pericarp, thickness, insoluble solids, lycopene, total solids, pH and TSS.

Insoluble solids besides its strong direct effect (0.77) influenced fruit shape index shape through indirect effect on total solids, consistency, lycopene, pericarp thickness and pH. Maximum indirect effect of insoluble solids was on consistency and total solids (0.62). Increase in consistency with elevated insoluble solids were reported earlier (Stevens and Paulson, 1976; Marsh et al., 1980; Yanovchick et al., 1980; Mohr, 1987).

Insoluble solids also made a major contribution (0.38) to the high direct effect of pericarp thickness (0.55) on fruit shape index. Increased pericarp thickness in fruits with shape index >1 was reported earlier (El-Sayed et al., 1966a; Roy et al., 1970; Roy and Choudhary, 1972; Rao and Choudhary, 1981). Increased pericarp thickness is attributed to more partitioning of dry matter into insoluble cell wall components (Stevens et al., 1977). This is further substantiated by the observed indirect influence of pericarp thickness (0.27) and consistency (0.34) on insoluble solids.

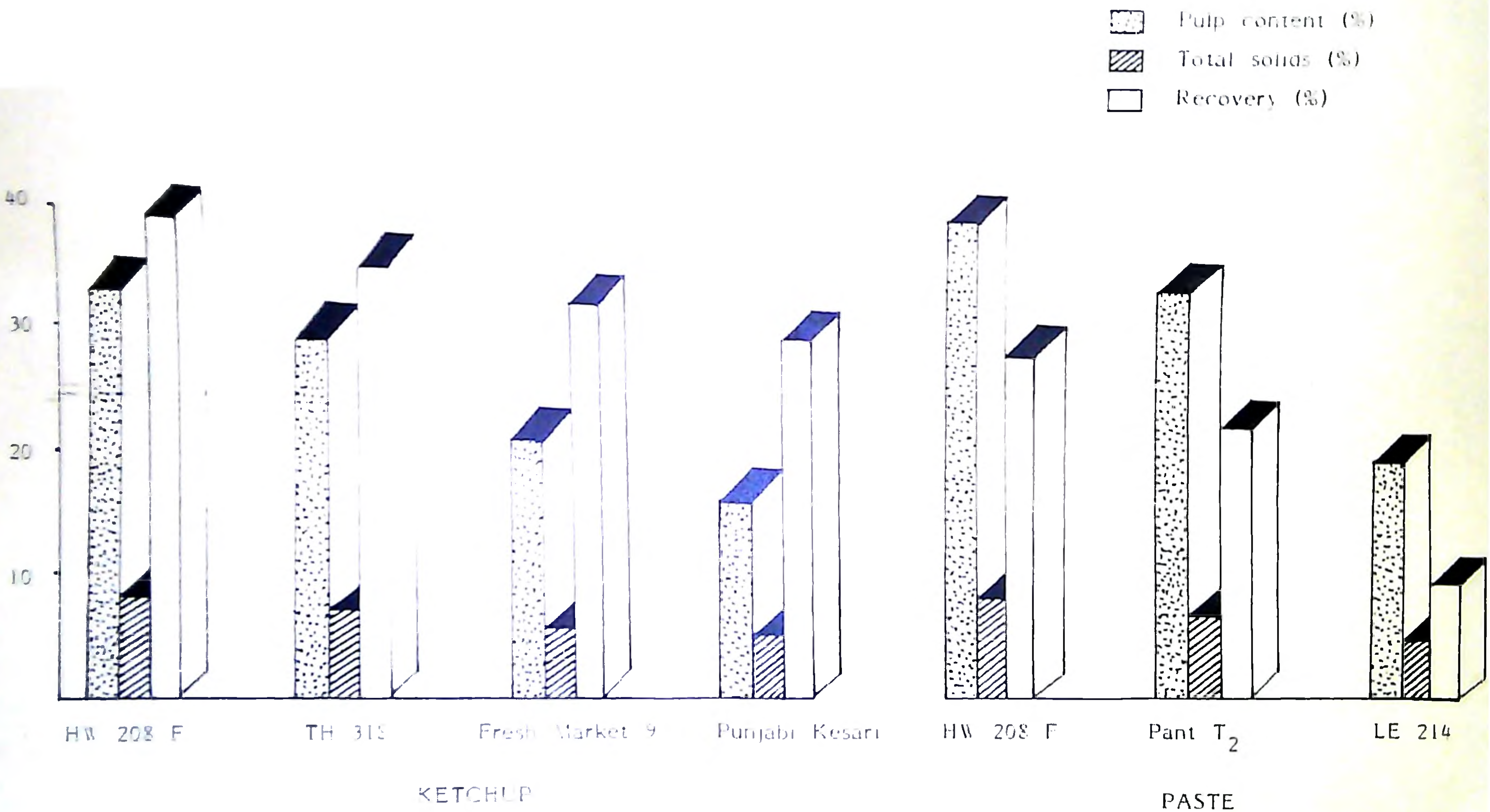
The negative direct effect of total solids (-0.65) and lycopene (-0.24) but its positive correlation (0.33 and 0.35, respectively) with fruit shape index was mainly due to the indirect influence of insoluble solids on total solids (0.62) and lycopene (0.59). The influence of gene 'hp' in increasing the consistency and lycopene substantiates the observed relation (Sayama and Tigchelaar, 1985).

Direct effect of pH on fruit shape index is negative (-0.07). But the high indirect influence of insoluble solids on pH (0.41) made the correlation between pH and shape index positive (0.26). This association is reasonable in the light of the reported evidence of low acidity in firm fruits with more insoluble solids having shape index above 1, due to the reduced locular area (Brecht et al., 1976; Stevens et al., 1977).

Acidity showed positive direct effect ([illegible]) on fruit shape index but the correlation was negative (-0.34). This can be attributed to the fairly high negative indirect influence of pericarp thickness (-0.41), insoluble solids (-0.39) and consistency (-0.24) on acidity. With increased fruit shape index, there is chance for increased acidity but due to strong influence of factors such as pericarp thickness, insoluble solids and consistency, the acidity will be lowered. Reduced acidity with increase in fruit shape index was reported in association with reduced locular area (Brecht et al., 1976; Stevens et al., 1977).

The locule number was reduced with increase in fruit shape index as indicated by the negative correlation (-0.53) and direct effect (-0.33). Negative relationship of locule number with fruit shape index is well established (El-Sayed et al., 1966a; Roy et al., 1970; Roy and Choudhary, 1972; Rao and Choudhary, 1981). Reducing sugar and juice yield also showed a negative relationship with fruit shape index. The fruit firmness

Fig.2 Relation of pulp content and total solids on recovery



increases pericarp thickness and reduces the locular area and since the locules contain more reducing sugar than pericarp, the reducing sugar content of the fruit will be lowered (Brecht et al., 1976). Also, the increased pericarp thickness increases the insoluble solids which again lower the sugars (Stevens et al., 1977). Total soluble solids do not make a significant relation with fruit shape index (0.09) but its fairly good direct effect was mainly through the indirect influence of acidity (0.24). This can be justified by the important contribution of organic acids to soluble solids in tomato (Williams and Bevenue, 1954).

Based on the above results, it is inferred that when we select tomatoes based on fruit shape index, the immediate direct effect is on insoluble solids. With increased insoluble solids, other fruit qualities such as total solids, consistency, lycopene, pH and pericarp thickness were enhanced, but with reduced acidity, reducing sugar and locules/fruit.

3. Identification of processing type(s) based on selection index

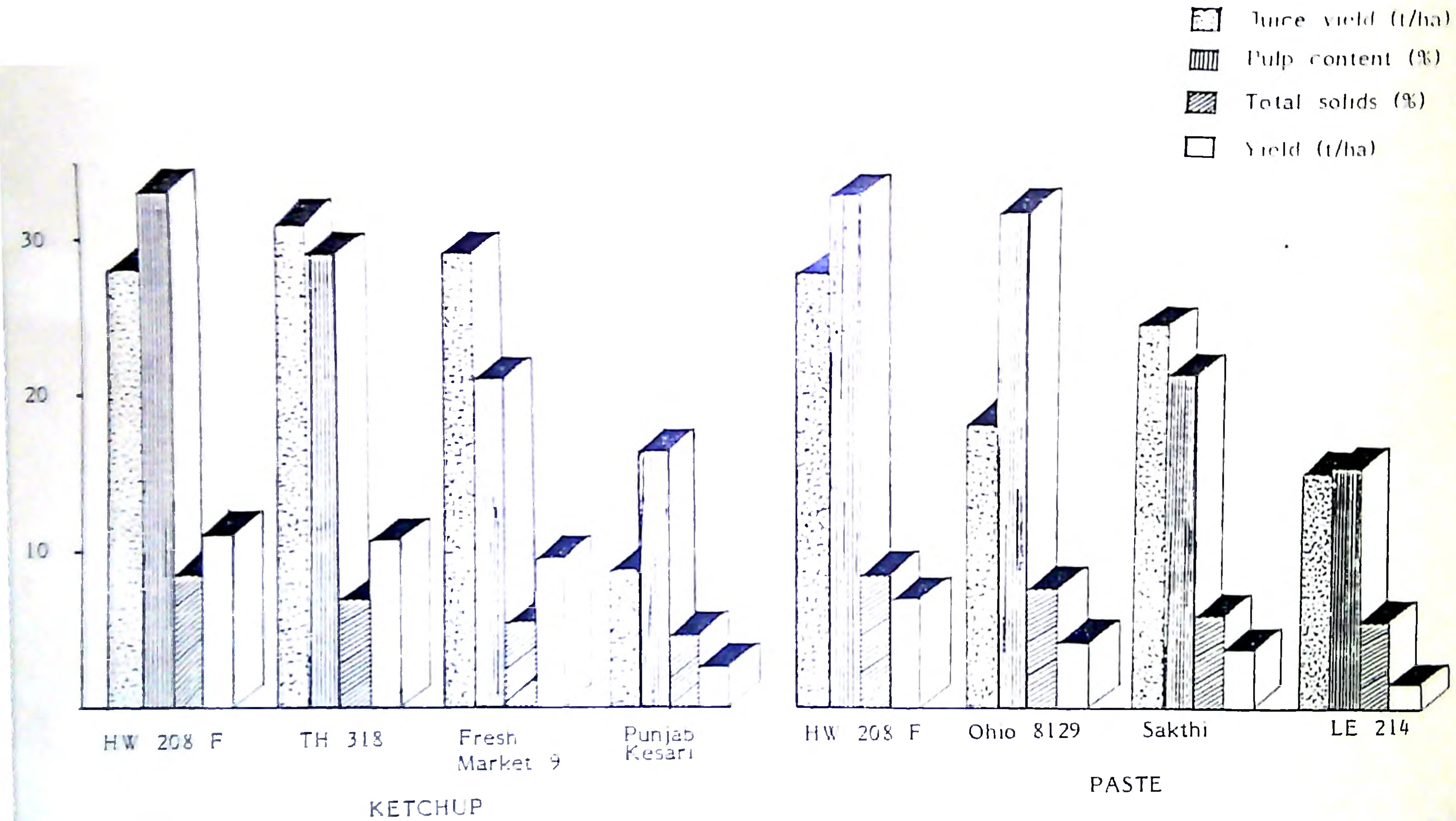
Based on selection indices Veeroma, HW 208 F, Ohio 8129, St 64 and Ohio 832 were chosen as the most ideal genotypes for processing. The single factor which contributed to the highest index value of Veeroma was TSS. In other genotypes coming on par with Veeroma for the index values, the standardised value for TSS was rather low or even negative as in the case of Ohio 832 (-0.75). With the increased TSS, the reducing sugar content which was negative for the other selected genotypes turned to be positive for Veeroma. In all the selected genotypes, acidity showed a negative value. Marutham the least ideal type had positive values only for acidity (0.41), pH (0.08) and juice yield (0.17) Fig.1.

B. Evaluation of tomato genotypes for ketchup and paste

1. Ketchup

The ketchup prepared from 42 genotypes were compared with Maggi ketchup (Plates IV and V). Ketchup recovery was found to be a function

Fig.3 Relation of juice yield, pulp content and total solids on yield

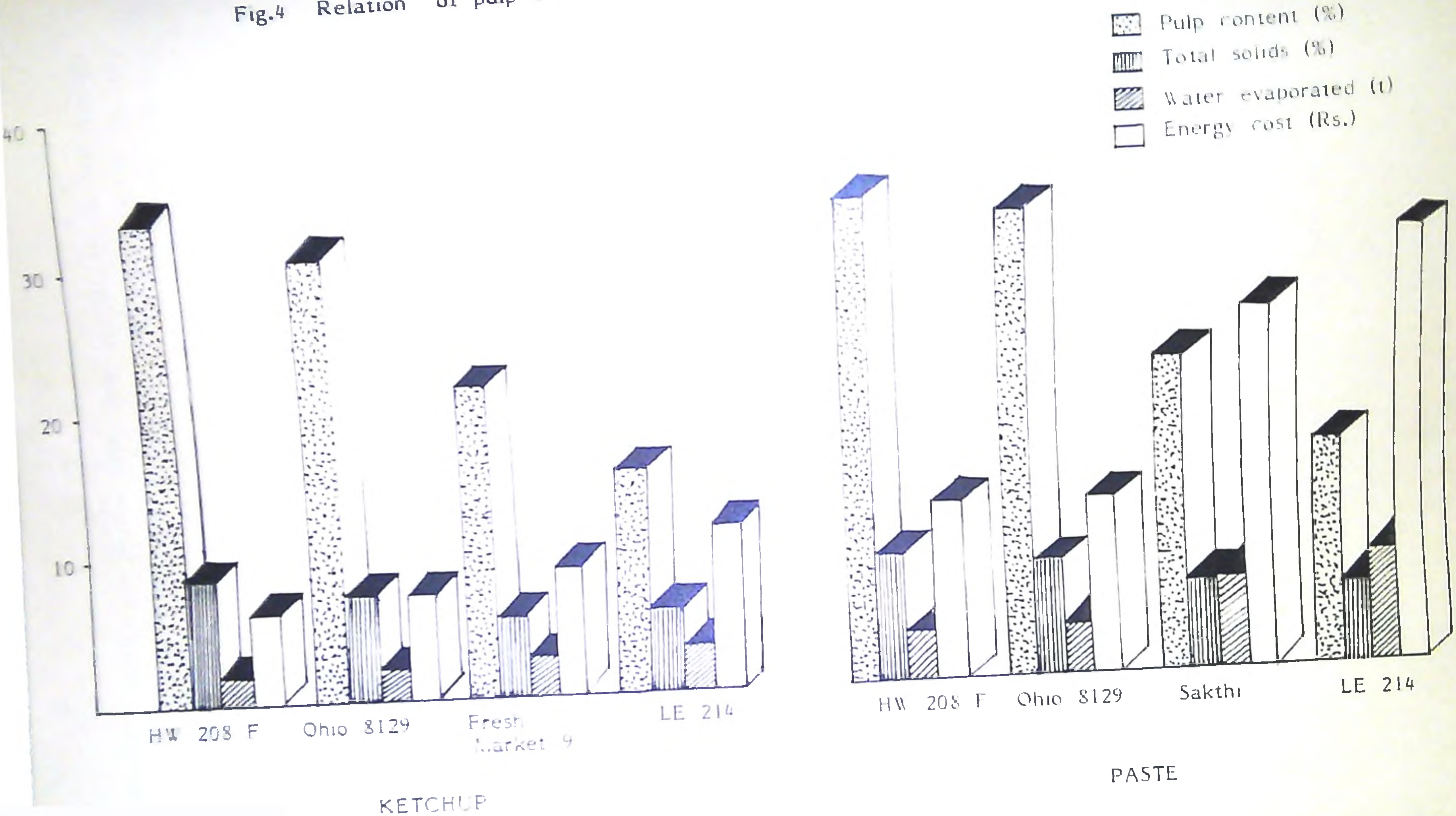


of pulp content and total solids of fruit. Genotypes with high pulp content and total solids recorded high recovery also (Fig.2). HW 208 F had the highest recovery of ketchup (39.13%). The ultimate ketchup yield which determines the usefulness of a variety for ketchup making depends on productivity of fruit and juice also (Fig.3). A high yielder of fruit gave a high yield of juice too. A higher pulp content and total solids rather than juice yield alone were observed in HW 208 F, the highest yielder of ketchup (10.95 t/ha). Even when the productivity of fruit and juice were high, if the pulp and total solids were low, the product yield will be lowered (Fresh Market 9 - 9.38 t/ha and Sakthi - 7.95 t/ha). A poor yielder of juice, irrespective of the pulp content and total solids gave only a low ketchup yield (Punjab Kesari - 2.37 t/ha).

The quantum of water to be evaporated/unit quantity of ketchup is an economic factor which decides the energy requirement and thus the cost of production. Genotypes with high total solids and pulp content needed lesser water removal and consequently low cost for energy (Fig.4). HW 208 F with the inherently high total solids and pulp content required the least water removal (1.56 t/t of ketchup) and the lowest energy cost (Rs.624/t of ketchup). Eventhough the ketchup yield/ha from H 7038 and TH 318 were comparable to that of HW 208 F, they required more water removal (1.86 and 1.84 t/t of ketchup respectively) which resulted in higher energy cost (Rs.744/- and Rs.736/- respectively). In genotypes with low content of pulp and total solids, the quantity of water to be evaporated and the resultant energy cost were high (LE 214 - 2.76 t/t of ketchup and Rs.1104/- respectively). The results are in agreement with Opena (1983) who observed greater product yield and less water removal from high solids tomatoes.

The ISI specifies a minimum of 25% TSS and 1.20% acidity for tomato ketchup. These two quality components were higher than the minimum limit prescribed, in the ketchup from all the genotypes. Among the quality factors, consistency, colour and flavour are important since they form grade criteria for ketchup.

Fig.4 Relation of pulp content and total solids on water evaporated and energy cost



Genotypes with high insoluble solids and total solids showed high consistency of ketchup also (Fig.5). Ketchup from HW 208 F and Ohio 832 recorded the highest consistency (0.52). The firm tomatoes had distinctly high insoluble solids and the ratio of total/insoluble solids was below the minimum of 8:1 proposed for a product of satisfactory consistency. Stevens and Paulson (1976) also found that firm fruited cultivars had high alcohol insoluble solids resulting in high viscosity and case yield. The fact that insoluble solids are mainly associated with consistency was well established (Goose and Binstead, 1973; Mohr, 1987; Setty et al., 1987).

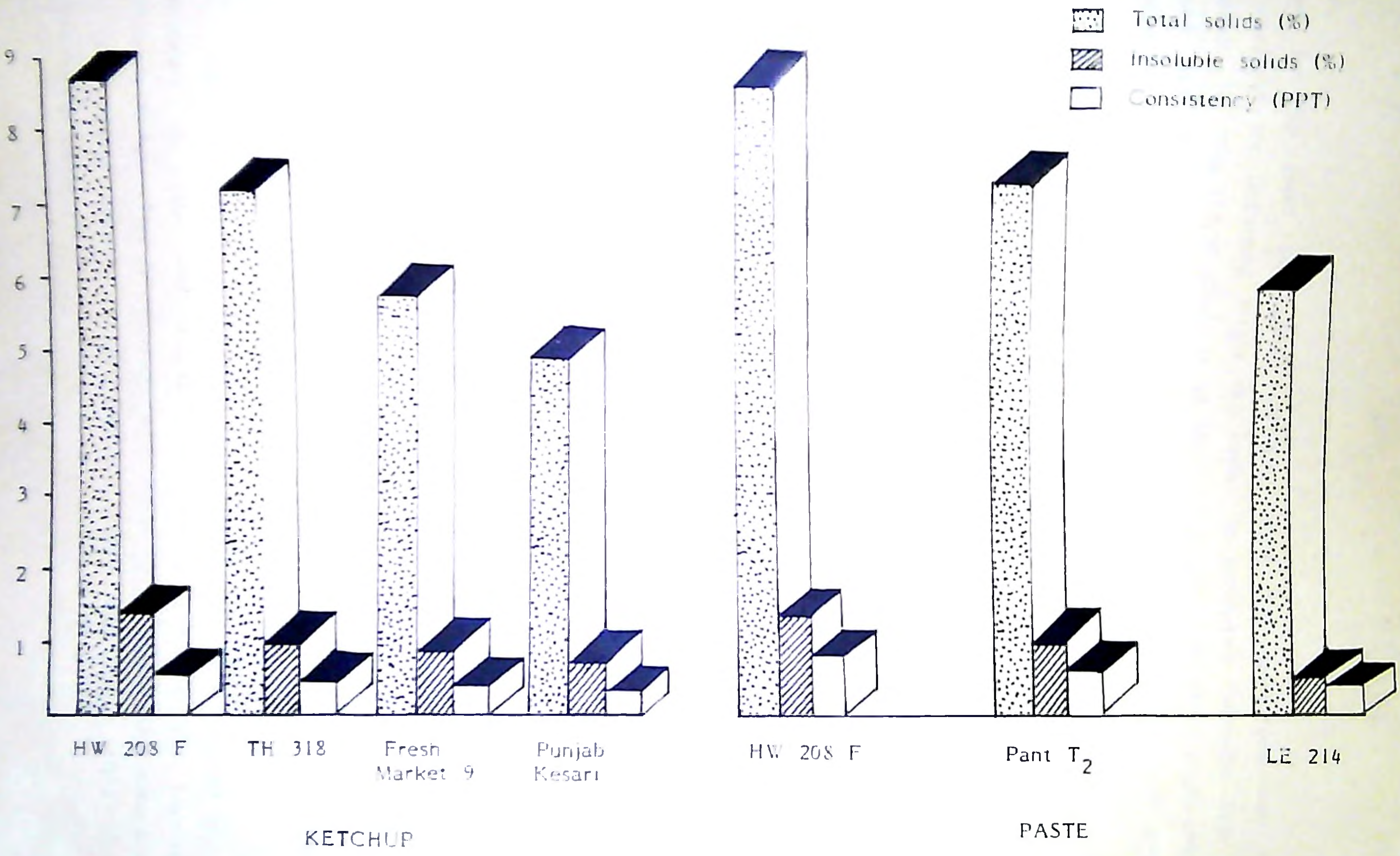
The lycopene content in ketchup ranged from 4.94 mg to 17.50 mg/100 g. Ohio 8129 (17.50 mg/100 g) and St 64 (16.62 mg/100 g) had exceptionally high content of lycopene, reasonably high ketchup recovery and consistency. Since the fruit yield was not high the ketchup yield/ha was only medium ([illegible] t/ha and 7.71 t/ha respectively).

The inherent sugars and acids in the fruit determine flavour, in a ketchup to which sugar, acetic acid and spices are added, the flavour was [illegible] these additives. The flavour rating during sensory evaluation [illegible] influenced by the additives also.

β carotene and ascorbic acid, though not a quality component of ketchup, showed considerable variation and followed a trend similar to the content in the fruit. The Maggi ketchup had exceptionally high β carotene but low acidity, reducing sugar and lycopene. This has to be viewed against adulteration of commercial ketchup with pulps of apple, papaya, ashgourd, pumpkin, sweet potato and carrot, to increase the bulk and reduce the cost (Beerh, 1982). However this was not reflected in the sensory rating and scored for Grade I ketchup, perhaps due to the proper blend of sugar and acids, better consistency due to added thickening agents and commercial manufacturing process.

Sensory evaluation indicated the superiority of HW 208 F for ketchup manufacture. HW 208 F scored the maximum (85.80) for Grade I ketchup because of high consistency and reasonable colour. Ohio 8129 (85.40) and St 64 (85.20) were also scored for Grade I standard. Though

Fig.5 Relation of total solids and insoluble solids on consistency



the ketchup yield was only moderate, these two genotypes can be considered for imparting bright red colour to genotypes otherwise low in colour. H 7038 (10.36 t/ha), St 61 (8.70 t/ha) and St 87 (8.63 t/ha) which gave high ketchup yield along with Grade II standards are also good genotypes for ketchup manufacture.

2. Paste

The paste prepared from 16 genotypes were compared with Hunt's paste and NAFED paste (Plates V and VI). Similar to ketchup, the paste recovery was also a function of total solids and pulp content (Fig.2), HW 208 F with the highest pulp content and total solids recorded the highest paste recovery (24.75%) followed by Ohio 832 (24.35%) and Ohio 8129 (24.17%). In addition, the paste yield depended on fruit and juice yield also (Fig.3). HW 208 F with the highest juice yield, pulp content and total solids recorded the maximum paste yield (6.93 t/ha). Since the contributory factors were moderately high St 87 and Veeroma also recorded high paste yield (5.85 t and 5.13 t/ha respectively). LE 214, even when the juice yield was moderate since the pulp content and total solids were low recorded the lowest paste yield (1.76 t/ha). Ohio 8129, even when the juice yield was moderate because of high pulp content and total solids recorded reasonable paste yield (4.42 t/ha). In Sakthi, eventhough the juice yield was high, the paste yield was low (3.69 t/ha) since the pulp and total solids were low. Genotypes with high paste/juice ratio (HW 208 F and St 87 - 0.25) needed minimum water to be evaporated (3.04 t/t of paste) and low cost for the water removal (Rs.1216.00) (Fig.4). LE 214 with the lowest paste/juice ratio (0.12) resulted in the highest quantity of water to be evaporated (7.66 t/t of paste) and the higher cost for water removal (Rs.3065/t of paste).

Genotypes with high insoluble solids and total solids showed high consistency of paste also (Fig.5). HW 208 F recorded the highest consistency (0.81). This is consistent with Marsh et al. (1980) who observed good relationship between water insoluble solids and total solids and consistency of paste.

The quality characteristics considered for sensory rating of paste were colour and absence of defects and extra weightage was given for colour. Ohio 8129 and St 64 inherently high in lycopene content yielded a deep red coloured paste having reasonable consistency also. This was reflected in the sensory rating (88.60 and 87.60 respectively). HW 208 F with the highest consistency of paste scored maximum for consistency (50.40) and was scored Grade I paste. St 87 also scored Grade I paste and this had the added advantage of reasonably high yield of paste.

Hunt's tomato paste from USA was exceptional in its almost a solid consistency, deep red colour and the highest sensory rating. The NAFED paste which scored Grade I standard (86.20) had colour rating less than Ohio 8129 and St 64.

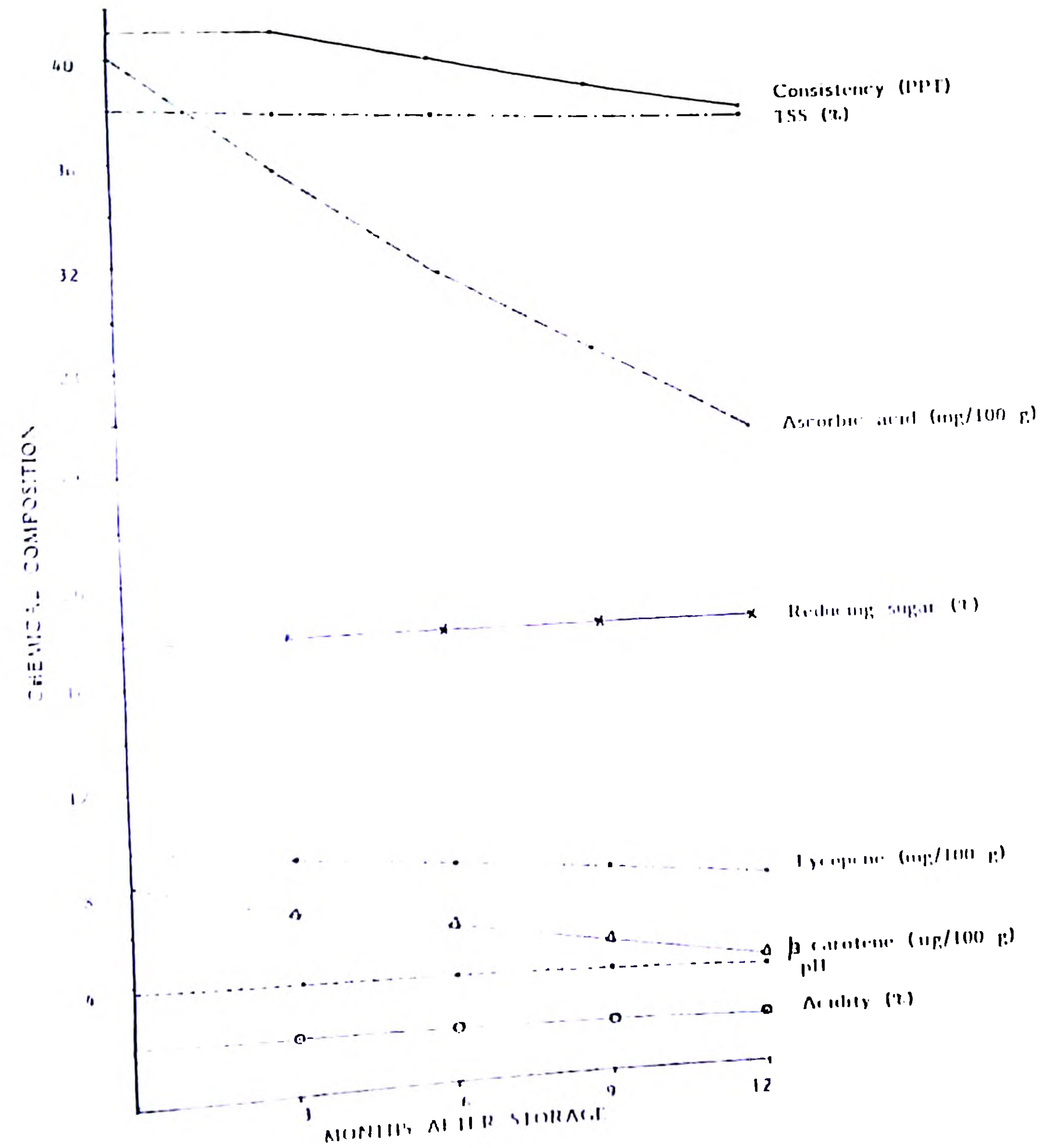
C. Evaluation of tomatoes for long shelf life of ketchup

1. Changes in physico-chemical composition

Appearance of ketchup during storage was lightly affected in a few genotypes by the blackneck formation and phase separation. The air trapped in the bottle during capping caused the darkening of ketchup at the neck portion (Garkviroj and Ranganna, 1976). The genotypes which showed pronounced phase separation had medium to low insoluble solids. The reduced insoluble solids may result in lowered pectin content since polygalacturonides which form the basic unit of pectin also form the major component of insoluble solids (Stevens and Paulson, 1976). The low pectin content which resulted from reduced insoluble solids caused reduced cell binding and thus substantiated the phase separation observed (Swamy et al., 1963).

A progressive decrease in acidity and concomitant increase in pH were observed with advanced storage. Degradation of acid content (Bhatnagar et al., 1987) explained the observed reduction. The reducing sugar content increased slightly with advance in storage life. In a product like ketchup which provides an acidic medium, the starch may be hydrolysed

Fig.6 Changes in chemical composition of ketchup during storage



to sugars resulting in an increase in sugar content and a reduction in acidity. The TSS was not changed significantly during storage (Table 70 & Fig.6). Sugars and acids are major constituents of total soluble solids (Williams and Bevenue, 1954) and a reduction in acid content and increase in sugar content might have counteracted to bring a balance in TSS content. The notable reduction in TSS as observed in Veeking and LE 214 may be explained by the unbalanced reduction in acid content and increase in reducing sugar.

Consistency was only slightly reduced during storage (Table 70 & Fig.6). The firm tomatoes which were high in insoluble solids were good in the retention of consistency during storage. The change in consistency upto nine months after storage was not significant. Takada (1984) made similar observations on paste stored for ten months at 30°C.

The retention of lycopene among genotypes during processing of ketchup ranged from 55.40% to 98.80%. This variation can be explained by the degradation of lycopene during heating and the rate of breakdown varied according to availability of oxygen, temperature and intensity of storage. The retention % was reduced to 76.12 (Table 70 & Fig.6). The reduction in lycopene during storage may be attributed to air in the finished product which impair the desirable bright colour of product (Markviroq and Rangamma, 1976). Ohio 8129 and St 64 were exceptional in retention of lycopene (94.83% and 94.69% respectively). Such varietal variations in retention were also observed by Swamy <u>et al.</u> (1963). The better retention of ascorbic acid which acts as an antioxidant may explain the retention of lycopene observed in Ohio 8129 and St 64.

The retention of β carotene during processing varied from 50.10% to 90.05%. Among quality components, β carotene showed maximum reduction during storage (Table 70 & Fig.6). Swamy <u>et al.</u> (1963) also observed variations in the retention of β carotene during storage.

During processing, the retention percentage of ascorbic acid varied from 39.57% to 79.83%. This is in conformity with reported variations in

Table 70. Changes in chemical composition and sensory scores of ketchup during storage upto 12 months

Components	Before storage	3 MAS	6 MAS	9 MAS	12 MAS
TSS (%)	38.00	37.86	37.79	37.68	37.57
Consistency (PPT)	0.41	0.41	0.40	0.39	0.38
Lycopene (mg/100 g)	9.59	8.93 (92.72)	8.41 (87.10)	7.94 (81.55)	7.45 (76.12)
Acidity (%)	2.18	2.07	1.97	1.86	1.80
pH	3.71	3.72	3.75	3.77	3.86
Reducing sugars (%)	17.66	17.68	17.68	17.70	17.70
β-carotene (µg/100 g)	827.14	687.96 (84.07)	599.22 (73.20)	514.24 (62.95)	433.28 (53.08)
Ascorbic acid (mg/100 g)	39.93	35.59 (89.48)	31.69 (79.97)	28.37 (71.80)	24.94 (63.26)
Sensory scores					
Consistency	17.58	17.33	16.75	16.12	15.91
Colour	18.24	17.70	17.16	16.50	15.72
Flavour	17.72	17.42	17.00	16.45	15.40
Absence of defects	18.26	17.87	17.61	17.38	17.03
Overall score	71.80	70.34	68.52	66.44	64.06

Parenthesis indicate per cent retention

MAS - Months after storage

retention during processing by Pruthi et al. (1980) and Wilska-Jeska et al. (1983). In 12 months time the percentage retention of ascorbic acid was dropped to 63.26 (Table 70 & Fig.6). Varietal variations in retention observed were in conformity with Swamy et al. (1963) and Sethi and Anand (1982). The reduction in ascorbic acid can be substantiated by oxidation of ascorbic acid to dehydroascorbic acid which is further degraded to products with no vitamin C activity (Sherkat and Luh, 1976). The reduction in acidity during storage might have accelerated loss of colour, flavour and vitamin C in the final stage (Leonard et al., 1959). The chemical changes were rapid at high temperature (Narkviroj and Ranganna, 1976; Pruthi et al., 1980) and for this reason, low temperature storage is advocated for ketchup. Hence, the observed chemical changes were quite natural in a product stored at room temperature.

[illegible] made in terms of consistency, colour, flavour, aroma [illegible] and overall scores changed significantly with genotypes and duration of storage. This reduction is reasonable because of the reduction in [illegible] components with advanced storage. Kwasniewska et al. (1984) [illegible] that organoleptic changes which affected colour and type of aroma [illegible] much pronounced at 37°C (Table 70).

2. Micro-organisms causing spoilage in ketchup

The mould contamination observed in LE 214, Sakthi and AC 142 showed no relation with the acidity and pH of the ketchup. These samples had the high acidity and low pH which are not conducive to the growth of many microbes. Spores of Aspergillus sp. is usually seen as an air contaminant. The air trapped during capping or the possible faulty capping might have predisposed the ketchup for contamination from this fungus. One micro-organism detected in the spoiled ketchup was Aspergillus flavus and since this forms a potential contaminant of black pepper (Martinez and Christensen, 1973; Guergue and Ramirez, 1977; Estelitta, 1982) there is also chance for the spoilage through black pepper added to ketchup.

D. Transfer of processing traits to a bacterial wilt resistant genetic background

I. Combining ability, gene action and heterosis

The resistant accessions Sakthi, LE 206 and LE 214 (Plates VI & VIII) were crossed with the selected processing lines (Plates IX & X). The performance of the salient F_1 hybrids is briefed (Tables 71 & 72).

Hybrids of Sakthi, LE 206 and LE 214 with TH 318 recorded significant heterobeltiosis and relative heterosis for plant height. LE 214 x TH 318 gave the highest per se performance (93.00 cm) which is due to the best general combiners involved in the cross.

The hybrids were late to harvest as indicated by the positive estimates of heterosis. Kurganskaya and Agentova (1974) found that heterosis for earliness occurred most often when both the parents were early. Therefore, the observed lateness can be attributed to the strong influence of male parents which were late. In concurrence with the observed lateness, Hewitt and Stevens (1979) also reported delayed maturity in hybrids. LE 214 x Ohio 8129 (-3.56) had maximum negative sca effect but the per se performance (105.20 days) was not the highest.

The only heterotic hybrid for fruits/plant was Sakthi x TH 318 (9.83% RH) and this showed significant positive sca effect also. The highest per se performance (32.40) resulted from the involvement of good general combiners in the cross. LE 206 x Fresh Market 9 which showed significant positive sca, resulted from poor x poor combiners.

Heterotic hybrids for fruit yield/plant were Sakthi x TH 318 (1280.34 g) and Sakthi x Fresh Market 9 (1155.47 g). The increased yield in these two hybrids may be due to the high yielding parents selected for hybridisation as suggested by Courtney and Peirce (1979). The lateness of parents Fresh Market 9 and TH 318 can also be a reason for heterosis as observed by Popova and Petrova (1979). Parents with high per se performance (Sakthi, TH 318, Fresh Market 9, HW 208 F) were good

Table 71. Heterotic F_1 hybrids identified by a Line x Tester analysis in tomato

Characters	Number of relatively heterotic hybrids	Number of heterobeltiotic hybrids
Plant height	3 (3)	3 (3)
Fruits/plant	1 (1)	-
Fruit yield/plant	2 (2)	2 (0)
Average fruit weight	3 (2)	-
Locules/fruit	8 (7)	2 (2)
Pericarp thickness	7 (3)	-
Storage life	12 (3)	1 (0)
Juice pH	13 (3)	2 (0)
TSS	16 (3)	5 (1)
Total solids	15 (14)	13 (8)
Insoluble solids	4 (1)	-
Reducing sugar	9 (3)	7 (1)
Acidity	10 (0)	-
Consistency	15 (9)	3 (3)
Lycopene	15 (14)	12 (4)
Ascorbic acid	6 (3)	3 (0)

Parenthesis indicate number of significant heterotic hybrids

Table 72. Performance of salient F_1 hybrids

Characters	Hybrids	*Per se* performance	Sca effect	Heterobeltiosis (%)	Relative heterosis (%)
Plant height (cm)	LE 214 x TH 318	93.00	2.25	9.93	14.39
Days to harvest	LE 206 x St 64	100.00	0.47	7.30	3.09
Fruits/plant	Sakthi x TH 318	32.40	6.16	-5.26	9.83
Yield/plant (g)	Sakthi x TH 318	1280.34	178.06	7.04	13.24
	Sakthi x Fresh Market 9	1155.47	71.12	8.48	9.20
Average fruit weight (g)	Sakthi x Fresh Market 9	70.97	13.54	-19.70	18.73
	Sakthi x HW 208 F	55.62	3.07	-19.55	10.90
Locules/fruit	LE 206 x Ohio 8129	5.00	0.33	55.56	78.57
Pericarp thickness (mm)	LE 206 x St 64	6.29	-0.13	-3.23	10.40
Storage life	LE 206 x Ohio 8129	22.80	0.61	-20.28	3.17
Juice content (%)	Sakthi x HW 208 F	85.60	0.36	-	3.51
TSS (%)	LE 206 x St 64	7.00	0.95	21.95	32.83
Total solids (%)	Sakthi x HW 208 F	9.18	0.14	11.95	28.75
	Sakthi x TH 318	8.57	0.50	28.49	34.64
Insoluble solids (%)	Sakthi x HW 208 F	0.91	0.07	-27.78	1.11
Reducing sugar (%)	LE 206 x Ohio 8129	3.92	0.05	19.88	20.62
	LE 206 x St 64	3.74	0.05	14.37	18.92
Acidity (%)	Sakthi x TH 318	0.52	0.012	-10.34	2.97
pH	Sakthi x HW 208 F	3.95	0.04	-8.99	-5.95
Consistency	Sakthi x HW 208 F	0.31	0.011	-6.06	14.81
Lycopene (mg/100 g)	LE 206 x Ohio 8129	11.66	1.41	78.02	107.29
	LE 206 x St 64	11.38	1.31	78.09	105.23
Ascorbic acid (mg/100 g)	LE 214 x Fresh Market 9	31.59	2.72	-18.75	-2.95
	Sakthi x HW 208 F	26.56	0.21	10.39	14.90

general combiners also. The hybrids which showed significant positive sca effects, Sakthi x TH 318 and Sakthi x Fresh Market 9 resulted from good x good general combiners whereas LE 206 x St 64 and LE 206 x Ohio 8129 resulted from poor x poor combiners.

Significant relative heterosis for average fruit weight was observed in Sakthi x Fresh Market 9 and Sakthi x HW 208 F (18.73 and 10.90% respectively). The increased fruit weight observed in the hybrids were in agreement with Larson and Currence (1944) who reported larger fruit size from those inbred lines having larger fruit. Also, agreed with the intermediate fruit size between parents reported by Tesi et al., 1970; Kaul et al., 1972 and Conti, 1974. Sakthi x Fresh Market 9 was the best hybrid which had the highest per se performance (70.97 g), high sca effect (13.54) and the parents were good general combiners also. Taking into account heterosis and per se performance Sakthi x HW 208 F was a better combination but with low sca effect.

Many hybrids produced fruits with round shape as indicated by the index value < 1 (0.86 to 0.92). The female parents involved in the cross had round fruits (0.79 to 0.89) and male parents ovate fruits (1.03 to 1.22). The results are in agreement with Rao and Choudhary (1981) who observed the F_1s to be intermediate in fruit shape when round and pear shaped varieties were crossed.

LE 206 x Ohio 8129 and LE 214 x St 64 had significant heterobeltiosis for locules/fruit (55.66% and 6.67% respectively). Five hybrids showed significant relative heterosis also. Heterobeltiosis and relative heterosis for locules/fruit were reported earlier (Anbu et al., 1976). No parent was a good combiner for locules/fruit. LE 206 x Ohio 8129 which had the highest sca (0.33) resulted from poor x poor combiners.

All the hybrids had increased pericarp thickness (4.68 mm to 6.29 mm) than the female parents (3.92 mm to 4.89 mm). Hybrids of Sakthi, LE 206 and LE 214 with St 64 showed significant relative heterosis. This observation corresponded to Rao and Choudhary (1981) who reported appreciable increase in flesh thickness when the second parent was firm fruited. LE 206 x St 64 had the highest per se performance (6.29 mm) which resulted from good general combiners involved in the cross. The sca effect was not significant indicating that good general combiners need not give high sca effect.

The F_1 hybrids, irrespective of the cracking response of the parents did not crack at all.

Hybrids of Sakthi, LE 206 and LE 214 with Fresh Market 9 showed significant relative heterosis for storage life and is in conformity with Jones and Miller (1984) who observed the hybrid fruits to have good shelf life. Among the hybrids, LE 206 x Ohio 8129 showed the highest storage life (22.3[illegible]). Both the parents involved in the cross were good combiners but the sca effect was not significant for storage life.

Sakthi x HW 208 F, Sakthi x Fresh Market 9 and LE 214 x HW 208 F showed significant relative heterosis for juice yield. HW 208 F had the highest per se performance (85.60%). HW 208 F was a good combiner but the sca effect (0.36) was not significant.

LE 206 x St 64 was the best hybrid for TSS content (7.00%). Heterobeltiosis and relative heterosis and sca effects were significant for this hybrid. Also, the parents were good general combiners. Sakthi x TH 318 and LE 214 x Fresh Market 9 also showed significant relative heterosis.

Maximum number of hybrids, expressed significant heterobeltiosis (8 Nos.) and relative heterosis (14 Nos.) for total solids. Sakthi x HW 208 F had the maximum total solids (9.18%) (Plate XI). This hybrid involved good x good combiners. The sca effect though positive was not significant. The highest heterobeltiosis, relative heterosis and high sca were expressed by Sakthi x TH 318. The observations are in agreement with Yadav et al. (1988) who observed heterosis for fruit dry matter. The highest sca effect was shown by LE 206 x St 64.

Increased insoluble solids more than the female parents were observed in hybrids. LE 214 x Fresh Market 9 expressed significant relative heterosis. The highest *per se* performance (0.91%) was shown by Sakthi x HW 208 F. The hybrid showed significant sca effect which may be due to the best combiner HW 208 F.

Seven hybrids exceeded the better parent of which LE 206 x Ohio 8129 only showed significant heterobeltiosis for reducing sugar. Significant relative heterosis was expressed by LE 206 x St 64, LE 206 x Ohio 8129, and LE 214 x Ohio 8129. Stevens (1979) and Scott (1984) reported higher levels of reducing sugar in the hybrids. The best combination for reducing sugar was LE 206 x Ohio 8129 which had the highest *per se* performance (3.92%), heterobeltiosis and relative heterosis. Ohio 8129 was the best combiner. Second better hybrid was LE 206 x St 64 (3.7[illegible]) in which St 64 was a good combiner.

Ten hybrids exceeded the mid parent in acidity but the heterotic effect was not significant. The hybrids were mainly intermediate between the parents in acidity as reported by Lukyanenko and Lukyanenko (1986). Sakthi x TH [illegible] had maximum acidity (0.52%). Though both the parents were good combiners, sca effect was not significant and negative.

Resulting from increased acid content, the hybrids had low pH, compared to the parents. Similar observations were made by Stevens (1979) and Conti *et al.* (1988). Sakthi x HW 208 F had the maximum pH (3.95). HW 208 F was the best combiner.

All the hybrids had higher consistency than the female parents which were low in consistency. The hybrids of Sakthi, LE 206 and LE 214 with Fresh Market 9 showed significantly positive heterobeltiosis. Nine out of 15 crosses showed significant relative heterosis also. Sakthi x HW 208 F which showed the highest *per se* performance (0.31) had one parent (HW 208 F) as good combiner. Sca effect, though not significant, was the highest (0.011) for this hybrid.

The highest estimate of heterobeltiosis and relative heterosis were observed for lycopene. In four, out of six crosses involving St 64 and Ohio 8129 as male parents, significantly higher heterobeltiosis was observed. LE 206 x St 64 (11.38 mg/100 g) and LE 206 x Ohio 8129 (11.66 mg/100 g) expressed maximum heterobeltiosis and relative heterosis respectively (Plates XII & XIII). These hybrids resulted from the good general combiners and had high sca effects also.

Three hybrids Sakthi x St 64, Sakthi x HW 208 F and LE 206 x St 64 showed significant relative heterosis for ascorbic acid. This is in agreement with Vienchu Thi Ngoe and Stein (1983). Though heterosis effect was negative, LE 214 x Fresh Market 9 showed the highest per se performance (31.59%). HW 208 F was the best combiner for ascorbic acid followed by LE 214.

Additive gene action predominated for plant height, days to harvest, shelf life, pericarp thickness, total solids, lycopene, ascorbic acid, juice yield, reducing sugar, consistency, shape index, acidity and pH. All these characters had fairly high heritability also. Significant advancement could be achieved by selection in the improvement of these characters. Non-additive gene action was observed for fruits/plant, yield/plant, average fruit weight, locules/fruit, TSS and insoluble solids (Table 73). Since additive and non-additive genetic variances were observed for the characters studied, biparental approach and recurrent selection can be utilized in order to exploit both gene actions simultaneously (Virdelwala et al., 1981).

2. Evaluation of F_1 hybrids for ketchup and paste

High solids and increased colour of the hybrids were reflected in the product recovery and colour of the product. Sakthi x HW 208 F recorded the highest recovery of ketchup (40.33%) followed by LE 206 x St 64, Sakthi x LE 206, LE 206 x Ohio 8129 and Sakthi x Ohio 8129. Sakthi x HW 208 F also had maximum consistency (0.48). All these hybrids scored for Grade II standards.

Table 73. Components of gene action for yield components, fruit and juice characteristics

Characters	Gene action
Plant height	Additive
Days to harvest	Additive
Fruits/plant	Non-additive
Fruit yield/plant	Non-additive
Average fruit weight	Non-additive
Fruit shape index	Additive
Locules/fruit	Non-additive
Pericarp thickness	Additive
Storage life	Additive
Juice yield	Additive
TSS	Non-additive
Total solids	Additive
Insoluble solids	Non-additive
Reducing sugar	Additive
Acidity	Additive
pH	Additive
Consistency	Additive
Lycopene	Additive
Ascorbic acid	Additive

For paste also, Sakthi x HW 208 F had the maximum recovery (28.08%) followed by LE 206 x Ohio 8129 and LE 206 x St 64. LE 206 x Ohio 8129 produced paste with deep red colour followed by LE 206 x St 64 and Sakthi x Ohio 8129. All these hybrids scored for Grade II paste.

Suitability of F_1 hybrids for whole fruit canning were indicated earlier by Rao and Choudhary (1981). It is to be noted here that Grade II standards attained by these hybrids is from a genetic background where the female parents have poor processing attributes.

3. Evaluation for bacterial wilt resistance

Sixty one tomato genotypes were highly susceptible to wilt and the F_1 hybrids of four susceptible genotypes with Sakthi and two susceptible genotypes with LE 206 were also highly susceptible. The results showed that resistance in Sakthi is monogenic and recessive whereas in LE 206 it is digenic with supplementary gene interaction. The recessive type of gene action in North Carolina source(s) of bacterial wilt resistance was also reported by Singh (1961). Sreelathakumary (1983) reported a complementary and hypostatic type of digenic recessive gene system responsible for wilt resistance. AVRDC (1975) reported that resistance to bacterial wilt was controlled by multiple recessive genes acting additively. Two independent gene system for wilt resistance, a multiple recessive and dominant were also observed (Tikoo et al., 1983).

In resistant plants in F_2, segregation was observed for uniform ripening, fruit size, shape and colour. The F_2's were crack resistant also. Promising F_2 segregants were selected for further improvement (Plates XIV & XV). As reported by Opena et al. (1986) it is reasonable to suggest that in early generations of hybrid progenies, selections should be concentrated on highly heritable quality traits and selection for wilt resistance should be deferred to the stage when genetic materials have reached family or line status. In the segregating generations from a recessive gene system, pure line selection can be adopted to improve the quality traits.

To sum up, the major findings are that the processing tomatoes were distinct from freshmarket types with respect to their shape having high total solids, insoluble solids, pulp content, consistency and lycopene. Screening tomato genotypes for tomato products projected the suitability of the variety HW 208 F for ketchup and Ohio 8129 and St 64 for paste making. The development of F_1 hybrids with bacterial wilt resistant Sakthi and LE 206 and selected processing types elicited increased fruit quality in terms of uniform ripening, high lycopene and solids and resistance to cracking. The recessive nature of wilt resistance in Sakthi and LE 206 makes it impossible to develop immediately F_1 hybrids combining both wilt resistance and processing quality. Identification of dominant sources of wilt resistance will be an effective and alternative approach. However, the isolation of bacterial wilt resistant segregants in F_2 having uniform ripening, good red colour and crack resistance forebode well to isolate better types in the advanced generations. Backcross breeding is another future line of work to incorporate processing qualities into wilt resistant sources. Technology development for paste manufacture should be considered for improvement of product quality.

Summary

SUMMARY

The investigations on evaluation for processing characteristics in tomato and their expression in a bacterial wilt resistant genetic background were carried out during September 1986 to January 1990 at College of Horticulture, Vellanikkara. Sixty four tomato accessions were evaluated for processing traits leading to high case yield, quality and shelf life of products - ketchup and paste. The selected processing genotypes were crossed with 'Sakthi' and two other resistant lines to develop processing lines possessing resistance to bacterial wilt. Parental combinations which resulted in heterotic F_1 hybrids for different character(s) were identified and type(s) of gene action governing processing traits were studied. The genetic bases of resistance to bacterial wilt were studied and the promising F_2 segregants were selected for further improvement.

Evaluation of the tomato genotypes revealed considerable variations in morphological and qualitative characters. AC 238 and Pusa Early Dwarf were the earliest genotypes during 1st and 2nd seasons (91.20 and 87.40 days respectively). In terms of economic earliness, LE 206 was top ranking (1.34). Sioux produced the biggest fruits (101.83 g) but the fruits were a fewer in number (5.70). AC 142 having small fruits had the maximum number of fruits (55.70). Fruit shape index was the highest (1.95) for Veepick characterised by long oval fruits and the lowest (0.71) for AC 2301 having an oblate shape. Thirty nine genotypes had fruits with elongate shape with shape index >1. Fruits with elongate shape had a fewer locules (range 2.0 to 4.9) and high pericarp thickness (4.16 mm to 7.52 mm) whereas round fruits had more locules (2.8 to 6.3) and a low pericarp thickness (2.77 mm to 5.93 mm) Ohio 832 had the highest pericarp thickness (7.42 mm). H 722 (33.20 days) and St 87 (34.00 days) were the least perishable during the first and second seasons respectively. Thirty genotypes produced fruits which did not crack.

Fruits with high pericarp thickness were firm also. These fruits had high total solids, pulp content, insoluble solids and consistency. The acidity was low and the pH was high. The TSS, reducing sugar and acidity were also low in these firm fruits. HW 208 F recorded the highest total solids (8.16%), insoluble solids (1.25%), pulp content (34.25%) and consistency (0.34). Ohio 8129 (6.36 mg/100 g) and E 6203 (6.62 mg/100 g) were the high lycopene lines during first and second seasons. EC 129355 was the highest yielder (1287.23 g/plant). Veeroma had the highest TSS (6.7%) and LE 214 the highest ascorbic acid content (40.93 mg/100 g).

Among the components of yield, index to earliness recorded maximum variability (gcv - 71.06; pcv - 105.28). Genetic advance as % of mean was the highest (98.83) but the heritability was only moderate (0.46%). Fruit cracking recorded maximum variability (gcv - 65.09; pcv - 53.66) and genetic advance as % of mean (104.42) among fruit characteristics. Insoluble solids showed the highest gcv (30.98) and pcv (32.[illegible]) among fruit juice characteristics. High heritability (0.93) coupled with high genetic advance as % of mean (61.62) was also observed.

Positive correlation was observed between fruit shape index and consistency (rg - 0.64), pericarp thickness (rg - 0.62), insoluble solids (rg - 0.59), lycopene (rg - 0.35), total solids (rg - 0.33), pH (rg - 0.26) and TSS (rg - 0.69). Somatic analyses further confirmed the results that fruits with high shape index have a fewer locules, thick pericarp, high total solids, insoluble solids, consistency, lycopene and pH but low acidity and reducing sugar.

Pulp and total solids content determine the product recovery. The ultimate product yield depended on juice yield from a unit area also. Total solids and pulp content also determine the excess water to be evaporated and the cost involved in concentrating the product to a fixed solids level. Content of insoluble solids was critical for consistency whereas lycopene was crucial for colour of product. HW 208 F with the highest total solids (8.16%) yielded maximum ketchup (10.95 t ha^{-1}) and paste (6.93 t ha^{-1}) and the least quantity of water to be removed saving considerable energy cost. HW 208 F with the highest consistency of ketchup (0.52) scored maximum (85.80) for Grade I standard, even with a moderate colour. Ohio 8129 and St 64 also scored for Grade I standard.

For tomato paste, colour is more important since high lycopene genotypes Ohio 8129 and St 64 scored high (88.60 and 87.60 respectively) but the paste yield were only moderate. HW 208 F and St 87 also had Grade I standard. St 87 had the added advantage of fairly high yield of paste ([illegible] t ha^{-1}). Hunt's tomato paste from USA was exceptional in its [illegible] with high lycopene content (25.44 mg/100 g) and high [illegible]. Ohio 8129 (25.37 mg/100 g) and St 64 (24.79 mg/100 g) were [illegible] to Hunt's paste in lycopene. The acidity of the products from [illegible] genotypes was within limits prescribed. The selection index [illegible] basis of processing qualities also revealed superiority of HW 2[illegible] ([illegible]), Ohio 8129 (10.26) and St 64 (9.86) for processing. [illegible] top ranking in the selection index based mainly on high [illegible] score in the sensory rating due to low consistency and [illegible].

[illegible] physical appearance of products, a few genotypes showed [illegible] formation and phase separation. Genotypes showed varied [illegible] in retention of quality components during processing and storage. Progressive decrease in acidity (2.18 to 1.80%) and concomitant increase in pH (3.71 to 3.86) were observed during storage. The reducing sugar content increased slightly (17.66 to 17.70%) with advanced storage life. TSS was not changed significantly during storage (38.0 to 37.57%).

The genotypes varied in the retention of lycopene, β carotene and ascorbic acid during processing and ranged from 55.40% to 98.80%, 50.10% to 90.05% and 39.57% to 79.83% respectively. With advanced storage upto 12 months, retention of lycopene, β carotene and ascorbic acid dropped to 76.12%, 53.08% and 63.26% respectively. Consequent to reduction in quality components, the sensory scores also changed with genotypes and duration of storage. Ohio 8129 and St 64 were exceptional in retention of lycopene (94.83% and 94.69% respectively) without notable reduction after 12 months. HW 208 F, Ohio 8129, St 64, Ohio 7814, Veeroma and Rubyvee retained the initial consistency throughout storage.

Visible microbial infection was observed in three samples of ketchup. Micro-organisms which caused spoilage were identified as Aspergillus flavus and Aspergillus fumigatus. The chemical components, acidity and pH of the product did not have a direct role in microbial spoilage.

The F_1 hybrids which had the highest *per se* performance were Sakthi x HW 208 F (9.18%) for total solids, Sakthi x HW 208 F (0.91%) for insoluble solids, LE 206 x St 64 (7.0%) for TSS and for lycopene LE 206 x [illegible] 8129 (11.66 mg/100) and LE 206 x St 64 (11.38 mg/100 g). Considering yield/plant, Sakthi x TH 318 (1280.34 g) and for average fruit weight [illegible] Fresh Market 9 (70.97 g) were promising. These hybrids had [illegible] high sca also. The hybrids produced fruits with intermediate [illegible], reducing sugar and firmness. All the F_1 hybrids were crack resistant.

Good general combiners were identified for different characters. They were Sakthi (yield/plant), Fresh Market 9 (average fruit weight), TH 318 (fruit shape index) St 64 (pericarp thickness, TSS), HW 208 F (juice yield, total solids, insoluble solids, consistency, pH, ascorbic acid) and Ohio 8129 (reducing sugar, lycopene, storage life).

Additive gene action predominated for plant height, days to harvest, storage life, pericarp thickness, total solids, lycopene, ascorbic acid, juice yield, reducing sugar, consistency, shape index, acidity and pH. Except shape index (0.23), acidity (0.19) and pH (0.07) all the characters had a high heritability also. Non-additive gene action was observed for fruits/plant, yield/plant, average fruit weight, locules/fruit, TSS and insoluble solids.

Evaluation of F_1 hybrids for ketchup and paste revealed their superiority for high product yield due to increased solids and better colour through increased lycopene. Sakthi x HW 208 F had the highest yield (40.33% and 25.08% respectively) and consistency (0.48 and 0.71 respectively) for ketchup and paste. LE 206 x Ohio 8129 and LE 206 x St 64 were promising for enhanced colour of products. Sakthi x HW 208 F, Sakthi x Ohio 8129, LE 206 x St 64, and LE 206 x Ohio 8129 were rated for Grade II standards for ketchup and paste and Sakthi x St 64 for ketchup alone. These F_1 hybrids had improved product quality over Sakthi and LE 206 which did not reach even Grade II standard.

Reaction of tomato genotypes to bacterial wilt indicated that all the processing lines were highly susceptible to wilt. Crosses using Sakthi and LE 206 with selected processing types, revealed a recessive and monogenic inheritance with Sakthi and recessive, digenic and supplementary gene interaction for wilt resistance with LE 206. The F_2 segregants [illegible] fruit colour and elongated fruit shape. All the F_2 segregants were free from fruit cracking.

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* The original not seen

Appendices

APPENDIX I

Method for giving scores for tomato ketchup

Characteristics	Description	Maximum number of points
Colour	Good, practically uniform colour; practically free from discolouration (such as blackening of the surface) due to oxidation or other causes, changes normally associated with processing shall not be considered as defects	25
	Good, reasonably uniform colour, reasonably free from discolouration	19
	Indication of developing black discolouration at the surface; colour not characteristic red, tending to be pink	16
Consistency	Good fluid consistency; uniform smooth texture; no tendency for separation of insoluble solids and liquid portions	25
	Reasonably good fluid consistency; reasonably uniform texture; little tendency to separate	19
	Fairly good fluid consistency; some tendency to separate	16
Flavour	Good, characteristic flavour of tomato ketchup; free from scorched burnt or any other objectionable flavour	25
	Reasonably good, characteristic flavour of tomato ketchup; having a slightly scorched taste	19
	Fair flavour; may have smell of being scorched or over burnt, but the product is acceptable	16
Absence of defects	Practically free from defects, such as presence of particles of seeds, skins, dark specks or other hard and coarse extraneous material	25
	Reasonably free from defects, some pieces of seeds or minute pieces of core may be present, not easily discernible to the eye	19
	Some pieces of seeds or pieces of core material readily noticeable on casual examination	1

APPENDIX II

Method of giving scores for tomato paste

Characteristics	Description	Maximum number of points
Colour	Good, practically uniform colour; practically free from discolouration due to oxidation or other causes; changes, normally associated with processing shall not be considered as defects	60
	Good, reasonably uniform colour; reasonably free from discolouration	45
	Fairly good colour, tending to be brownish	39
Absence of defects	Practically free from defects, such as presence of seeds, skin and other hard and coarse extraneous material; shall be free from bitter, scorched, astringent or burnt or any other objectionable flavour; shall have fluid consistency and shall not show excessive separation of liquid from suspended solids	40
	Reasonably free from defects, a slight bitter taste present; having tendency towards separation	30
	Some scorched and astringent flavour; some pieces of seeds, skin may be present, readily noticeable on casual examination	26

APPENDIX - III

Mean performance of tomato genotypes for fruit yield and its components

Genotypes	Plant height (cm)	Days to flower	Days to harvest	Index to earliness	Fruit/ plant	Fruit yield/ plant (g)
Ohio 832	81.80	74.0	110.4	0.03	12.4	602.08
Ohio 7814	69.40	75.2	108.0	0.10	22.4	992.36
Ohio 8129	83.80	73.6	107.2	0.17	26.0	783.32
St 61	86.80	73.2	102.8	0.37	39.6	1012.04
St 64	88.60	75.2	103.4	0.32	29.6	823.66
St 87	80.00	73.4	106.8	0.14	24.4	1044.12
ONt 828	69.40	72.4	108.2	0.10	31.0	924.24
Ont 8210	69.60	76.8	105.4	0.01	7.8	388.96
H 722	86.20	76.8	107.4	0.04	16.0	627.86
H 2653	91.20	74.6	104.6	0.08	10.6	389.76
H 7038	86.40	73.0	103.4	0.19	19.2	1068.18
FM 6203	87.60	72.0	103.8	0.03	16.4	516.20
HW 208 F	84.00	71.2	109.8	0.01	17.0	[illegible]
TH 318	73.20	75.6	104.8	0.18	21.2	[illegible]
Veepick	120.00	70.2	106.6	0.20	[illegible]	[illegible]
Veepro	93.60	67.6	102.6	0.36	[illegible]	[illegible]
Veeking	88.40	66.8	103.8	0.19	15.6	[illegible]
Veemore	91.60	66.0	92.4	0.45	[illegible]	[illegible]
Veeroma	95.00	66.4	100.4	0.33	[illegible]	[illegible]
Rubyvee	86.60	66.0	96.2	0.53	[illegible]	763.18
UC 28	95.80	66.2	102.6	0.62	[illegible]	[illegible]
UC 82	72.00	63.8	98.2	0.61	[illegible]	[illegible]
E 6203	91.20	66.4	98.2	0.36	[illegible]	[illegible]
Processor 40	68.20	66.2	104.4	0.11	[illegible]	[illegible]
Roma	104.60	74.0	102.6	0.03	[illegible]	[illegible]
San Marzano	98.80	65.6	102.8	0.09	[illegible]	[illegible]
Heinz 1350	91.80	67.0	102.0	[illegible]	[illegible]	[illegible]
Sioux	102.20	66.6	103.2	0.15	[illegible]	613.38
Punjab Chhuhara	70.40	61.6	96.8	0.19	[illegible]	564.48
Labonitha	72.20	61.6	96.0	0.30	[illegible]	525.50
IHR 674	72.40	66.8	96.0	0.38	30.0	[illegible]
Sel 11	94.00	64.6	96.8	0.05	26.8	[illegible]
Pant T_2	94.60	68.0	103.2	0.07	[illegible]	[illegible]
Fire Ball	94.00	63.6	94.0	0.29	[illegible]	[illegible]
Fresh Market 9	85.80	63.4	100.8	[illegible]	[illegible]	[illegible]
DMM (EC 108759)	93.40	66.6	95.6	0.26	[illegible]	821.54

Contd.

Appendix -III (contd.)

Genotypes	Plant height (cm)	Days to flower	Days to harvest	Index to earliness	Fruit/ plant	Fruit yield/ plant (g)
EC 129968	113.40	64.8	94.0	0.51	52.40	871.16
EC $104162/P_2$-1	73.00	67.6	97.2	0.63	29.00	991.66
EC 54645	95.40	67.6	100.0	0.40	13.80	901.58
EC 50366-1-1	110.60	68.8	93.2	0.51	19.80	663.74
EC $129588/P_1$	104.40	66.0	107.2	0.47	17.40	802.80
EC 129599	78.60	62.4	91.4	0.49	33.80	945.25
EC128965	122.60	65.6	96.2	0.50	31.80	822.30
EC 129355	104.40	65.8	99.4	0.38	43.60	1258.98
EC 101652	121.20	68.2	96.0	0.22	27.80	875.22
Kt 1	120.40	62.4	91.4	0.46	33.20	992.68
Kt 2	134.80	67.4	98.2	0.73	19.60	[illegible]
Kt 3	125.00	60.6	95.8	0.52	28.40	223.26
Kt 4	136.00	65.6	102.8	0.35	22.40	[illegible]
HS 101	[illegible]	62.2	96.2	0.69	[illegible]	[illegible]
HS 102	[illegible]	[illegible]	[illegible]	0.21	10.60	[illegible]
AC 142	[illegible]	[illegible]	[illegible]	1.12	[illegible]	[illegible]
AC 238	[illegible]	[illegible]	[illegible]	0.31	[illegible]	[illegible]
AC 2301	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
S 12	[illegible]	[illegible]	[illegible]	0.72	[illegible]	[illegible]
Sweet 72	[illegible]	[illegible]	[illegible]	0.23	[illegible]	[illegible]
Punjab Kesari	[illegible]	[illegible]	[illegible]	0.11	[illegible]	[illegible]
Pusa Early Dwarf	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Money Maker	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Marutham	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Pusa Ruby	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LE 206	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LE 214	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sakthi	[illegible]	63.2	[illegible]	[illegible]	[illegible]	[illegible]
CD (0.05)	[illegible]	[illegible]	[illegible]	0.35	[illegible]	[illegible]
CD (0.01)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

S_1 - September 1986-January 1987

APPENDIX - III

Mean performance of tomato genotypes for fruit characteristics

Genotypes	Average fruit weight (g)	Fruit shape index	Locules/fruit *	Pericarp thickness (mm)	Fruit cracking** (%)	Storage life (days)
Ohio 832	34.68	1.31	3.2 (1.79)	7.46	0 (1.00)	31.8
Ohio 7814	36.67	1.27	2.2 (1.48)	7.18	0 (1.00)	29.8
Ohio 8129	31.10	1.20	2.0 (1.41)	5.72	0 (1.00)	25.6
St 61	27.44	1.39	2.0 (1.41)	5.98	0 (1.00)	18.2
St 64	30.22	1.03	2.6 (1.61)	6.28	0 (1.00)	26.8
St 87	48.38	1.27	3.0 (1.73)	6.48	0 (1.00)	32.4
ONt 828	34.12	1.14	2.4 (1.54)	6.20	0 (1.00)	21.6
ONt 8210	33.08	1.16	3.0 (1.73)	5.32	0 (1.00)	19.6
H 722	41.90	1.37	2.0 (1.41)	5.24	0 (1.00)	33.2
H 2653	41.36	1.41	2.2 (1.48)	5.06	0 (1.00)	30.6
H 7038	58.60	1.22	3.2 (1.77)	5.59	0 (1.00)	19.2
FM 6203	[illegible]	1.18	2.4 (1.54)	5.06	0 [illegible]	[illegible]
HW 208 F	[illegible]	1.04	4.8 (2.19)	5.12	0 [illegible]	[illegible]
TH 318	[illegible]	1.11	4.2 (2.05)	6.76	0 [illegible]	17.0
Veepick	[illegible]	2.02	3.0 (1.73)	[illegible]	[illegible]	[illegible]
Veepro	[illegible]	[illegible]	3.6 [illegible]	[illegible]	[illegible]	[illegible]
Veeking	[illegible]	1.02	4.2 [illegible]	[illegible]	[illegible]	[illegible]
Veemore	[illegible]	0.92	5.6 [illegible]	[illegible]	1.51 [illegible]	[illegible]
Veeroma	[illegible]	1.47	2.2 (1.48)	[illegible]	[illegible]	[illegible]
Rubyvee	[illegible]	1.25	4.4 [illegible]	[illegible]	[illegible]	[illegible]
UC 28	[illegible]	1.20	3.0 (1.73)	5.02	[illegible]	[illegible]
UC 82	[illegible]	1.29	2.0 (1.41)	6.48	[illegible]	[illegible]
E 6203	[illegible]	1.36	2.6 [illegible]	[illegible]	[illegible]	[illegible]
Professor 40	[illegible]	1.19	1.8 [illegible]	[illegible]	[illegible]	[illegible]
Roma	[illegible]	1.42	2.0 (1.41)	[illegible]	[illegible]	[illegible]
San Marzano	29.18	1.52	2.4 (1.54)	[illegible]	[illegible]	[illegible]
Heinz 1350	[illegible]	0.77	6.2 [illegible]	5.59	[illegible]	[illegible]
Sioux	101.22	0.71	4.8 (2.19)	5.96	[illegible]	[illegible]
Punjab Chhuhara	22.29	1.50	2.0 (1.41)	5.16	0 (1.00)	[illegible]
Labonitha	22.85	1.06	2.0 (1.41)	4.86	0 (1.00)	[illegible]
IHR 674	33.39	1.25	2.8 (1.67)	5.28	0 (1.00)	22.2
Sel 11	28.55	1.51	2.0 (1.41)	5.52	7.29 (2.81)	9.0
Pant T_2	22.30	1.52	2.2 (1.48)	5.07	2.00 (1.46)	22.6
Fire Ball	23.80	0.94	2.4 (1.54)	4.40	15.21 [illegible]	15.0

(Contd.)

Appendix - III (Contd.)

Genotypes	Average fruit weight (g)	Fruit shape index	Locules/fruit*	Pericarp thickness (mm)	Fruit cracking** (%)	Storage life (days)
Fresh Market 9	96.64	1.02	5.0 (2.23)	5.25	4.44 (1.76)	22.4
DMM (EC 108759)	28.17	1.67	2.0 (1.41)	5.46	0 (1.00)	4.8
EC 129068	18.9[illegible]	0.72	2.6 (1.61)	4.74	26.94 (4.80)	18.6
EC 104162/P$_2$-1	36.20	1.19	2.4 (1.54)	6.64	22.43 (4.48)	19.8
EC 54643	71.34	1.01	4.8 (2.19)	6.12	9.33 (2.98)	18.4
EC [illegible]	[illegible]	0.96	3.0 (1.73)	4.52	37.87 (5.98)	13.2
EC 12[illegible]	55.17	1.00	4.6 (2.14)	5.78	16.90 (3.77)	16.0
EC 1295[illegible]	[illegible].76	1.24	2.2 (1.48)	5.22	8.07 (2.95)	8.6
EC 12[illegible]	[illegible]	0.75	3.6 (1.89)	5.28	8.76 (2.45)	7.0
EC 12[illegible]	[illegible]	1.21	3.0 (1.72)	7.06	8.99 (3.00)	22.0
EC 1[illegible]	[illegible]	0.89	4.2 (2.03)	4.46	7.69 (2.71)	18.2
Kt 1	[illegible]	0.87	3.2 (1.79)	5.02	9.15 (3.14)	13.0
Kt 2		0.87	3.0 (1.72)	5.88	7.5[illegible] (2.81)	13.6
Kt 3	[illegible]	0.[illegible]7	5.[illegible] (2.23)	4.89	17.[illegible] (4.2[illegible])	1[illegible]
Kt 4	[illegible]	[illegible]	3.[illegible] (1.[illegible])	4.72	3.13 (1.7[illegible])	1[illegible].8
HS 101	[illegible]	0.71	3.0 (1.73)	4.60	0 (1.0[illegible])	17.5
HS 102	[illegible]	[illegible]	3.[illegible] (1.99)	4.24	7.31 (2.52)	17.6
AC 142	[illegible]	0.93	2.6 (1.61)	3.92	0 (1.[illegible])	15.[illegible]
AC 213	[illegible]	0.73	5.6 (2.30)	2.92	5.2[illegible] (2.[illegible])	[illegible].2
AC 2[illegible]	[illegible]	0.71	3.8 (2.0[illegible])	4.12	21.[illegible]2 (4.[illegible]3)	[illegible]
S 12	[illegible]	0.88	3.6 (1.89)	4.04	22.[illegible] (4.37)	19.4
Sweet 72	[illegible]	0.75	4.0 (1.99)	2.70	[illegible] (2.5[illegible])	11.2
Punjab [illegible]	[illegible]	1.0[illegible]	4.2 (2.05)	3.15	0 (1.00)	12.[illegible]
Pusa Early Dwarf	17.2[illegible]	0.71	2.8 (1.[illegible])	3.0[illegible]	0 (1.00)	9.0
Money Maker	11.36	0.89	3.2 (1.79)	3.[illegible]	0 (1.00)	14.4
Maruthum	[illegible]	0.71	3.2 (1.79)	3.18	[illegible] (2.80)	9.6
Pusa Ruby	2[illegible].61	0.75	4.[illegible] (2.0[illegible])	3.14	0 (1.00)	10.2
LE 206	11.19	0.88	3.8 (1.94)	4.96	0 (1.00)	16.0
LE 210	28.70	0.89	3.0 (1.72)	4.76	7.70 (2.91)	4.6
Sakthi	36.70	0.92	4.0 (1.99)	3.96	22.77 (4.64)	12.8
CD (0.05)	17.57	0.07	0.22	0.83	1.17	1.22
CD (0.01)	21.09	0.10	0.28	1.04	1.89	[illegible]

* and ** Parentheses indicate $\sqrt{x}$ and $\sqrt{x+1}$ transformed values, respectively

S_1 - September 1986-January 1987

APPENDIX - III

Mean performance of tomato genotypes for fruit [illegible] characteristics

Genotypes	Juice yield (%)	Juice yield (t ha-1)	TSS (%)	Total [illegible] (%)	[illegible] (%)	Total [illegible] [illegible]	Reducing sugars (%)	Acidity (%)	pH
Omo 831	8[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.8[illegible]	0.29	4.5[illegible]
Omo 78[illegible]	8[illegible]	22.5[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.33	0.39	4.43
Omo 8125	81.[illegible]	17.79	4.9[illegible]	[illegible]	1.1[illegible]	6.68	3.72	0.38	4.45
Sx 61	85.0	21.84	4.90	6.4[illegible]	0.92	7.12	2.47	0.35	4.40
Sx 64	87.2	14.95	4.70	7.24	1.06	6.93	3.21	0.45	4.49
Sx 87	80.4	21.56	4.60	7.25	0.96	7.56	2.89	0.30	4.50
ONx 821	87.0	22.33	4.74	7.18	0.88	8.14	2.72	0.38	4.58
Onx 8211	76.8	8.32	3.90	6.03	0.77	7.84	3.51	0.32	4.77
H 722	70.8	12.37	4.30	6.89	1.14	6.06	3.74	0.37	4.51
H 2653	82.0	8.86	4.80	7.43	1.15	6.45	2.88	0.41	4.42
H 7033	81.2	24.11	4.50	6.54	0.91	7.19	3.26	0.39	4.50
FM 6203	80.6	11.46	5.00	6.52	1.10	6.56	2.84	0.39	4.49
HW 208 F	86.0	24.52	5.00	8.03	1.21	6.70	3.23	0.40	4.35
TH 318	81.6	23.16	4.58	6.21	0.79	7.89	2.75	0.40	4.48
Veepick	80.4	10.18	5.40	5.94	0.68	8.80	2.90	0.45	4.05
Veepro	73.6	19.15	4.60	5.79	0.66	8.75	3.08	0.38	4.14
Veeking	74.6	17.99	4.00	5.10	0.50	10.37	2.40	0.28	4.18
Veemore	79.4	25.66	4.40	5.10	0.75	6.78	3.30	0.48	4.11
Veeroma	82.8	19.25	6.60	7.69	0.95	8.15	3.59	0.40	4.18
Rubyvee	73.6	15.61	4.60	6.32	0.76	8.37	2.95	0.32	4.24
UC 28	72.4	18.66	4.00	5.14	0.60	8.71	2.56	0.30	4.82
UC 82	79.8	22.57	4.70	5.87	0.51	11.59	2.55	0.34	4.12
E 6203	82.8	17.24	5.00	6.12	0.83	7.43	2.61	0.35	4.20

Contd.

Appendix -III (contd.)

Genotypes	[illegible] yield (%)	[illegible] yield ([illegible])	TSS (%)	Total solids ([illegible])	Insoluble solids (%)	Total soluble/insoluble solids ratio	Reducing sugars (%)	Acidity (%)	pH
Processor 40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.35	0.32	4.36
Roma	74.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.53	0.60	4.21
San Marzano	72.6	12.9[illegible]	[illegible]	[illegible]	[illegible]	9.91	2.79	0.33	4.14
Heinz 1350	73.4	13.7[illegible]	[illegible]	[illegible]	0.64	9.51	2.67	0.35	4.05
Sioux	74.6	12.72	4.52	6.25	0.64	9.55	3.01	0.41	4.05
Punjab Chhuhara	72.6	11.45	6.20	6.87	0.73	9.44	3.86	0.65	4.08
Labonita	8[illegible]	11.82	6.10	6.41	0.73	8.82	4.47	0.52	3.90
IHR 674	74.[illegible]	17.56	4.00	4.87	0.47	10.39	4.10	0.67	4.38
Sel 11	77.8	16.32	4.80	5.77	0.46	12.46	3.87	0.46	4.24
Pant T_2	70.0	12.18	6.00	7.03	0.83	8.51	3.80	0.68	4.25
Fire Ball	80.0	20.57	5.40	5.95	0.60	10.04	3.38	0.47	4.10
Fresh Market 9	85.2	24.07	4.20	5.48	0.77	7.30	2.50	0.33	3.92
DMM (EC 108759)	77.4	17.55	5.10	5.90	0.72	8.16	3.19	0.46	4.07
EC 129968	81.2	19.67	5.20	5.76	0.44	13.23	3.96	0.58	4.09
EC $104162/P_2$-1	66.4	12.12	4.60	5.10	0.51	9.95	3.24	0.38	4.16
EC 54645	75.6	12.89	5.00	6.28	0.59	10.72	3.09	0.40	4.18
EC 50366-1-1	77.0	14.33	6.00	6.42	0.41	16.16	3.33	0.55	4.26
EC $129599/P_1$	72.4	16.12	5.00	5.42	0.70	7.78	3.04	0.40	4.03
EC 129599	84.6	22.15	5.00	5.54	0.49	11.32	3.31	0.44	4.08
EC 128965	76.0	17.61	4.60	5.97	0.76	7.81	4.24	0.44	4.12
EC 129355	79.6	27.82	4.80	5.53	0.54	10.19	3.56	0.40	4.36
EC 101652	73.4	11.80	5.80	6.38	0.60	10.67	3.12	0.46	4.10
Kt 1	80.0	20.07	4.20	4.93	0.46	10.66	2.40	0.44	3.98
Kt 2	80.6	18.72	4.40	6.36	0.74	8.59	3.87	0.41	4.24

Contd.

Appendix - III. (contd.)

Genotypes	Juice yield (%)	Juice yield (t ha^{-1})	TSS (%)	Total solids (%)	Insoluble solids (%)	Total solid insoluble solids ratio	Reducing sugars (%)	Acidity (%)	pH
Kt 3	31.2	27.87	4.60	6.11	0.66	9.29	2.64	0.53	4.13
Kt 4	73.2	17.31	4.70	5.60	0.92	6.14	2.88	0.44	4.15
HS 101	33.4	17.42	5.10	5.87	0.48	12.28	3.69	0.52	4.24
HS 102	32.3	9.38	5.40	6.18	0.55	11.22	3.20	0.43	4.04
AC 142	32.6	20.06	5.20	5.72	0.59	9.73	3.97	0.52	4.05
AC 238	32.0	5.69	5.40	5.75	0.44	12.99	4.12	0.64	4.18
AC 2301	73.6	18.56	5.00	5.82	0.58	10.11	3.25	0.58	3.88
S 12	32.0	14.70	5.80	6.36	0.66	10.38	3.15	0.60	4.09
Sweet 72	[illegible]	5.35	5.60	6.04	0.41	14.79	3.46	0.55	4.09
Punjab Kesari	34.0	8.55	4.10	4.49	0.39	11.87	2.75	0.59	4.40
Pusa Early Dwarf	31.2	7.44	5.60	6.27	0.47	13.29	3.58	0.74	4.14
Money Maker	70.3	9.63	5.26	5.59	0.44	13.16	3.66	0.47	4.42
Marutham	73.6	14.65	4.10	4.74	0.46	10.23	2.55	0.50	4.14
Pusa Ruby	76.0	3.20	4.70	5.79	0.51	11.31	2.40	0.68	4.25
LE 206	73.2	19.30	5.80	6.35	0.42	15.38	3.11	0.55	3.84
LE 214	71.6	14.64	5.00	5.65	0.40	14.26	2.97	0.46	4.04
Saikthi	[illegible]	24.32	5.70	5.93	0.53	11.33	3.30	0.56	4.00
CD (0.05)	[illegible]	5.20	0.60	0.63	0.09	1.63	0.62	0.12	0.14
CD (0.01)	6.67	6.33	0.78	0.83	0.12	2.15	0.81	0.16	0.19

S_1 - September 1986-January 1987

APPENDIX - III

Mean performance of tomato genotypes for fruit juice characteristics

Genotypes	Sugar acid ratio	Pulp content (%)	Consistency (PPT)	Lycopene (mg/100 g)	β carotene (μg/100 g)	Ascorbic acid (mg/100 g)
Ohio 832	10.00	33.23	0.33	5.49	223.60	11.49
Ohio 7814	8.72	31.25	0.32	5.01	385.53	26.89
Ohio 8129	9.76	32.55	0.32	6.36	247.63	18.58
St 61	7.08	27.87	0.28	5.36	472.03	10.65
St 64	7.30	31.27	0.31	6.20	245.60	18.49
St 87	9.56	33.42	0.34	5.32	204.03	27.35
ONt 828	7.12	30.40	0.31	4.92	472.00	12.47
ONt 8210	10.99	22.99	0.23	2.56	275.43	12.73
H 722	10.17	33.58	0.34	5.54	403.40	20.91
H 2653	7.93	30.98	0.31	4.85	362.93	19.99
H 7038	8.40	28.77	0.29	3.91	335.97	18.74
FM 6203	7.31	30.57	0.31	5.62	427.60	19.86
HW 203 I	8.57	34.83	0.35	5.51	350.17	23.31
TH 318	7.55	25.80	0.25	3.78	336.60	14.81
Veepick	[illegible]	24.47	0.24	3.69	418.53	22.65
Veepro	8.13	25.91	0.26	4.71	513.27	19.39
Veeking	[illegible]	19.27	0.19	4.99	512.83	19.02
Veemore	6.42	21.51	0.22	3.93	431.10	30.69
Veeroma	9.12	29.85	0.30	4.95	430.40	26.14
Rubyvee	9.22	31.53	0.32	4.53	240.47	22.36
JC 28	8.57	25.21	0.24	3.64	358.47	27.55
JC 82	5.66	23.85	0.24	3.75	503.57	26.62
? 6203	7.93	27.01	0.29	6.27	545.17	24.09
Processor 40	7.64	24.24	0.24	3.57	336.80	24.13
Roma	5.91	28.51	0.29	3.70	407.20	17.24
San Marzano	8.18	28.18	0.28	3.68	476.70	26.78
Heinz 1350	7.77	21.27	0.21	3.24	262.00	28.80
Sioux	7.40	26.29	0.27	3.07	353.37	27.27
Punjab Chhuhara	6.14	17.97	0.18	3.78	519.93	24.79
Labonitha	8.86	19.76	0.20	4.30	496.23	32.91
HR 674	6.35	23.45	0.21	3.85	346.77	24.55
Sel 11	8.43	23.49	0.23	3.63	329.80	17.23
Pant T_2	5.41	25.11	0.25	4.11	270.47	30.90
Fire Ball	7.68	22.76	0.23	3.55	382.03	24.78
Fresh Market 9	7.61	21.94	0.22	3.75	352.21	25.60
DMM (EC 108759)	6.95	26.01	0.26	2.70	164.37	11.16

Contd

Appendix - III (contd.)

Genotypes	Sugar acid ratio	Pulp content (%)	Consistency (PPT)	Lycopene (mg/100 g)	β carotene (μg/100 g)	Ascorbic acid (mg/100 g)
EC 129968	7.22	21.73	0.23	3.44	268.60	32.50
EC 104162/P_2-1	8.83	20.69	0.21	3.01	452.07	25.61
EC 54645	8.34	20.36	0.21	2.95	224.93	24.63
EC 50366-1-1	6.16	22.22	0.22	2.31	473.73	[illegible]
EC 129599/P_1	7.67	14.31	0.14	3.70	346.27	28.26
EC 129599	7.51	21.90	0.22	3.42	438.97	23.24
EC 128965	9.76	21.66	0.22	3.73	400.37	25.80
EC 129355	9.50	26.84	0.27	3.09	387.30	32.20
EC 101652	6.83	24.72	0.25	3.37	414.67	26.29
Kt 1	5.50	21.59	0.22	3.40	473.97	24.99
Kt 2	7.53	23.32	0.24	3.45	361.93	26.17
Kt 3	4.99	19.39	0.20	4.19	450.20	22.76
Kt 4	6.51	22.50	0.23	3.36	426.10	29.25
HS 101	7.17	20.07	0.20	3.61	406.10	22.52
HS 102	7.44	21.29	0.21	2.99	528.70	31.06
AC 142	7.64	16.03	0.16	3.99	[illegible]	[illegible]
AC 238	6.59	17.67	0.18	3.12	[illegible]	[illegible]
AC 2301	5.62	17.71	0.17	4.62	580.37	27.79
S 12	5.52	21.53	0.22	3.62	[illegible]	23.15
Sweet 72	6.62	14.63	0.14	1.59	[illegible]	31.48
Punjab Kesari	4.41	16.89	0.17	1.59	[illegible]	21.59
Pusa Early Dwarf	4.97	17.36	0.18	3.45	[illegible]	28.33
Money Maker	7.36	21.02	0.21	2.82	[illegible]	35.19
Marutham	5.42	16.09	0.16	2.68	[illegible]	[illegible]
Pusa Ruby	1.55	21.22	0.21	2.90	[illegible]	[illegible]
LE 206	5.62	17.51	0.17	4.67	541.23	25.44
LE 214	6.51	16.71	0.17	3.04	[illegible]	41.50
Sakthi	5.94	20.03	0.20	2.39	[illegible]	24.29
CD (0.05)	2.22	4.77	0.05	0.94	58.87	[illegible]
CD (0.01)	2.91	6.27	0.06	1.23	[illegible]	9.00

S_1 - September 1986 January 1987

APPENDIX - IV

Mean performance of tomato genotypes for fruit yield and its components

Genotypes	Plant height (cm)	Days to flower	Days to harvest	Index to earliness	Fruits/plant	Fruit yield/plant (g)
Ohio 832	86.8	74.20	106.40	0.05	16.80	599.40
Ohio 7814	68.6	76.40	104.20	0.13	25.60	936.64
Ohio 8129	85.4	69.60	107.80	0.17	24.60	820.10
St 61	90.2	70.20	101.20	0.21	35.60	1011.48
St 64	88.4	75.80	104.20	0.31	27.40	902.72
St 87	80.6	71.80	105.80	0.11	25.00	1068.62
ONt 828	73.6	73.60	107.80	0.10	28.60	905.78
ONt 8210	61.0	74.00	102.00	0.01	10.20	487.10
H 722	81.4	76.80	106.60	0.08	15.80	633.48
H 2653	87.2	73.60	105.80	0.11	10.80	403.42
H 7038	85.2	73.40	102.20	0.20	23.40	1291.90
FM 6253	85.6	70.40	105.00	0.09	16.60	554.10
HW 203 T	50.6	71.80	105.80	0.11	25.00	1068.62
TH 318	75.8	76.80	104.00	0.19	22.40	1313.83
Veepr[illegible]	103.0	63.00	108.00	0.24	12.40	511.72
Veepr[illegible]	75.2	65.60	102.60	0.32	27.80	844.98
Veeking	[illegible]	63.00	103.20	0.22	11.20	732.86
Vee[illegible]	79.6	65.20	96.50	0.41	30.00	1150.15
Veer[illegible]	70.8	64.60	94.80	0.31	30.20	933.16
Rubyve[illegible]	82.8	68.00	97.80	0.55	22.60	801.10
UC 28	72.4	67.40	106.40	0.13	24.80	960.75
UC 82	76.6	60.40	94.60	0.71	27.20	932.30
E 6201	71.6	65.40	101.20	0.41	24.80	749.03
Processor 49	63.5	64.20	106.20	0.16	18.60	868.16
Roma	100.4	75.20	103.00	0.04	19.00	560.10
San Marzano	95.0	60.40	101.60	0.10	33.60	657.04
Heinz 1350	91.6	70.40	96.40	0.46	8.00	692.44
Sioux	100.0	62.80	102.20	0.22	5.40	566.40
Punjab Chhuhara	73.8	64.80	101.40	0.20	30.00	625.40
Labonitha	71.0	64.20	98.60	0.28	21.80	484.14
HIR 674	76.2	69.60	97.40	0.35	21.40	793.40
Sel 11	90.0	64.40	97.80	0.08	27.00	791.32
Pant T_2	92.4	69.20	103.80	0.04	22.60	575.64
Fire Ball	96.0	65.00	97.40	0.86	40.00	988.92

Contd.

Appendix -IV (contd.)

Genotypes	Plant height (cm)	Days to flower	Days to harvest	Index to earliness	Fruits/plant	Fruit yield/plant (g)
Fresh Market 9	83.6	63.80	103.60	0.42	14.20	1254.38
DMM (EC 108759)	91.0	65.80	92.00	0.27	27.60	763.65
EC 129968	105.8	66.00	96.40	0.56	47.20	920.09
EC 104162/P_2-1	76.6	65.00	96.80	0.61	28.60	986.39
EC 54645	98.0	66.20	103.00	0.42	12.80	862.12
EC 50366-1-1	100.4	64.40	91.40	0.50	18.80	668.59
EC 129599/P_1	103.8	63.40	105.20	0.51	16.00	738.78
EC 129599	75.0	59.80	89.20	0.53	30.20	897.80
EC 128965	113.2	67.00	98.00	0.53	28.20	890.40
EC 129351	102.2	67.20	102.00	0.42	45.60	[illegible]
E 101652	115.0	70.20	92.60	0.24	26.20	570.92
Kt 1	121.8	60.20	98.60	0.48	31.80	849.94
Kt 2	110.3	65.40	96.40	0.76	17.20	708.24
Kt 3	109.2	64.80	99.20	0.56	[illegible]	[illegible]
Kt 4	118.6	70.00	103.60	0.38	21.20	[illegible]
HS 101	92.0	66.60	100.60	0.70	[illegible]	[illegible]
HS 102	90.8	69.60	96.80	0.25	15.20	[illegible]
AC 142	[illegible]	63.80	96.80	1.16	[illegible]	[illegible]
AC 238	[illegible]	62.00	93.40	0.34	[illegible]	[illegible]
AC 2301	79.3	64.20	91.00	0.56	[illegible]	[illegible]
S 12	75.0	60.60	91.00	0.71	[illegible]	[illegible]
Sweet 72	[illegible]	65.00	96.40	0.20	[illegible]	[illegible]
Punjab Kesari	93.0	65.20	91.60	0.13	[illegible]	[illegible]
Pusa Early Dwarf	83.4	59.60	87.60	0.81	[illegible]	[illegible]
Money Maker	110.2	63.80	101.60	0.15	[illegible]	[illegible]
Marutham	83.6	67.60	100.80	0.53	[illegible]	[illegible]
Pusa Ruby	78.4	68.40	100.80	0.11	16.60	[illegible]
LE 206	70.0	57.80	91.40	1.41	[illegible]	[illegible]
LE 214	78.8	59.20	91.80	0.22	24.80	[illegible]
Sakthi	67.0	65.00	92.80	1.00	30.20	[illegible]
CD (0.05)	11.82	2.46	4.23	0.34	[illegible]	[illegible]
CD (0.01)	15.53	1.29	5.56	0.45	[illegible]	[illegible]

S_2 - September 1987-January 1988

APPENDIX - IV

Mean performance of tomato genotypes for fruit characteristics

Genotypes	Average fruit weight (g)	Fruit shape index	Locules*/ fruit	Pericarp thickness (mm)	Fruit** cracking (%)	Storage life (days)
Ohio 832	36.37	1.38	3.2 (1.79)	7.58	0 (1.00)	31.6
Ohio 7814	37.48	1.31	2.2 (1.48)	5.43	0 (1.00)	29.6
Ohio 8129	38.32	1.19	2.0 (1.41)	6.32	0 (1.00)	28.0
St 61	29.43	1.29	2.0 (1.41)	6.09	0 (1.00)	24.0
St 64	33.85	1.08	2.6 (1.61)	6.50	0 (1.00)	26.4
St 87	[illegible]	1.24	3.0 (1.73)	6.52	0 (1.00)	34.0
ONt 828	[illegible]	1.18	2.4 (1.54)	6.34	0 (1.00)	21.8
ONt 8216	[illegible]	1.11	3.0 (1.73)	5.45	0 (1.00)	21.2
H 722	[illegible]	1.34	2.0 (1.41)	5.54	0 (1.00)	33.4
H 2653	[illegible]	1.36	2.2 (1.48)	5.17	0 (1.00)	28.8
H 7013	[illegible]	1.17	3.2 (1.27)	5.54	0 (1.00)	21.6
FM 6203	[illegible]	1.23	[illegible]	5.18	0 (1.00)	[illegible]
HW 293-1	[illegible]	1.08	5.0 (2.23)	5.31	0 (1.00)	24.2
TH 318	[illegible]	1.09	6.2 (2.04)	6.39	0 (1.00)	20.0
Veepick	[illegible]	1.88	3.2 (1.79)	5.26	2.92 (1.75)	24.0
Veepro	[illegible]	1.21	3.6 (1.89)	7.07	1.67 (1.51)	15.8
Veeking	[illegible]	1.91	4.2 (2.03)	6.33	2.56 (1.69)	22.6
Veemore	[illegible]	0.81	5.4 (2.31)	5.06	2.08 (1.66)	12.4
Veeromato	[illegible]	1.41	2.2 (1.48)	6.19	0 (1.00)	23.2
Rubyvee	[illegible]	1.30	4.4 (2.08)	5.56	0 (1.00)	25.4
UC 28	[illegible]	1.26	3.0 (1.73)	5.61	2.22 (1.62)	26.0
UC 82	15.76	1.21	2.0 (1.41)	6.68	2.38 (1.65)	26.0
E 6203	[illegible]	1.12	2.6 (1.60)	6.89	1.74 (1.52)	24.4
Processor 49	[illegible]	1.11	[illegible]	[illegible]	0 (1.00)	[illegible]
Roma	[illegible]	1.36	2.0 (1.41)	6.53	0 (1.00)	18.4
San Marzano	20.36	1.52	2.4 (1.54)	7.19	0 (1.00)	20.0
Heinz 1350	97.35	0.98	6.4 (2.53)	5.24	9.91 (2.82)	23.8
Sioux	100.69	0.91	5.2 (2.27)	5.91	57.28 (7.32)	20.0
Punjab Chhuhara	21.98	1.42	2.0 (1.41)	5.13	0 (1.00)	15.6
Labonitha	20.69	1.18	2.0 (1.41)	4.87	0 (1.00)	20.0
IIHR 674	34.89	1.23	2.8 (1.67)	5.39	0 (1.00)	25.0
Sel 11	29.53	1.43	2.0 (1.41)	5.64	8.82 (2.89)	8.8
Pant T_2	25.14	1.50	2.2 (1.48)	5.13	0.60 (1.13)	21.2
Fire Ball	25.57	0.92	2.4 (1.56)	4.64	17.33 (3.82)	19.8

Contd.

Appendix - IV (contd.)

Genotypes	Average fruit weight (g)	Fruit shape index	Locules*/fruit	Pericarp thickness (mm)	Fruit** cracking (%)	Storage life (days)
Fresh Market 9	97.68	1.00	4.8 (2.18)	6.27	3.83 (1.89)	20.60
DMM (EC 108739)	27.43	1.60	2.0 (1.41)	5.78	0 (1.00)	8.00
EC 129968	21.77	0.85	2.6 (1.61)	4.63	30.39 (5.48)	19.00
EC 104162/P_2-1	36.97	1.14	2.4 (1.54)	6.59	22.12 (4.62)	20.60
EC 54645	73.57	1.02	4.6 (2.14)	6.41	11.06 (3.16)	20.40
EC 50366-1-1	35.55	0.97	3.0 (1.71)	4.27	39.71 (6.11)	14.40
EC 129599/P_1	54.14	1.04	4.6 (2.14)	5.88	20.67 (3.79)	19.20
EC 129599	31.13	1.16	2.2 (1.48)	5.04	11.38 (3.25)	10.40
EC 128965	28.42	0.87	3.6 (1.89)	5.27	15.04 (3.46)	9.20
EC 129335	22.51	1.19	3.0 (1.72)	6.86	14.27 (3.62)	23.00
EC 101632	26.47	0.96	4.2 (2.03)	4.71	9.53 (2.78)	20.60
Kt 1	27.46	0.88	3.2 (1.79)	5.37	8.20 (2.77)	12.20
Kt 2	53.47	0.89	3.0 (1.72)	5.60	7.74 (2.45)	15.20
Kt 3	46.02	0.96	4.6 (2.14)	4.52	7.13 (4.17)	22.00
Kt 4	43.20	1.00	3.4 (1.84)	4.62	2.21 [illegible]	11.60
HS 101	38.18	0.91	3.0 (1.73)	4.60	0 (1.00)	[illegible]
HS 102	38.05	0.91	3.6 (1.88)	3.44	9.88 (3.20)	14.80
AC 142	15.89	0.84	2.0 (1.41)	4.06	0 (1.00)	17.00
AC 238	14.62	0.74	5.4 (2.31)	2.84	[illegible]	[illegible]
AC 2301	29.82	0.70	3.8 (2.04)	4.44	[illegible]	[illegible]
S 12	24.95	0.88	3.4 (1.94)	4.13	[illegible]	[illegible]
Sweet 72	12.69	0.76	4.0 (1.93)	2.95	[illegible]	[illegible]
Punjab Kesari	25.16	1.12	4.2 (2.05)	3.56	0 [illegible]	[illegible]
Pusa Early Dwarf	18.63	0.74	2.8 (1.66)	3.44	0 [illegible]	[illegible]
Money Maker	36.56	0.73	3.2 (1.79)	3.52	0 [illegible]	16.40
Marutham	30.01	0.99	3.2 (1.79)	3.28	[illegible]	[illegible]
Pusa Ruby	24.11	0.73	4.6 (2.14)	3.02	0 [illegible]	8.80
LE 206	30.11	0.88	3.6 (1.89)	4.31	0 [illegible]	16.20
LE 214	27.67	0.90	3.0 (1.72)	5.02	[illegible]	16.00
Sakthi	35.01	0.94	4.0 (1.99)	3.91	31.86 (5.55)	10.40
CD (0.05)	17.10	0.17	0.22	0.57	1.40	[illegible]
CD (0.01)	22.60	0.23	0.29	0.75	1.83	2.73

* and ** Parenthesis indicate $\sqrt{x}$ transformed $\sqrt{x+1}$ values

S_2 - September 1987 to January 1988

APPENDIX - IV

Mean performance of tomato genotypes for fruit juice characteristics

Genotypes	Juice yield (%)	Juice yield (t ha-1)	T[illegible] (%)	[illegible]	L[illegible] (%)	Total sugar : [illegible] ratio	Reducing sugar (%)	Acidity (%)	pH
Ohio 832	80.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6.61	2.94	0.34	4.46
Ohio 7814	82.4	2[illegible].42	[illegible]	[illegible]	[illegible]	7.14	3.49	0.40	4.42
Ohio 8129	80.2	18.[illegible]	5.[illegible]	[illegible]	1.1[illegible]	7.01	2.94	0.34	4.50
St 61	84.6	2[illegible]	5.[illegible]	6.21	0.8[illegible]	7.29	2.63	0.40	4.30
St 64	84.3	21.2[illegible]	4.9[illegible]	7.6[illegible]	1.2[illegible]	6.43	2.86	0.36	4.44
St 87	79.4	23.64	4.74	7.[illegible]	1.35	7.11	2.40	0.35	4.48
ONT 823	84.2	21.13	4.76	6.9[illegible]	0.93	7.45	2.89	0.42	4.50
ONT 8210	84.0	12.57	4.13	6.02	0.75	8.04	3.48	0.40	4.80
H 722	76.6	13.49	4.93	6.75	1.07	6.39	3.84	0.39	4.40
H 2653	80.0	8.96	5.00	7.60	1.10	7.00	2.70	0.37	4.40
H 7038	82.6	29.64	4.54	6.73	0.90	7.49	3.19	0.44	4.60
FM 6203	82.4	12.73	4.90	6.63	0.90	7.40	2.79	0.38	4.48
HS 208 F	85.2	27.93	5.04	8.30	1.28	6.47	3.05	0.40	4.46
TH 318	84.0	30.63	5.00	6.93	0.90	7.70	3.11	0.47	4.60
Veepick	79.0	11.23	5.20	5.96	0.71	8.36	3.16	0.56	4.06
Veepro	76.0	13.04	4.50	5.96	0.69	8.69	3.14	0.36	4.16
Veeking	74.6	15.11	3.99	5.07	0.60	8.41	2.58	0.35	4.12
Veemore	81.4	26.03	4.50	5.16	0.70	7.41	3.10	0.55	4.16
Veeroma	83.2	21.54	6.30	7.79	1.00	7.79	3.35	0.43	4.30
Rubyvee	72.4	16.13	4.59	6.39	0.80	7.99	2.97	0.40	4.28
UC 28	72.8	1[illegible].53	4.29	5.26	0.61	8.71	2.50	0.34	4.52
UC 82	80.0	1[illegible].04	4.70	5.96	0.66	9.07	3.04	0.35	4.30

Contd.

Appendix - IV (contd.)

Genotypes	Juice yield (%)	Juice yield (t ha⁻¹)	TSS (%)	Total solids (%)	[illegible]	Total solids [illegible] ratio	Reducing sugar (%)	Acidity (%)	pH
E 6203	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.63	0.38	4.26
Processor 40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.28	0.36	4.40
Roma	80.2	12.44	[illegible]	[illegible]	[illegible]	9.21	3.21	0.62	4.22
San Marzano	71.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.60	0.37	4.20
Heinz 1350	78.2	[illegible]	[illegible]	6.22	0.68	8.83	2.30	0.41	4.16
Sioux	78.0	11.85	4.70	6.16	0.71	8.62	3.23	0.48	4.12
Pusa Chhuhara	75.6	13.19	6.20	6.98	0.77	9.09	4.01	0.64	4.08
[illegible]	83.2	11.16	6.20	6.50	0.80	8.34	4.20	0.62	4.00
IHR 674	74.6	16.49	3.94	5.50	0.52	10.66	4.28	0.61	4.46
Sel 11	79.2	17.40	4.96	5.95	0.54	11.10	3.73	0.40	4.28
Pant T_2	73.60	11.82	6.30	7.13	0.92	7.41	3.64	0.66	4.34
Fire Ball	82.20	22.52	5.44	5.96	0.66	9.09	3.95	0.42	4.02
Fresh Market 9	84.20	29.32	4.10	5.49	0.80	6.87	2.76	0.38	3.98
DMM (EC 108759)	80.00	16.84	5.00	5.80	0.80	7.34	3.32	0.65	4.11
EC 129968	80.20	25.43	5.04	5.89	0.38	15.45	4.00	0.69	4.02
EC 104162/P_2-1	69.60	19.17	4.80	5.12	0.49	10.47	3.35	0.38	4.16
EC 54645	77.20	18.46	4.90	6.00	0.64	9.94	3.18	0.41	4.24
EC 50366-1-1	78.20	14.60	5.40	6.52	0.50	12.97	3.45	0.52	3.98
EC 129599/P_1	76.00	15.56	4.80	5.47	0.72	7.62	3.17	0.37	4.02
EC 129599	83.60	20.82	4.80	5.79	0.52	11.24	3.40	0.59	4.10
EC 128965	75.60	16.77	4.60	6.23	0.72	8.64	4.55	0.40	4.04
EC 129355	79.00	28.79	5.10	5.64	0.52	10.84	3.61	0.42	4.40

Contd.

Appendix - IV (contd.)

Genotypes	Juice yield (%)	Juice yield (t ha^{-1})	TSS (%)	Total solids (%)	Insoluble (%)	Total solids: insoluble ratio	Reducing sugar (%)	Acidity (%)	pH
EC 101652	76.40	12.22	[illegible]	[illegible]	0.65	9.93	3.45	0.58	4.18
Kt 1	30.20	13.79	[illegible]	5.11	0.50	10.04	2.62	0.40	3.98
Kt 2	30.60	[illegible]	[illegible]	[illegible]	0.78	8.24	4.06	0.40	4.40
Kt 3	30.60	26.15	4.60	6.09	0.60	10.16	2.90	0.47	3.94
Kt 4	79.40	19.96	4.50	5.75	0.93	6.21	2.96	0.42	4.16
HS 101	34.30	17.20	5.20	5.91	0.49	12.16	4.09	0.58	4.12
HS 102	33.00	12.15	5.34	6.11	0.63	9.76	3.08	0.53	4.08
AC 142	30.60	13.31	4.80	5.67	0.63	9.22	4.08	0.54	4.06
AC 238	30.00	6.55	5.10	5.89	0.49	12.38	4.03	0.68	4.20
AC 2301	30.60	13.41	5.14	5.95	0.60	9.98	3.27	0.65	4.02
S 12	31.60	17.45	5.70	7.02	0.71	9.99	3.10	0.67	4.12
Sweet 72	30.00	9.40	5.60	6.00	0.46	13.37	3.56	0.60	4.12
Punjab Kesari	35.40	8.79	4.14	4.73	0.43	11.12	2.78	0.59	4.36
Pusa Early Dwarf	31.20	9.31	5.80	6.29	0.49	12.77	3.69	0.73	4.16
Money Maker	72.20	15.72	5.20	5.53	0.49	11.30	3.22	0.52	4.48
Marutham[s]	31.20	16.37	[illegible]	[illegible]	0.52	9.62	2.63	0.53	4.24
Pusa Ruby	[illegible]	[illegible]	3.76	[illegible]	0.48	11.25	[illegible]	0.66	4.44
LE 206	[illegible]	[illegible]	[illegible]	[illegible]	0.48	13.64	2.96	0.51	3.96
LE 214	[illegible]	[illegible]	[illegible]	[illegible]	0.50	11.43	[illegible]	0.54	4.10
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.52	11.65	[illegible]	0.62	4.10
CD (0.05)	[illegible]	[illegible]	[illegible]	[illegible]	0.09	1.63	[illegible]	0.12	0.18
CD (0.01)	[illegible]	[illegible]	[illegible]	[illegible]	0.12	2.15	[illegible]	0.16	0.24

S2 - September 1987-January 1988

APPENDIX - IV

Mean performance of tomato genotypes for fruit juice characteristics

Genotypes	Sugar acid ratio	Pulp content (%)	Consistency (PPT)	Lycopene (mg/100 g)	β-carotene (μg/100 g)	Ascorbic acid (mg/100 g)
Ohio 832	8.84	31.79	0.32	5.50	251.47	12.22
Ohio 7814	8.69	29.70	0.30	5.23	405.43	22.12
Ohio 8129	8.48	32.09	0.32	6.54	301.27	17.37
St 61	6.58	28.40	0.28	5.19	478.70	10.60
St 64	7.90	28.86	0.29	6.35	351.23	18.57
St 87	6.92	32.14	0.32	5.63	246.57	25.79
ONt 828	6.84	28.67	0.29	5.07	429.70	14.31
ONt 8215	8.61	25.54	0.25	3.48	252.13	14.47
H 722	9.59	32.40	0.32	5.52	411.13	21.98
H 2653	[illegible]	30.32	0.30	4.98	417.07	18.07
H [illegible]	7.25	29.08	0.29	4.08	333.40	21.00
FM 6203	7.45	[illegible]	0.30	5.60	395.73	18.24
HW [illegible]	[illegible]	[illegible]	0.34	5.76	347.27	21.58
TH [illegible]	[illegible]	[illegible]	0.29	4.84	344.50	16.23
Veepr[illegible]	[illegible]	[illegible]	0.26	3.77	407.53	20.80
Veepr[illegible]	9.62	26.18	0.27	4.76	535.70	18.27
Veeking	[illegible]	[illegible]	0.22	5.05	518.70	18.03
Veemor[illegible]	[illegible]	[illegible]	0.21	3.96	449.10	31.05
Veeroma	7.31	[illegible]	0.30	5.09	428.70	25.27
Rubyvee	7.66	23.57	0.30	4.52	243.17	19.96
UC 28	[illegible]	25.11	0.25	3.79	377.00	26.88
UC 82	[illegible]	[illegible]	0.21	3.71	510.63	25.08
E 6203	[illegible]	[illegible]	0.31	[illegible]	[illegible]	[illegible]
Processor 40	[illegible]	[illegible]	0.25	3.30	365.51	25.45
Roma	5.14	[illegible]	0.28	3.81	613.87	19.01
San Marzano	[illegible]	[illegible]	0.28	3.66	668.80	26.58
Heinz 1350	5.69	22.12	0.22	3.23	273.73	28.13
Sioux	7.60	25.46	0.26	3.22	350.50	27.14
Punjab Chhuhara	6.43	18.95	0.19	3.63	522.13	21.81
Labonitha	6.90	18.63	0.19	4.51	469.40	32.03
IIHR 674	7.40	24.48	0.24	3.58	330.13	25.33
Sel 11	9.64	25.45	0.25	3.41	347.53	17.68
Pant T_2	5.59	28.60	0.29	4.15	271.80	28.27
Fire Ball	9.88	23.45	0.23	3.63	327.77	26.96

Contd.

Appendix - IV (contd.)

Genotypes	Sugar acid ratio	Pulp content (%)	Consistency (PPT)	Lycopene (mg/100 g)	β carotene (μg/100 g)	Ascorbic acid (mg/100 g)
Fresh Market 9	7.21	21.15	0.21	3.72	322.87	26.50
DMM (EC 108759)	5.15	24.68	0.25	2.72	363.07	32.31
EC 129968	5.89	20.75	0.21	3.50	296.13	30.42
EC 104162/P_2-1	8.93	19.94	0.20	3.08	439.17	28.58
EC 54645	7.89	21.03	0.21	2.78	218.10	29.36
EC 50366-1-1	6.65	20.43	0.20	2.39	458.57	25.75
EC 129599/P_1	8.57	15.91	0.16	3.91	366.70	26.91
EC 129599	5.78	22.00	0.22	3.43	414.80	22.38
EC 128965	11.76	21.87	0.22	3.89	404.40	25.76
EC 129355	8.66	25.44	0.25	3.12	320.83	31.55
EC 101652	6.06	25.67	0.26	3.54	405.43	24.24
Kt 1	6.51	21.10	0.21	3.43	442.00	24.91
Kt 2	19.25	24.42	0.24	3.23	340.87	23.89
Kt 3	[illegible]	21.09	0.21	3.92	448.73	22.26
Kt 4	[illegible]	22.98	0.23	3.52	418.90	31.57
HS 101	[illegible]	22.59	0.23	3.47	392.57	20.82
HS 102	5.92	22.62	0.23	2.90	508.70	29.27
AC 142	7.55	18.13	9.19	3.79	412.03	25.50
AC 238	6.01	17.58	0.18	3.46	127.77	29.87
AC 2301	5.22	18.58	0.19	4.58	552.20	27.40
S 12	6.75	21.22	0.21	3.73	569.47	25.76
Sweet 72	6.09	16.80	0.17	1.63	455.83	28.92
Punjab Kesari	4.75	16.55	0.17	1.52	182.53	20.14
Pusa Early Dwarf	5.65	17.78	0.18	3.69	306.97	28.78
Money Maker	6.27	19.28	0.19	2.71	252.90	32.82
Marutham	5.75	17.69	0.18	2.67	357.80	21.18
Pusa Ruby	3.72	18.80	0.19	2.63	345.97	18.53
LE 206	5.72	18.91	0.19	4.68	446.40	24.60
LE 214	5.91	15.57	0.16	3.24	397.70	18.36
Sakthi	5.32	21.87	0.22	2.34	302.03	26.67
CD (0.05)	2.34	1.83	0.02	0.60	70.28	6.85
CD (0.01)	3.08	2.41	0.03	0.79	92.35	9.00

EVALUATION FOR PROCESSING CHARACTERISTICS AND THEIR EXPRESSION IN A BACTERIAL WILT RESISTANT GENETIC BACKGROUND IN TOMATO

BY

ALICE KURIAN

ABSTRACT OF THESIS

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ABSTRACT

The present study was undertaken to identify ideal processing types suitable for ketchup and paste making and associated shelf life of ketchup. The prospects of growing these processing types are precarious in Kerala, unless processing traits are coupled with bacterial wilt resistance. The outcome of the investigations on evaluation for processing characteristics in tomato and their expression in a bacterial wilt resistant genetic background are briefed below.

The processing tomatoes were distinct from fresh market types with respect to their elongated shape with shape index >1, characterised by fewer locules, high pericarp thickness, increased firmness and resistance to cracking. The firm fruits had comparatively high insoluble solids. Ideal types also indicated high total solids, pulp content, consistency and lycopene. Reducing sugar and TSS were low due to partitioning of more of the solids into cell wall components. Acidity was also slightly reduced due to reduced locular area. Fruit shape index was related to quality traits as confirmed by somatic analyses.

Pulp content and total solids of fresh tomato are indicators of the product recovery and the excess water to be evaporated which in turn tell upon the cost of concentrating the product to a fixed solids level. Insoluble solids content determine the consistency and consistency of the product is a major grade criterion of ketchup. HW 208 F with the highest ketchup yield (10.95 t ha^{-1}), low energy cost, highest consistency and maximum sensory score was the most ideal genotype for ketchup. Ohio 8129 and St 64 were more suited for paste making due to their bright red colour, since colour decides the paste quality.

Physical appearance of the product during storage was affected only in a few genotypes by blackneck formation and phase separation. Genotypes showed varied response in retention of quality components during

storage. β carotene registered drastic reduction during storage followed by reduction in ascorbic acid and lycopene content. Acidity, consistency and TSS showed slight reduction with advanced storage whereas reducing sugar and pH showed an upward trend. Ohio 8129 and St 64 were unique in the retention of colour, ascorbic acid and consistency of ketchup during storage. Microbial spoilage of ketchup during storage was caused by _Aspergillus flavus_ and _Aspergillus fumigatus_.

The processing genotypes were highly susceptible to wilt. The F_1 hybrids between bacterial wilt resistant lines and processing lines also succumbed to wilt but they exhibited qualitative improvement in Sakthi x HW 208 F for total solids and insoluble solids, and LE 206 x Ohio 8129, LE 206 x St 64 for colour. All the hybrids were crack resistant also. Evaluation of F_1 hybrids for ketchup and paste revealed that Sakthi x HW 208 F which outyielded other crosses in case of yield and consistency hold promise as the best material for ketchup and paste. LE 206 x Ohio 8129 and LE 206 x St 64 were promising for quality due to enhanced colour.

Additive gene action governed characters like plant height, days to harvest, storage life, pericarp thickness, total solids, lycopene, ascorbic acid, juice yield, reducing sugar, consistency, shape index, acidity and pH. Predominance of non-additive gene action was observed for fruits/plant, yield/plant, average fruit weight, locules/fruit, TSS and insoluble solids.

Inheritance to bacterial wilt resistance revealed a recessive model with monogenic inheritance in Sakthi and digenic inheritance in LE 206.