

**ASSESSMENT OF GENETIC VARIABILITY IN SEGREGATING
POPULATION (F₂) OF CHERRY TOMATO (*Solanum lycopersicum*
L. var. cerasiforme)**

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COLLEGE OF AGRICULTURE, SHIVAMOGGA
UNIVERSITY OF AGRICULTURAL AND HORTICULTURAL
SCIENCES, SHIVAMOGGA
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DEPARTMENT OF GENETICS AND PLANT BREEDING
COLLEGE OF AGRICULTURE, SHIVAMOGGA
UNIVERSITY OF AGRICULTURAL AND HORTICULTURAL SCIENCES
SHIVAMOGGA

C E R T I F I C A T E

This is to certify that the thesis entitled 'ASSESSMENT OF GENETIC VARIABILITY IN SEGREGATING POPULATION (F₂) OF CHERRY TOMATO (*Solanum lycopersicum* L. var. *cerasiformae*)' submitted in partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **GENETICS AND PLANT BREEDING** to the College of Agriculture, Shivamogga, University of Agricultural and Horticultural Sciences, Shivamogga is a bonafide record of research work carried out by **Ms. RAJESHWARI, TELI, A., ID No. MA1TAG0229** (rajeshwariteli401@gmail.com) during the period of study in this university under my guidance and supervision and no part of this thesis has previously formed the basis for the award of any other degree, diploma, associateship, fellowship or any other similar titles.

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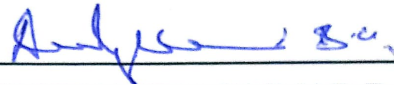



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(**Rajeshwari, Teli, A.**)

**Assessment of genetic variability in segregating population (F₂) of cherry tomato
(*Solanum lycopersicum* L. var. *cerasiforme*).**


RAJESHWARI, TELI, A.

ABSTRACT

The present investigation was carried out to assess the extent of genetic variability and identification of transgressive segregants in segregating (F₂) population (250) of cross IIHR 2358 (Tomato) and Australian red (cherry tomato) for yield and quality traits. The experiment was undertaken at ZAHRS Navile, Shivamogga during *Kharif*-2018. Genetic variability analysis showed that existence of sufficient amount of variability for most of the traits. High estimates of phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were observed for number of cluster per plant, number of flowers per plant, number of fruits per plant, primary branches per plant, pericarp thickness (mm) and lycopene content (mg/100g). The estimates of heritability and GAM were high for all studied traits except for days to first flowering, number of locules per fruit, TSS (Brix) and pulp content (%). Correlation analysis revealed fruit yield per plant had significant and positive association with number of clusters per plant, number of fruits per plant, plant height (cm), number of branches, average fruit weight (g) and fruit width (mm). Path coefficient analysis had showed positive direct effect of fruit yield on number of clusters per plant, plant height (cm), number of branches per plant, average fruit weight (g) and fruit width (mm). Among the 250 F₂ plants P-165, P-128, P-168, P-59, P-17, P-03, P-64, P-48, P-18 and P-41 identified superior transgressive segregants can be evaluated for further advanced to stabilization and can be used as parents in hybridization programme for yield and quality traits.

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ಚೆರಿ ಟೊಮ್ಯಾಟೋ (ಸೂಲಾನಂ ಲೈಕೋಪರ್ಸಿಕಂ ಎಲ್. ವೆರೈಟಿ ಸೆರಾಸಿಫಾಲೆ) ಪ್ರತ್ಯೇಕತೆಯ ಪೀಳಿಗೆಯಲ್ಲಿ
(ಎಫ್.೨) ಅಣುವಂಶೀಯ ಪರಿವರ್ತನಶೀಲತೆಯ ಮೌಲ್ಯಮಾಪನ

(ರಾಜೇಶ್ವರಿ, ತೇಲಿ, ಎ.)

ಸಾರಾಂಶ

ಪ್ರಸ್ತುತ ಅಧ್ಯಯನವನ್ನು ೨೦೧೮ ರ ಮುಂಗಾರಿನಲ್ಲಿ ಕೃಷಿ ಮತ್ತು ತೋಟಗಾರಿಕೆ ಸಂಶೋಧನಾ ಕೇಂದ್ರ, ನವಿಲೆ, ಶಿವಮೊಗ್ಗದಲ್ಲಿ ಕೈಗೊಳ್ಳಲಾಯಿತು. ಐಐಹೆಚ್‌ಆರ್ ೨೩೫೮ (ಟೊಮ್ಯಾಟೋ) ಮತ್ತು ಆಸ್ಟ್ರೇಲಿಯನ್ ಕೆಂಪು (ಚೆರಿ ಟೊಮ್ಯಾಟೋ) ತಳಿಗಳ ಸಂಕರಣದ ಎರಡನೇ ಪೀಳಿಗೆಯ ಗಿಡಗಳಲ್ಲಿ (೨೫೦) ಹಣ್ಣಿನ ಇಳುವರಿ ಸಂಭಂಧಿತ ಗುಣಲಕ್ಷಣಗಳ ಪರಿವರ್ತನಶೀಲತೆ, ಗುಣ ಸಂಯೋಜನೆ, ಪಥ ವಿಶ್ಲೇಷಣೆ ಹಾಗೂ ಉತ್ಪನ್ನ ಅಪೇಕ್ಷಣೀಯ ಪ್ರತ್ಯೇಕಗಳನ್ನು ಗುರುತಿಸಲು ಅಗ್ನುಮೆಂಟೆಡ್ ವಿನ್ಯಾಸದಲ್ಲಿ ಕೈಗೊಳ್ಳಲಾಯಿತು. ಅನೋವ ಪರೀಕ್ಷೆಗೆ ಒಳಪಡಿಸಿದ ಸಸ್ಯ ಸಂತತಿಯು ಎಲ್ಲಾ ಗುಣಲಕ್ಷಣಗಳಿಗೂ ಗಮನಾರ್ಹ ವೈವಿಧ್ಯತೆಯನ್ನು ಪ್ರದರ್ಶಿಸಿರುತ್ತದೆ. ಪ್ರತಿ ಸಸ್ಯದ ಗೊಂಚಲುಗಳ ಸಂಖ್ಯೆ, ಪ್ರತಿ ಸಸ್ಯದ ಹೂಗಳ ಸಂಖ್ಯೆ, ಪ್ರತಿ ಸಸ್ಯದ ಹಣ್ಣುಗಳ ಸಂಖ್ಯೆ, ಪ್ರತಿ ಸಸ್ಯದ ಪ್ರಾಥಮಿಕ ಟೊಂಗಗಳು, ತಿರುಳಿನ ದಪ್ಪ ಮತ್ತು ಲೈಕೋಪಿನ್ ಅಂಶಗಳಲ್ಲಿ ಹೆಚ್ಚಿನ ವ್ಯತ್ಯಾಸದ ವಿಭಿನ್ನಾರ್ಥ ಗುಣಾಂಕ (ಜಿ.ಸಿ.ವಿ.) ಮತ್ತು ವ್ಯತ್ಯಾಸದ ವಂಶವಾಹಿ ಬಗೆ ಗುಣಾಂಕ (ಪಿ.ಸಿ.ವಿ), ಸಸ್ಯಗಳ ಎತ್ತರ, ಪ್ರತಿ ಗಿಡದ ರೆಂಬೆಗಳ ಸಂಖ್ಯೆ, ಸರಾಸರಿ ಹಣ್ಣಿನ ತೂಕ, ಮತ್ತು ಹಣ್ಣಿನ ವ್ಯಾಸ ಇವುಗಳು ದೃಶ್ಯರೂಪಿಯ ಮಟ್ಟದಲ್ಲಿ ಗಮನಾರ್ಹ ಸಂಬಂಧವನ್ನು ಹಣ್ಣಿನ ಇಳುವರಿ ಜೊತೆಗೆ ಹೊಂದಿದೆ. ಹಣ್ಣಿನ ಇಳುವರಿಯ ಜೊತೆಗೆ ಸರಾಸರಿ ಹಣ್ಣಿನ ತೂಕ ನಂತರದಲ್ಲಿ ಪ್ರತಿ ಸಸ್ಯದ ಒಟ್ಟು ಹಣ್ಣುಗಳು ಹೆಚ್ಚಿನ ನೇರ ಧನಾತ್ಮಕ ಪರೋಕ್ಷ ಪರಿಣಾಮವನ್ನು ಬೀರಿದೆ. ಇಳುವರಿ ಮತ್ತು ಗುಣಮಟ್ಟದ ಗುಣಲಕ್ಷಣಗಳಿಗಾಗಿ ಮೌಲ್ಯಮಾಪನ ಮಾಡಲಾದ ಸಸ್ಯ ಸಂತತಿಯಲ್ಲಿ ಪ್ರತ್ಯೇಕ ಗುರುತಿಸಲ್ಪಟ್ಟ ಉತ್ಪನ್ನ ಅಪೇಕ್ಷಣೀಯ ಪ್ರತ್ಯೇಕಗಳನ್ನು (ಪಿ-೧೬೫, ಪಿ-೧೨೮, ಪಿ-೧೬೮, ಪಿ-೫೯, ಪಿ-೧೨, ಪಿ-೦೩, ಪಿ-೬೪, ಪಿ-೪೮, ಪಿ-೧೮ ಮತ್ತು ಪಿ-೪೧) ಗಳನ್ನು ಮುಂದಿನ ಪೀಳಿಗೆಗೆ ಮೌಲ್ಯಮಾಪನ ಮಾಡಬಹುದು, ಸಂಕರಣದ ಕಾರ್ಯಕ್ರಮದಲ್ಲಿ ಪೋಷಕವಾಗಿ ಬಳಸಬಹುದು ಮತ್ತು ಸ್ಥಿರೀಕರಣಕ್ಕಾಗಿ ಮುಂದುವರಿಯುವುದನ್ನು ಮಾಡಬಹುದಾಗಿದೆ.

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INTRODUCTION

I INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most important vegetables, belonging to the family Solanaceae. It was introduced to India in the 17th century by Europeans and native being South America where it was diversified first in Mexico-Peru-Ecuador region. Today it has become part and parcel of Indian food.

India is the second largest tomato producer in the world after China and is grown in an area of 8 lakh hectares with the production of 19.66 million metric tons and productivity of 33.55 metric tons per hectare. In India major tomato growing states are Andhra Pradesh, Madhya Pradesh, Karnataka, Gujarat, Odisha, West Bengal, Chhattisgarh, Maharashtra, Bihar, Haryana, Uttar Pradesh, Telangana and Tamil Nadu. Karnataka is the leading producer of tomato in the country with an area of 63,730 hectares and production of 21 lakh metric tons and productivity of 24.36 metric tons per hectare (Anon., 2018).

Tomato is consumed in both fresh and processed form. Nutritionally, it is considered as 'protective food,' and it is a significant dietary source of antioxidants like lycopene, β -carotene, ascorbic acid, folic acid, phenolic acids and flavonoids. One medium fresh tomato (135g) provides 47 per cent Recommended Dietary Allowance (RDA) of vitamin C, 22 per cent RDA vitamin A and 25 calories. Its nutritional importance is enlarged with antioxidant, blood purification and intestinal antiseptic properties of lycopene and anticancerous properties (Chakraborty *et al.*, 2007).

Generally, these are considered to be similar but not identical to the wild relative of the domestic tomato. Although cherry tomato is vegetable, it is consumed more as a fruit rather than as vegetable; hence these are called 'salad tomato.' Cherry tomato has originated from Andes of Chile, Bolivia, Peru, Ecuador and Colombia and it is diversified in Central America, California, Korea, Germany, Mexico and Florida.

Cherry tomato is a warm season crop and requires long growing periods. Cherry tomatoes are generally show determinate, semi-determinate, or indeterminate nature of growth habitat, presence of long racemes with many fruits of intense color and flavor, generally round in shape and are resistant to diseases and tolerant to high relative humidity (> 80 %) and present a highly variable number of fruits per cluster (15-50) and have excellent taste (Nelson and Franco, 2012). Plants have stout branches trailing in habit, leaves flat or slightly curved. Botanically the fruit is a berry, very abundant, borne in short, branched clusters, globular, perfectly smooth, with no apparent sutures. Fruit diameter ranges from 0.5 to 0.75 inch. Tomato is a typical day neutral plant and is mainly self-pollinated, but a certain per cent of cross-pollination also occurs. The flowers are borne on the cymose inflorescence. A flower

is perfect and hermaphrodite. It contains fertile stamen, usually five, short style and protective anthers (fused) that surrounds the stigma. Dehiscence of anther occurs in a basipetal manner.

Cherry tomato is widely grown for its edible fruits, which can be consumed either fresh as a salad or after cooking snacks. Cherry tomatoes are perfect for making processed products like sauce, soup, ketchup, puree, curries, paste, powder, rasam and sandwich. Unripe green fruits used for the preparation of pickle and chutney. The size ranged from thumb tip to the size of a golf ball and can range from being spherical to slightly oblong in shape (Mahesh *et al.*, 2017).

Cherry tomato is a good source of nutrition and contains carbohydrate (6g/100g), sugar (4g/ 100g), protein (1g /100g), calcium (1 %) and iron (2 %). These are a great source of vitamin A (25 %) and vitamin C (13mg /100g), dietary fibers, vitamin E, thiamine, niacin, phosphorus, copper and potassium. These are low in sodium (7.0 mg) and very low in total fat (0.3g), saturated fat and cholesterol (0 mg). Cherry tomato has several medicinal values as it promotes gastric secretion, blood purification and intestinal antiseptic, used in the treatment of mouth and throat cancer (Anon., 2009).

Development of tomatoes for fresh market and processing purpose need improvement of quality traits like color, total soluble solids fruit pH, acidity and viscosity which helps in value addition and prevention of post-harvest losses. Therefore, there is a necessary for breeding cherry tomato to improve traits about fresh and processed forms with high nutritive value.

Although cherry tomatoes have more nutrition compared to normal tomato, there is less work concerning quality improvement in cherry tomato. Hence there is a need for improvement of varieties and hybrids especially for fresh market and processing qualities along with the high nutritive value and higher yield.

Though cherry tomato became popular as a cash crop in some Asian countries, it is still new in India. Therefore, it is essential to assess the quantum of genetic variability, nature of character association concerning different characters, which would help plant breeders in planning a successful breeding program.

The success of a crop improvement program depends on the extent of genetic variability existing in population. The role of genetic variability in crops is of paramount importance in selecting the best genotypes for making rapid improvement in yield and related characters as well as to select the most potential parents for making hybridization programme successful. Exploiting genetic variability of specific traits in segregating population of tomato has greater importance for genetic

improvement of the crop. So, evaluation of genetic variability and heritability is essential.

Yield is a complex character resulting from multiplicative interactions of various yield components. Therefore, correlation studies between yield and other traits will be of interest to breeders in planning the hybridization program and evaluating the individual plants in segregating populations. It is most important to know the direct and indirect influences of these traits which influence yield for selecting suitable genotypes for yield. Therefore, path coefficient analysis has been employed in many vegetables to overcome the unreliability of the correlation coefficient.

Keeping all the above considerations, the present study was planned and executed with the following objectives.

1. To assess the genetic variability for yield and its related traits in segregating population of cherry tomato
2. To study nature and magnitude of association among yield traits through correlation and path analysis
3. To identify transgressive segregants for yield traits in cherry tomato

REVIEW OF LITERATURE

II REVIEW OF LITERATURE

The research carried out in the past on the genetic variability, correlation and path analysis for fruit bio-chemical, morpho-physiological and yield traits of tomato are reviewed below under the following headings,

2.1 Assessment of genetic variability for yield and yield attributing traits

2.2 Study the nature and magnitude of association among yield traits through correlation and path analysis.

2.3 Identification of transgressive segregants for yield and its related traits.

2.1. Assessment of genetic variability for yield and yield attributing traits

Khanom *et al.* (2008) studied 55 tomato genotypes to elucidate genotypic variability, heritability and genetic advance for yield and yield contributing characters. They observed little differences between the genotypic coefficient of variation and phenotypic coefficient of variation for all the characters except dry matter content and yield per plant. They reported high heritability coupled with high genetic advance in percentage of mean for number of primary branches per plant, number of days to first flowering, plant height, number of bunches per plant, individual fruit weight, number of fruits per plant, and number of seeds per fruit.

Ghosh *et al.* (2010) studied variability in segregating generation (F_2) of exotic tomato hybrids. They reported very little differences between PCV and GCV for the traits days to first flowering (PCV=9.21, GCV=7.82), fruit diameter (PCV=17.10, GCV=14.92) fruit length (PCV=17.14, GCV=14.84) and high heritability (>50 %) for all the yield contributing characters except flowers per cluster (47.83 %).

Prema *et al.* (2011) studied genetic variability in six cherry tomato genotypes. They reported high PCV and GCV for average fruit weight (g), pericarp thickness of fruit (cm), fruit yield per plant (kg), lycopene content ($\mu\text{g}/100\text{g}$), TSS of fruit ($^\circ\text{Brix}$) and fruit width (cm). And observed high heritability with high genetic advance for average fruit weight (g), days to 50 % flowering and high heritability was coupled with moderate genetic advance for plant height at 90 days after transplantation, days to first flowering and ascorbic acid content.

Ruksara and Paul, (2011) studied genetic variability, heritability and genetic advance in *Solanum lycopersicum* under RCBD with three replications among 60 genotypes. They reported the higher phenotypic coefficient of variation than genotypic coefficient of variation for all characters studied and observed high heritability for characters like β -carotene, ascorbic acid and lycopene content.

Islam *et al.* (2012) studied nine traits of 11 cherry tomato (*Solanum lycopersicum* L. var. *cerasiforme* (Dunal) A. Gray) inbred lines. They reported high genotypic and phenotypic coefficients of variation for individual fruit weight (68.16 and 74.23 %, respectively) followed by number of fruits/plant (58.8 and 68.34 %, respectively). And reported High heritability, genetic advance and genotypic coefficient of variation for the traits like individual fruit weight, number of fruits and clusters/plant, fruit yield/plant showed low heritability along with low genetic advance. Among the lines, they reported CH154 produced the highest number of fruits/plant (291) and highest fruit yield (1.89 kg/ plant and 63.4 t / ha).

Dharaminder *et al.* (2013) studied genetic variability in twenty-six genotypes of tomato. They observed 'EC-357838' showed the highest mean value for number of fruit per plant, total soluble solids, and yield per plant. They recorded high PCV, GCV and heritability coupled with high genetic gain for plant height, yield per plant, number of fruit per plant and fruit weight.

Adhi *et al.* (2013) studied twenty-four hybrids along with their 11 parents of tomato (8 lines and three testers) for genetic variability. They reported high PCV and GCV for the traits like plant height, number of fruits per cluster, average fruit weight, yield per plant, titrable acidity, ascorbic acid and lycopene. And observed high heritability with high genetic advance as per cent of mean for number of primary branches per plant, plant height, number of fruits per cluster, fruit length, fruit width, average fruit weight, number of locules per fruit, pericarp thickness, titrable acidity, ascorbic acid, lycopene and shelf life.

Sayeda *et al.* (2016) studied thirteen tomato genotypes to estimate variability, heritability and genetic advance for yield and yield contributing characters. They observed a high degree of significant variation for all the characters studied except pericarp thickness and number of locules. And also reported highest GCV for fruit yield per plant and PCV for fruit yield per plant and number of locules, while lowest GCV was noticed for days to first harvest, days to 50 per cent flowering and pericarp thickness and PCV for days to first harvest and days to 50 per cent flowering. They also observed High heritability with high genetic advance as per cent of mean recorded for fruit yield per plant and average fruit weight.

Sushay *et al.* (2013) studied the extent of genetic variability and association among characters in thirty-six tomato genotypes. They reported highly significant difference ($p < 0.01$) was observed among the tested genotypes for all the characters and observed the highest heritability for number of matured fruits per plant (98.34 %) and the least for number of primary branches (47.36 %).

Nwosu *et al.* (2014) studied the extent of genetic variability among 19 accessions of tomato (*Solanum spp.*) under RCBD. They reported high significant differences among the accessions for all attributes studied. They recorded high genotypic and phenotypic coefficients of variation among the accessions. And observed very high genetic advance and heritability for leaf length, leaf width, days to flower, days to 50 per cent flowering, number of fruits per plant, fruit length, fruit diameter, fruit weight and 1000 seed weight.

Parvati *et al.* (2015) studied twelve traits of seven cherry tomato (*Solanum lycopersicum var. cerasiforme*). They reported high GCV and PCV for average fruit weight (67.76 and 67.9 %, respectively) followed by number of fruits/plant (56.45 and 57.28 %, respectively). They observed high estimates of heritability, genetic advance and GCV for the traits of average fruit weight and number of fruits/plant and fruit yield/plant showed high heritability along with low genetic advance.

Ullah *et al.* (2015) studied the extent of genetic variability in twenty genotypes of tomato. They reported high genotypic and phenotypic coefficients of variation for fruits per plant, locule number per fruit and fruit yield per plant and high heritability were observed for flowers per cluster, fruits per plant, fruit weight and fruit length. They recorded high heritability associated with high genetic advance for fruits per plant (52.30 %), fruit weight (46.32 %) and flower per cluster (33.50 %).

Meena *et al.* (2015) studied the extent of genetic variability in tomato genotypes. They reported magnitude of PCV was higher than GCV for all traits studied and high heritability with GA was observed for fruit yield per plant (1129.78 %), plant height (43.37 %), number of flowers per plant (40.35 %), number of number of leaves per plant (25.48 %) and ascorbic acid (22.68 %).

Renuka *et al.* (2012) studied genetic variability in nine genotypes of cherry tomato. They reported high GCV and PCV for average fruit weight (67.76 and 67.90 %, respectively) followed by number of fruits/plant (56.45 and 57.28 %, respectively). And observed that high estimates of heritability, genetic advance, and genotypic coefficient of variation for the traits like average fruit weight, number of fruits/plant and yield/plant. Among the lines studied, IIHR-2754 produced the highest number of fruits/plant (498.67), maximum fruits (96.67 fruits / kg and height cluster / plant).

Neeraj *et al.* (2015a) evaluated thirty-five genotypes of tomato for genetic variability in Randomized Complete Block Design with three replications. They observed the high magnitude of phenotypic as well as genotypic coefficients of variation for fruit yield per plant followed by average fruit weight, number of locules per fruit, number of fruits per plant, number of primary branches per plant and plant

height. They reported high heritability along with high genetic advance in per cent of mean for all the traits except days to 50 per cent flowering.

Arun *et al.* (2016) studied nineteen characters in 40 tomato genotypes in RCBD design. They reported high PCV and GCV for plant height, average fruit weight, number of fruit per cluster, fruit length, fruit width, pericarp thickness, ascorbic acid and lycopene content and also observed moderate to low PCV and GCV for number of primary branches per plant, days to 50% flowering, days to first fruit harvest, fruit yield per plant, total soluble solids, titrable acidity, total sugars and reducing sugars. They recorded high heritability with high genetic advance as per cent of mean for plant height, fruit length, fruit width, average fruit weight, fruit yield per plant, pericarp thickness, total soluble solids, titrable acidity, ascorbic acid content, total sugars, reducing sugars and lycopene content and moderate genetic advance as per cent of mean with high heritability for days to first fruit harvest.

Sunil *et al.* (2016) studied genetic variability in sixty genotypes of tomato. They reported high GCV and PCV (20- 40 %) for fruit volume, average fruit weight, polar diameter, yield per plant, number of seeds per fruit, number of branches at 60 DAT, pericarp thickness, number of fruits per plant, number of locules per fruit, thousand seed weight, lycopene content, β - carotene content, ascorbic acid content, TSS : Acid Ratio. They observed high heritability (20-40 %) with high GAM (20-40 %) for polar diameter, fruit volume, number of seeds per fruit, average fruit weight, number of fruits per plant, fruit yield per plot, lycopene content, equatorial diameter, number of branches at 60 DAT, plant height at 60 and 90 DAT, number of branches at 90 DAT, plant spread from east to west at 60 and 90 DAT, plant canopy at 60 and 90 DAT.

Amarjeet *et al.* (2016) studied the extent of genetic variability, heritability and genetic gain in 56 genotypes of tomato under Randomized Complete Block Design (RCBD) with three replications. They reported the magnitude of the phenotypic coefficient of variation was slightly higher than the genotypic coefficient of variation for all the studied traits. And observed high estimates of heritability and genetic gain for number of fruits per plant, average fruit weight, fruit yield per plant, locular wall thickness and lycopene content.

Arvind *et al.* (2017) studied thirty-five genotypes of tomato for yield and yield attributing characters. They reported high magnitude of phenotypic as well as genotypic coefficients of variation for fruit yield per plant followed by average fruit weight, number of locules per fruit, number of fruits per plant, plant height and number of primary branches per plant except for Days to 50 per cent and recorded high heritability coupled with high genetic advance for all the traits except days to 50 per cent flowering.

Bilal *et al.* (2017) studied genetic components in F₂ population of cross wild tomato (*Solanum pimplifolium*) variety Cauoldera (Wild) and cultivated tomato (*Solanum lycopersicum*) KHT5 for quantitative characteristics of tomato. They reported higher differences between phenotypic and genotypic coefficient of variance for all characteristics except fruit diameter. They observed the highest values of heritability and genetic advance in means for the majority of the traits.

Mamatha *et al.* (2017) evaluated the F₂ population of cross Utkal Raja × Arka Sourabh to estimate genetic variability for fruit quality and yield traits and reported higher estimates of PCV and GCV for plant height, number of branches, Number of clusters per plant, average fruit weight and yield per plant. TSS and total acidity recorded moderate PCV and GCV. Higher heritability coupled with high genetic advance as per cent mean observed for plant height, number of clusters per plant, average fruit weight, yield per plant and total acidity.

Mahantagouda *et al.* (2017a) studied genetic parameters in F₂ population of the cross IHR-2201 × C-13-1-2-1 in tomato (*Solanum lycopersicum*). They observed little differences between GCV and PCV for all the characters except fruit firmness (kg/cm²) and TSS (°B) and reported traits showed high heritability coupled with high genetic advance as per cent mean for plant height, number of branches, number of fruits per plant, average fruit weight, pericarp thickness, number of locules, ascorbic acid and yield per plant.

Mahesh *et al.* (2017) studied genetic parameters in cherry tomato. They evaluated 36 genotypes of cherry tomato in RCBD design. They reported high PCV than GCV for all the characters studied. They recorded very high heritability (> 90 %) coupled with very high genetic advance as per cent over a mean (> 40 %) for the characters like plant height at 30 days after transplanting, pericarp thickness, average fruit weight, number of fruits per plant, lycopene content. They reported high heritability with high genetic advance as per cent mean (GAM) in number of primary branches at 60 and 90 DAT, polar diameter and equatorial diameter.

Priyanka *et al.* (2017) studied genetic variability in the twenty genotypes for yield and yield contributing characters. They observed High values of GCV and PCV for characters like number of fruits per plant (55.74, 56.21 % respectively), number of locules per fruit (36.44, 37.15 %, respectively), average fruit weight (35.45, 35.97 %, respectively) fruit yield per plant (31.09, 32.35 %, respectively) marketable fruit yield per plot (31.10, 32.36 %, respectively) . And recorded high heritability with high genetic advance for plant height, fruit shape index, number of locules per fruit, fruit yield per plant, fruit yield per plot, TSS⁰ Brix, ascorbic acid, Beta carotene, pericarp thickness.

Rakesh *et al.* (2018) evaluated twelve tomato genotypes for genetic variability, heritability and genetic advance in quality attributes and reported wider range Vitamin C (22.70- 25.49 mg/100g). Moderate GCV was observed for TSS (8.99%). High and low heritability was recorded for TSS (7 %) and Vitamin C (29%), respectively. The higher genetic advance was recorded for TSS (15.74 %).

2.2 Study the nature and magnitude of association among yield traits through correlation and path analysis

Joshi *et al.* (2004) reported that number of fruits per plant is most important yield contributing trait followed by plant height. Maximum positive direct effect of number of fruits per plant was on yield.

Manivanna and Prasad, (2005) studied correlation and path analysis in cherry tomato cultivars like 315483, 165700, 257680, 251709, 315479, 162508 and 151628. They reported fruit yield was significantly and positively correlated with the number of leaves, fruit weight and juice content and path analysis revealed the highest direct effect of fruit weight on fruit yield.

Hidayatullah *et al.* (2008) studied correlation analysis in thirty-six tomato genotypes. They reported fruit weight/ plant showed high and positive genotypic and phenotypic correlation with number of picking and the number of fruits per plant.

Ghosh *et al.* (2010) studied character association and path coefficient analysis in F₂ segregating generations of exotic tomato hybrids. They reported significant positive genotypic and phenotypic correlation was observed for plant height, days to first flowering, number of clusters per plant, number of flowers per plant, number of fruits per cluster with fruit yield per plant. And also observed fruits per plant showed the highest positive direct effect (1.09) on fruit yield per plant followed by individual fruits per plant (0.67).

Islam *et al.* (2010) studied correlations and path coefficient in 39 exotic tomatoes (*Solanum lycopersicum* L.) genotypes for nine yield contributing characters. They reported yield per plant was highly significant and positively correlated with flowers per plant, fruits per plant, fruit length, fruit diameter and individual fruit weight. They observed fruits per plant showed the highest positive direct effect (0.98) on yield per plant followed by individual fruit weight (0.96) and highest negative direct effect on yield per plant showed by days to first flowering (-0.28) followed by fruit length (-0.14). They recorded a very low residual effect (0.18).

Jitendra and Devendra, (2011) studied nineteen genotypes along with two checks of tomato in Randomized Block Design with three replications. They reported

correlation analysis revealed high direct and significant positive association with fruit weight influenced the fruit yield per plant.

Manna and Paul (2012b) reported that the fruit yield per plant was positively and significantly correlated with pericarp thickness, fruit length, fruit weight and number of fruits per plant indicating relative importance of these characters for yield improvement. The path coefficient analysis revealed that number of locules per fruit, TSS, fruit length, fruit weight, vitamin C content and pericarp thickness had a positive direct effect on fruit yield, while fruit width and total acid content had strong negative effects on the fruit yield.

Rajasekhar *et al.* (2013) studied correlation and path analysis in nineteen tomato genotypes for yield and quality characters. They reported fruit yield per plant was positively and significantly correlated with number of fruits per plant and fruit width and negatively and significantly correlated with days to last fruit harvest and shelf life. They recorded plant height, number of fruits per plant, fruit length, fruit width and ascorbic acid had high positive direct effects on fruit yield per plant.

Monamodi *et al.* (2013) evaluated tomato genotypes by correlation and path analysis to determine direct and indirect effects of the morpho-physiological traits on yield and reported that the yield was positive and significantly correlated to plant height. Path coefficient analysis showed that fruit weight directly related to yield with a direct effect of 0.75.

Dharamindra *et al.* (2013) studied twenty-six genotypes of tomato to know the nature of correlation and path coefficient analysis between yield and yield-contributing characters. They observed correlation for yield was significantly and positively associated with number of fruits per plant and per cluster. Also path analysis at the genotypic level indicated that fruit weight had the most positive direct effect on yield per plant followed by fruit diameter, number of fruit per plant and number of fruit per cluster.

Sushay *et al.* (2013) studied the association among characters in 36 tomato genotypes. They reported the highest phenotypic and genotypic coefficient of correlation was observed for number of matured recorded fruits per plant and fruits set percentage. They recorded yield per hectare had a highest positive and highly significant phenotypic correlation with weight of fruits per plant, fruit set percentage and it showed negative and highly significant phenotypic correlation with days 50 per cent fruiting and days to maturity.

Meena *et al.* (2015) studied nineteen indeterminate tomato germplasm to estimate the nature and magnitude of associations of different characters with fruit yield and among yield attributing traits and reported fruit yield was significantly and

positively correlated with number of flowers per plant followed by number of fruits per plant and fruit weight at genotypic and phenotypic level. They recorded fruit weight had a very high positive direct genotypic and phenotypic effect on fruit yield per plant followed by fruit set per cent, number of flowers per plant, number of fruits per plant, TSS Brix, plant height, radial diameter of fruit, and days to 50% flowering. They observed low Residual effect for yield.

Parvati *et al.* (2015) studied correlation in seven cherry tomato lines. They reported fruit yield/plant did not show significant and positive correlation with the other characters. Among the lines, L 03686 produced the highest number of fruits/plant (450) and maximum fruit yield (2.2 kg / plant) and height cluster per plant (56).

Neeraj *et al.* (2015b) studied thirty-five genotypes of tomato in RCBD design to know the nature of correlation and path coefficient analysis. They reported genotypic correlation coefficients were mostly similar in nature and higher in magnitude than the corresponding phenotypic correlation coefficients. And observed fruit yield per plant had exhibited a highly significant and positive association with average fruit weight. They also observed average fruit weight and number of fruits per plant showed positive direct effect on fruit yield per plant.

Salehur *et al.* (2015) studied forty-eight genotypes of tomato for yield contributing characters to observe their associations and direct and indirect effect on yield. They observed most of the genotypic correlation coefficient was higher than the respective phenotypic correlation coefficients and also, narrow difference between phenotypic and genotypic correlation coefficient was noticed for almost all the pairs of characters studied. They reported fruit/cluster showed a non-significant positive association with yield/plant at genotypic and phenotypic level but the individual weight of fruit had significant negative association at phenotypic level with yield/plant and recorded path coefficient analysis for number of fruits per cluster had the highest positive direct effects on fruit yield/plant.

Mohammad *et al.* (2015) studied correlation and path analysis in twenty parental genotypes of tomato for yield and yield attributing traits. They reported significant positive genotypic and phenotypic correlation for fruits per plant, fruit weight, fruit diameter and locule number per fruit with fruit yield per plant and fruit diameter showed the highest positive direct effect (3.25) on fruit yield per plant followed by fruits per plant (1.54).

Renuka *et al.* (2017) studied correlation and path analysis of 22 genotypes of tomato they recorded positive and significant association of fruit yield per plant with number of fruits per plant and yield per plot. And observed genotypic path coefficient

analysis revealed direct and positive influence of number of fruits per plant, locules per fruit, pericarp thickness and number of primary branches on fruit yield per plant.

Kaushal *et al.* (2017) studied correlation in twenty five tomato germplasm conducted in Randomized Block Design with three replications. They reported yield per hectare had positive correlation with number of fruits per plant, pericarp thickness, number of locules per fruit, average fruit weight, ascorbic acid content and yield per plant and Path analysis indicated that positive direct effect on fruit yield per hectare was exerted by yield per plant, number of flowers per inflorescence, number of locules per fruit, ascorbic acid content, percentage acidity, fruit diameter, plant height and total soluble solids.

Lakshmi *et al.* (2017) evaluated two F₂ populations of two promising hybrids Arka Samrat and Arka Rakshak for fruit yield and its component traits by correlation and path analysis and reported that the yield per plant had highly significant and positive phenotypic correlation with average fruit weight (0.7732 and 0.8532), number of fruits per plant (0.4378 and 0.2011), plant height and ascorbic acid content (0.1982 and 0.1906) respectively in both the populations. Path analysis for fruit yield per plant revealed that average fruit weight (0.8961 and 0.0274), number of fruits per plant (0.6206 and 0.5354) had direct and positive effects with yield per plant.

Mahantgouda *et al.* (2017b) evaluated F₂ population of the cross IIHR-2201 X C-13-1-2-1 to know the nature of correlation and path analysis. They reported number of fruits per plant followed by plant height, average fruit weight, number of branches per plant, number of locules per fruit, pericarp thickness, fruit length and ascorbic acid showed direct positive effect on yield per plant and other parameters like fruit width followed by fruit firmness, total soluble solids, days to first anthesis and pH showed direct negative effect.

Meera *et al.* (2018) studied correlation and path analysis in 18 genotypes of tomato in RCBD replicated thrice. They reported both at phenotypic and genotypic level, fruit yield was positive and significantly correlated with plant height and primary branches and traits like average fruit weight, number of locules, fruit length, per cent fruit set, flower cluster, days to fruit set, fruit per plant showed positive direct effect on marketable fruit yield per plant.

Ashish *et al.* (2018) studied correlation and path analysis in seven parents including one hybrid check (BSS-488) for yield and quality contributing traits in tomato. They reported fruit yield per plant exhibited positive correlation with average fruit weight and titrable acidity at both genotypic and phenotypic levels and recorded total soluble solids found positive correlation with total phenolic content, total antioxidant, lycopene content and total carotenoid content and also reported negative

correlation with titrable acidity. They observed average fruit weight (1.069) exhibited very high positive direct effect on fruit yield per plant followed by number of fruits per plant (0.603), days to first fruit setting (0.456) and equatorial fruit diameter (0.307).

Barrera *et al.* (2018) studied correlation and path analysis among primary and secondary production components of cherry tomato genotypes. They reported genotypic correlations among the traits showed the similar magnitude and same direction of their respective phenotypic correlations. They recorded path analysis 92.2 per cent of the variation on the total soluble solids among the evaluated genotypes.

2.3. Identification of transgressive segregants for yield and its related traits

Kamani and Monpara, (2006) studied F₂ population of two crosses H7 × PLR1 and H7 × GBL1 of brinjal in four replications of RBD. They observed transgressive segregants for most of the traits studied in one or both directions.

Gustav *et al.* (2010) studied F₂ population of cross *Lycopersicon esculentum* (Ca, cv 'Caimanta') and *L. esculentum* var. *cerasiforme* (LA1385) for fruit quality traits. They observed transgressive inheritance for traits such as shape, color, firmness, and shelf life. And also observed F₂ generations of cross between the normal ripening cultivar and LA1385 of *S. lycopersicum* var. *cerasiforme* offers the best possibility to obtain long shelf life tomato genotypes with good fruit quality.

Islam *et al.* (2012) evaluated nineteen segregating lines of tomato at the Horticulture Research Centre of BARI. They reported highest number of fruits per plant was observed in the line 14-1-1-1-1 and individual fruit weight was only 58.4 g and the line 15-3-4-2-1 had the highest individual fruit weight (162.3 g). They had also recorded highest fruit yield for the line 15-3-4-2-1 (81.6 t / ha), which was closely followed by the line 15-1-2-2-1 (79.5 t / ha).

Ramesh *et al.* (2013) evaluated ten F₂ populations of brinjal in an RCBD with three replications. They reported among the F₂ lines L₅ × T₄ (Palamedu Local × EP 65) and L₄ × T₁ (Alagarkovil Local × Annamalai) had the highest mean with high variability for individual fruit weight and fruit yield per plant and also favorable low mean with high variability was observed for days to first flowering in the crosses L₅ × T₂ (Palamedu Local x KKM 1) and L₄ × T₂ (Alagarkovil Local x KKM 1).

Kshirsagar *et al.*, (2014) studied F₄ generation of tomato for transgressive segregation of important quantitative traits in two crosses M-3-1 × 18-1-1 (C1) and M-3-1 × H-36 (C2). They reported that highest transgressive segregants were observed for average equatorial diameter (15.56 %), followed by fruit yield per plant (11.50 %) and average fruit weight (11.50 %) in M-3-1 × 18-1-1 (C1), whereas for

fruit yield per plant (12.68 %) and average equatorial diameter (6.88 %) in M-3-1 × H-36 (C2) of F₄ generation.

Reddy (2017) evaluated 54 genotypes of tomato. They selected five diverse plants and made crosses among them. They reported that F₂ population of crosses such as GT-20 × H-86 (for primary branches / plant), Pant T-3 × H-86 (for flowers per cluster and yield / plant), T-Local × H-24 (for fruits per cluster and average fruit weight), Kashishard × H-86 (for fruits / plant), Flawery × Azad T-5 (for fruit density), B-S-31-3 × Azad T-5 (for pericarp thickness), EC-521087 × H-24 (for carotene and ascorbic acid) and T-Local × H-86 (for shelf life).

Shreya *et al.* (2017) studied transgressive individuals in groundnut. They observed transgressive segregants exceeds the better parent for traits like SCMR, SLA, total biomass, harvest index, shoot weight, root weight, shelling out-turn, mature pod weight and kernel weight per plant.

Anusha *et al.* (2019) studied transgressive segregation in F₂ generation in desi cotton. They reported that F₂ of cross JLA-794 × JLA-505 (39) exhibited the highest frequency of transgressive segregants for seed cotton yield per plant followed by AKA-7 × PA-255 (32) and PA-183 × PA-710 (26). They also recorded Plant no. 92 was the most transgressive segregant in cross JLA-794 × JLA-505 for seed cotton yield per plant, recorded 82.2 per cent higher seed cotton yield, sympodia per plant, bolls per plant and ginning percentage.

MATERIAL AND METHODS

III MATERIALS AND METHODS

The present investigation was carried out by conducting the field experiment during *kharif* 2018 at University of Agricultural and Horticultural Sciences, Navile, Shivamogga.

The details of experimental material, collection of data on different traits, analytical procedure used for statistical analysis and interpretation of data of experiment presented in this chapter.

3.1 Experimental site

The experiment on assessment of genetic variability in segregating population (F₂) of cross IIHR 2358 X Australian red was carried out at Zonal Agricultural and Regional Horticultural Station, UAHS campus, Navule, Shivamogga, which is geographically situated between 1327' to 1439' N latitude and 7437' to 7552' E longitude with an altitude of 650m above MSL. The experimental site is located in southern transition agro climatic zone of Karnataka, Zone 7.

3.2 Experimental material

The experiment consist of 250 segregating population (F₂) of cross IIHR-2358 × Australian red which was crossed in the year 2016 at Department of Genetics and Plant Breeding, Shivamogga.

3.3 Climatic conditions

Total rainfall of 1232.8 mm was received during year of investigation the Meteorological data received at ZAHRS, Navule, Shivamogga during 2018-19. The soil of experiment was clay loam and fertility level was medium to high.

3.4 Layout of Experiment

All the recommended crop production and protection practices were followed to raise a healthy crop. Initially, tomato seeds were sown in the portrays and thirty days old seedlings were transplanted to the main field in augmented design with standard spacing of 90 cm × 45 cm accommodating a plant population of 10 per row.

3.5 Recording of observations

Observations on each plant of F₂ generation along with their parents were recorded for fruit biochemical, morpho-physiological and yield characters. The characters studied and techniques adopted to record the observations as follows.



Plate 3.1: General view of experimental plot in ZAHRS, Navule, Shivamogga

3.5.1 Fruit biochemical characters

All observations were recorded at the red ripe stage of each F₂ plants along with the parents as follows

3.5.1.1 TSS Content (Brix)

Mean Brix value was measured using Erma hand refractometer in the fresh juice of five randomly selected ripe fruits from each plant.

3.5.1.2 pH Content

The pH of the five tomato fruit juice samples of each plant was recorded using a Siemens pH meter.

3.5.1.3 Lycopene content (mg/100g)

Lycopene content analysed by spectrophotometric method (Lichtenthaler, 1987) and expressed as mg / 100g.

Procedure

1. Take 5 g of sample into a mortar, add one spatula of Calcium carbonate (CaCO₃) and grind with acetone. Extract the residue with more solvent until the supernatant becomes colorless. All the extractions should be carried out under low light or red light.
2. Collect the upper layer and repeat the same by taking 5 ml hexane.
3. Dry with anhydrous Sodium sulphate (Na₂SO₄) and make up the volume to 25 ml with hexane and read absorbance at 503 nm in a spectrophotometer.
4. Calculate the lycopene and express the value as mg/100g fresh weight using standard curve. Then the mean lycopene content of five fruits was computed as genotype mean.

$$\text{Lycopene (mg/100g)} = \frac{\text{OD}_{503\text{nm}} \times \text{Std. Value } (\mu\text{g/OD}) \times \text{Total Vol. of extract} \times 100}{\text{Wt. of the sample (g)} \times 1000}$$

3.5.1.4 Ascorbic acid (mg/100g)

Titrimetric estimation of vitamin C is conventionally done using 2, 6-Dichloro Phenol Indo Phenol (DCPIP) dye solution. This dye exhibits blue color in alkaline medium and pink in acidic medium. Ascorbic acid reduces the dye to a colourless form. The reaction is quantitative and specific for ascorbic acid at pH 1.0 to 3.5 (Anon., 2006).

Reagents

- 4 per cent Oxalic acid
- 2, 6-Dichlorophenol Indo-Phenol Sodium Salt ($C_{12}H_6Cl_2N NaO_2 \cdot 2H_2O$) dye solution: Dissolve 50 mg of 2, 6-Dichlorophenol indophenol in distilled water, mix with 4.2 mg of Anhydrous Sodium Bicarbonate and make up the volume to 200 ml.
- Standard ascorbic acid ($C_6H_8O_6$) solution: 0.01 per cent in 4 per cent oxalic acid.

Procedure

Vitamin C content determined by 2, 6-Dichlorophenol indophenol (DCPIP) method (AOAC, 967.21).

1. Ten grams of tomato puree was mixed thoroughly with 4 per cent oxalic acid solution. Homogenize with 4 per cent oxalic acid in a pestle and mortar 2 to 3 times, squeezed through a muslin cloth and volume was made up to 50 ml.
2. Vitamin C content present in the solution was estimated by titrating a known quantity (10 ml) of the extract against DCPIP. The end point is the appearance of pink colour.
3. Vitamin C content calculated as mg of ascorbic acid equivalents per 100 g fresh weight using a standard curve of L-Ascorbic acid. Mean Ascorbic acid content of five fruits computed as genotype mean.

$$\text{Vitamin C (mg/100g)} = \frac{\text{Titre value} \times \text{Std. value } (\mu\text{g}) \times \text{Total Vol. of extract}}{\text{Assay volume} \times \text{Wt. of the sample (g)} \times 1000} \times 100$$

3.5.2 Fruit morpho-physiological characters

All observations were recorded at the red ripe stage of tomato fruits as follows

3.5.2.1 Fruit length (mm)

Average length in centimeters of the five randomly selected fruits of each plant measured from stem end to blossom end after cutting the fruit vertically using digital vernier caliper.

3.5.2.2 Fruit width (mm)

Mean equatorial diameter in centimeters of five randomly selected fruits of each plants measured at the maximum perimeter using digital vernier caliper.

3.5.2.3 Pericarp thickness (mm)

An average thickness of the pericarp measured in millimetres in the transversely cut fruits using digital vernier calliper for five randomly selected fruits of each plants.

3.5.2.4 Pulp content (%)

The average pulp per cent content was estimated in five randomly selected fruits of each plants by using the formula given below.

$$\text{Pulp content (\%)} = \frac{\text{Weight of pulp (g) (After removing fruit juice and seed)}}{\text{fruit weight (g)}} \times 100$$

3.5.2.5 Number of locules

Locules number of tomatoes counted after cutting of fruit transversely from the middle portion. Mean locule number of five fruits were computed.

3.5.3 Fruit yield characters

3.5.3.1 Days to first flowering

The number of days taken for appearance for first flower bud is recorded in each plants.

3.5.3.2 Plant height (cm)

Individual Plant height was measured in centimetres from base of the plant (ground level) to the tip of the plant at the time of physiological maturity.

3.5.3.3 Number of branches

Total number of branches per plant were counted and recorded as number of branches per plant.

3.5.3.4 Number of clusters

The total number of clusters on each plant were counted and recorded.

3.5.3.5 Number of fruits per cluster

The total number of fruits per cluster on each plant were counted and recorded.

3.5.3.6 Average fruit weight per plant (g)

Five fruits are selected randomly from each plant and mean was calculated for each plant and expressed in grams per plant.

3.5.3.7 Yield per plant (g)

Fresh weight of fruits per plant at various pickings was recorded and mean fruit weight was calculated and expressed yield in grams per plant.

3.6 Stastical analysis

The data recorded from the experiment was subjected to various statistical analysis to draw the suitable inference. The details of the statistical procedure followed are given below.

3.6.1 Descriptive statistics

The following descriptive statistics were calculated as per Sunderaraj *et al.* (1972) in *SPSS* software at the Department of Genetics and Plant Breeding, UAHS, Shivamogga.

3.6.1.1 Mean

Mean was the sum of all observations in a sample divided by the number of observations (n).

$$\bar{X} = \left[\frac{\sum_{i=1}^n X_i}{n} \right]$$

Where X_i = i^{th} observation of a population

n = number of observations

3.6.1.2 Range

The range was the minimum and maximum values of the observations in a sample of genotypes.

3.6.1.3 Standard error

It was the measure of uncontrolled variation present in a sample which was estimated by dividing the standard deviation (SD) by the square root of number of observations (n) in the sample and was denoted by SE.

$$SE = \frac{SD}{\sqrt{n}}$$

3.6.1.4 Variance

Variance is defined as the average of the squared deviation so find individual observation from the mean. It is expressed as the sum of squares of the deviations of all observations of a sample from its mean and divided by (n-1), where n is the number of observations. It is estimated by the following the formula given below

$$\text{Variance} = \frac{\sum(X - \bar{X})^2}{n}$$

Where,

X_i = i^{th} observation of a population

n = Number of observations

3.6.1.5 Critical difference (CD)

It is calculated to judge whether the difference between two particular treatments was significant or not.

$$CD = \sqrt{2} \times SEm \times t\alpha$$

3.6.1.6 Estimation of genetic parameters

Genotypic and phenotypic variances were estimated using the formula given by Weber and Moorthy (1952).

3.6.1.6.1 Genotypic and phenotypic variances

The genotypic and phenotypic variances were computed based on the expected mean sum of squares from ANOVA table as follows:

$$\text{Genotypic variance } \sigma^2_g = \frac{\text{MSS (genotype)} - \text{MSS (error)}}{\text{Number of blocks}}$$

$$\text{Phenotypic variance } (\sigma^2_p) = \sigma^2_g + \sigma^2_e$$

$$\text{Environmental variance } (\sigma^2_e) = Me$$

3.6.1.6.2 Coefficients of variations

Genotypic and phenotypic coefficients of variations were computed according to Burton and De vane, (1953) based on the estimate of genotypic and phenotypic variances as follows.

3.6.1.6.2.1 Genotypic co-efficient of variation (GCV)

$$GCV (\%) = \frac{\sigma_g}{\bar{X}} \times 100$$

3.6.1.6.2.2 Phenotypic co-efficient of variation (PCV)

$$PCV (\%) = \frac{\sigma_p}{\bar{X}} \times 100$$

\bar{X} = General mean

σ_g = Genotypic standard deviation

σ_p = Phenotypic standard deviation

GCV and PCV were classified as suggested by Sivasubramanian and Madhavamenon (1973) as follows,

0 -10 %: Low

10.01-20%: Moderate

20.01- 21% and above: High

3.6.1.6.3 Heritability

Broad-sense heritability was estimated as the ratio of genotypic variance to the phenotypic variation and expressed in percentage.

$$h^2_{(bs)} = \frac{\sigma^2_g}{\sigma^2_p} \times 10$$

Where,

σ^2_g = Genotypic variance

σ^2_p = Phenotypic variance

Heritability percentage was categorized as demonstrated by Robinson *et al.* (1949).

0-30 %: Low

30.01-60 %: Moderate

>60 %: High

3.6.1.6.4 Genetic advance (GA)

Genetic advance (GA) was computed using the formula given by Robinson *et al.* (1949).

$$GA = h^2 \times K \times \sigma_p$$

Where,

K = selection differential at given intensity

σ_p = Phenotypic standard deviations

h^2 = Heritability at broad sense

3.6.1.6.5 Genetic advance as percentage over mean (GAM)

Genetic advance as percentage over mean was worked out as suggested by Johnson *et al.* (1955).

$$GAM = \frac{GA}{\bar{X}} \times 100$$

Where,

GA = Genetic advance

X = General mean of the character

The GAM was categorized as suggested by Johnson *et al.* (1955).

0-10 %: Low

10.01-20 %: Moderate

>20.01 %: High

3.6.1.6.6 Skewness and Kurtosis

Skewness, the third degree statistics and kurtosis, the fourth degree statistics were estimated as per Snedecor and Cochran (1994). This helps to understand the nature of distribution of progenies for growth and yield related traits. The mean values of F₂ generation were used for estimation of coefficients of skewness and kurtosis using 'SPSS' software program. Kurtosis denotes the relative number of genes controlling the traits (Robson, 1956). Three types of kurtosis were recognized based on the kurtosis value which depends on the distribution curve.

If kurtosis value = 3 = Normal curve = Mesokurtic

If kurtosis value > 3 = Leaping curve = Leptokurtic

If kurtosis value < 3 = Flat curve = Platykurtic

Similarly, the lack of symmetry, *i.e.*, skewness was recognized based on the coefficient of skewness. Its values range from -3 to +3. The type of distribution based on the skewness values are as follows.

If skewness value zero = symmetrical distribution

If skewness value negative = negatively skewed distribution

If skewness value positive = positively skewed distribution

3.6.1.7 Correlation coefficient

The correlation coefficient were calculated to determine the degree of association of characters with yield and also among the different yield components. Both genotypic and phenotypic coefficients of correlation between all pairs of characters were determined by using variance and covariance components. Among all-important character combinations at phenotypic (r_p) and genotypic (r_g) level were estimated by employing formula given by Al-Jibouri *et al.* (1958). Analysis was done using WINDOSTAT software (Version 9.2).

Where,

$$\text{Phenotypic correlation} = r_{xy}(p) = \frac{\text{Cov}_{(xy)}(p)}{\sqrt{\sigma^2(x)_p \times \sigma^2(y)_p}}$$

$COV_{xy}(p) =$ Phenotypic covariance's between 'x' and 'y' characters

$V_x(p) =$ Phenotypic variances of 'x' character

$V_y(p) =$ Phenotypic variances of 'y' character

The test of significance for association between characters was done by comparing table 'r' values at n-2 error degrees of freedom for phenotypic and genotypic correlations with estimated values, respectively.

3.6.1.8 Path coefficient analysis

Path co-efficient analysis suggested by Wright (1921) and Dewey and Lu (1959) was carried out to know the direct and indirect effect of the morphological traits on fruit yield. The following set of simultaneous equations were formed and solved for estimating various direct and indirect effects. Analysis was done using WINDOSTAT software (Version 9.2).

$$r_1y = a + r_{12}b + r_{13}c + \dots + r_{1i}i$$

$$r_2y = a + r_{21}a + b + r_{23}c + \dots + r_{2i}i$$

$$r_3y = r_{31}a + r_{32}b + c + \dots + r_{3i}i$$

$$r_{11}y = r_{11}a + r_{12}b + r_{13}c + \dots + I$$

Where, r_1y to $r_{11}y =$ Co-efficient of correlation between causal factors 1 to 1 with dependent characters y.

r_{12} to $r_{1i} =$ Co-efficient of correlation among causal factors

a, b, c...i = Direct effects of characters 'a' to 'I' on the dependent character 'y.'

Residual effect (R) was computed as follows.

$$\text{Residual effect (R)} = 1 - \sqrt{a^2 + b^2 + c^2 + \dots + i^2 + 2abr_{12} + 2acr_{13} + \dots}$$

Lenka and Mishra (1973) have suggested scales for path coefficients analysis.

0.00-0.09: Negligible

0.10-0.19: Low

0.20-0.29: Moderate

0.30-0.99: High

>1.00: Very high

EXPERIMENTAL RESULTS

IV EXPERIMENTAL RESULTS

The experiment was conducted during *Kharif*-2018 to elucidate the extent of genetic variability in IIHR 2358 × Australian Red. The results of the present investigation are presented under following subheadings,

- 4.1 To assess the genetic variability for yield and its related traits in segregating population of cherry tomato
- 4.2 To study the nature and magnitude of association among yield traits through correlation and path analysis.
- 4.3 To identify transgressive segregants for yield traits in cherry tomato.

4.1 To assess the genetic variability for yield and its related traits in segregating population of cherry tomato

4.1.1. Per se performance, skewness and kurtosis in the F₂ generation

Mean performance, range, skewness, and kurtosis of F₂ segregating generation of a cross IIHR-2358 × Australian Red for fruit biochemical, morpho-physiological and yield attributing traits during *Kharif* 2018. The details of the result of the traits are presented under the following headings in Table 4.1.

4.1.1.1 Days to first flowering

Days to first flowering ranged between 24.00 to 38.00 days with a mean 31.57 days as against parental mean of IIHR-2358 (31.80 days) and Australian Red (25.00 days) and positively skewed (0.18) with platykurtic (-1.08) distribution.

4.1.1.2 Number of clusters per plant

The number of clusters ranged from 2.00 to 26.00 with a mean of 10.44 as against parental mean of IIHR-2358 (9.60) and Australian Red (14.40) and positively skewed (0.74) with platykurtic (0.81) distribution.

4.1.1.3 Number of flowers per cluster

Number of flowers per cluster ranged between 4.00 to 13.00 with a mean of 7.38 as against parental mean of IIHR-2358 (5.60) and Australian Red (13.80) and positively skewed (0.22) with platykurtic (-0.14) distribution.

4.1.1.4 Number of fruit per cluster

The number of fruit per cluster ranged from 2.00 to 8.00 with a mean of 4.01 as against parental mean of IIHR-2358 (3.40) and Australian Red (10.60) and positively skewed (0.54) with platykurtic (0.12) distribution.

Table 4.1: Estimation of Range, Mean, Skewness and Kurtosis for yield and yield related traits in segregating population (F₂) of cherry tomato

Sl. No.	Characters	Mean of F ₂ ± SEM	Mean of IHR2358	Mean of Australian Red	Range		Skewness	Kurtosis	Kurtosis type
					Min.	Max.			
1	Days to first flowering	31.57±0.211	31.80	25.00	24.00	38.00	0.18	-1.08	P
2	Number of cluster per plant	10.44±0.268	9.60	14.40	2.00	26.00	0.74	0.81	P
3	Number of flowers per cluster	7.38±0.116	5.60	13.80	4.00	13.00	0.22	-0.14	P
4	Number of fruits per cluster	4.01±0.075	3.40	10.60	2.00	8.00	0.54	0.12	P
5	Number of fruits per plant	81.00±1.35	32.64	152.64	6.00	156.00	1.33	3.88	L
6	Primary branches per plant	2.96±0.51	2.40	3.00	1.00	5.00	0.25	-0.70	P
7	Secondary branches per plant	9.05±0.096	6.01	10.08	5.14	12.67	-0.06	-0.85	P
8	Average fruit weight (g)	62.5± 0.944	79.53	9.70	41.29	101.24	0.24	-0.35	P
9	Number of locule per fruit	4.18±0.49	4.10	2.50	2.50	7.06	0.69	1.33	P
10	Plant height (cm)	116.11±0.99	57.30	105.00	68.92	163.30	-0.01	-0.24	P
11	Fruit width (mm)	4.03±0.37	34.61	5.15	25.43	59.08	0.17	0.63	P
12	Fruit length (mm)	3.64±0.32	35.17	7.12	21.43	56.29	-0.09	0.69	P
13	Total soluble solids (Brix %)	5.85±0.07	3.32	4.48	4.00	11.00	1.41	3.20	L
14	pH	4.27±0.03	5.40	4.57	2.82	6.43	1.29	4.23	L
15	Pericarp thickness (mm)	2.99±0.05	4.90	1.08	1.20	4.70	0.98	2.24	P
16	Lycopene content (mg/100 g)	2.73±0.84	0.65	2.44	0.21	8.39	0.06	-0.31	P
17	Ascorbic acid content (mg/100 g)	4.98±0.06	10.73	5.06	3.06	7.25	0.41	-0.28	P
18	Pulp content (%)	75.31±0.24	75.30	72.05	63.17	87.45	-0.73	1.66	P
19	Fruit yield (g)	812.23±8.95	1088.80	667.40	456.00	1293.00	0.66	0.57	P

P= platykurtic

L= leptokurtic

Max= maximum

Min= minimum

4.1.1.5 Number of fruits per plant

The number of fruits per plant ranged from 6.00 to 156.00 with a mean 81.00 as against parental mean of IIHR-2358 (32.64) and Australian Red (152.64) and positively skewed (1.33) with leptokurtic (3.88) distribution.

4.1.1.6 Number of primary branches per plant

Number of primary branches ranged between 1.00 to 5.00 with a mean of 2.96 as against parental mean of IIHR-2358 (2.40) and Australian Red (3.00) and positively skewed (0.25) with platykurtic (-0.70) distribution.

4.1.1.7 Number of secondary branches per plant

Number of secondary branches ranged between 5.14 to 12.67 with a mean 9.05 of as against parental mean of IIHR-2358 (6.01) and Australian Red (10.08) and negatively skewed (-0.06) with platykurtic (-0.85) distribution.

4.1.1.8 Average fruit weight (g)

Average fruit weight ranged between 41.29 to 101.24 g with a mean of 62.50 g, as against parental mean of IIHR-2358 (79.53 g) and Australian Red (9.70 g) and positively skewed (0.24) with platykurtic (-0.35) distribution.

4.1.1.9 Number of locule per fruit

Locule number ranged from 2.50 to 7.06 with a mean of 4.18 as against parental mean of IIHR-2358 (4.10) and Australian Red (2.50) and positively skewed (0.69) with platykurtic (1.33) distribution.

4.1.1.10 Plant height (cm)

Plant height ranged from 68.92 to 163.30cm with a mean of 116.11 cm as against parental mean of IIHR-2358 (57.30 cm) and Australian Red (105.00 cm) and negatively skewed (-0.01) with platykurtic (-0.24) distribution.

4.1.1.11 Fruit width (mm)

Fruit diameter ranged from 25.43 to 59.08 mm with a mean of 4.03 mm as against parental mean of IIHR-2358 (34.61 mm) and Australian Red (5.15 mm) and positively skewed (0.17) with platykurtic (0.63) distribution.

4.1.1.12 Fruit length (mm)

Fruit length ranged from 21.43 mm to 56.29 mm with a mean of 3.64 as against parental mean of IIHR-2358 (35.17 mm) and Australian Red (7.12 mm) and negatively skewed (-0.09) with platykurtic (0.69) distribution.

4.1.1.13 TSS content (%)

Total soluble solids ranged between 4.00 to 11.00 per cent with a mean of 5.85 per cent as against parental mean of IIHR 2358 (3.32 %) and Australian Red (4.48 %) respectively. And showed positively skewed (1.41) with leptokurtic (3.20) distribution.

4.1.1.14 pH content

pH content ranged between 2.82 to 6.43 with a mean of 4.27 as against parental mean of IIHR-2358 (5.40 %) and Australian Red (4.57 %), respectively and positively skewed (1.29) with leptokurtic (4.23) distribution.

4.1.1.15 Pericarp thickness (mm)

Pericarp thickness ranged from 1.20 to 4.70 mm with a mean of 2.99 mm as against parental mean of IIHR-2358 (4.90 mm) and Australian Red (1.08 mm) and positively skewed (0.98) with platykurtic (2.24) distribution.

4.1.1.16 Lycopene content (mg / 100 g)

Lycopene content ranged between 0.21 to 8.39 mg / 100 g with a mean of 2.73 mg / 100 g as against parental mean of IIHR-2358 (0.65 mg / 100 g) and Australian Red (2.44 mg/100g) and positively skewed (0.06) with platykurtic (-0.31) distribution.

4.1.1.17 Ascorbic acid content (mg/100g)

Ascorbic acid content ranged from 3.06 to 7.25 mg / 100g with a mean of 4.98 mg / 100g as against parental mean of IIHR-2358 (10.73 mg / 100g) and Australian Red (5.06 mg /100g) and positively skewed (0.41) with platykurtic (-0.28) distribution.

4.1.1.18 Pulp content (%)

Pulp content ranged from 63.17 to 87.45 per cent with a mean of 75.31 % as against parental mean of IIHR-2358 (75.30 %) and Australian Red (63.17 %) and negatively skewed (-0.73) with platykurtic (1.66) distribution.

4.1.1.19 Fruit yield per plant (g)

Fruit yield per plant ranged between 456.00 to 1293.00 g with a mean of (812.23 g) as against parental mean of IIHR-2358 (1088.80 g) and Australian Red (667.40 g) and positively skewed (0.66) with platykurtic (0.57) distribution.

4.1.2 Variability parameters for yield and its related traits in F₂ generation of cross IIHR-2358 × Australian.red

The genetic variability parameter, viz., phenotypic coefficient of variation (PCV), genotypic co-efficient of variation (GCV), heritability (broad sense), genetic advance and genetic advance as per cent mean for all the nineteen traits are furnished in Table 4.2.

4.1.2.1 Days to first flowering (days)

The moderate phenotypic and genotypic coefficients of variability of 10.56 and 9.93 per cent, respectively were recorded. High heritability estimates of 88.49 per cent coupled with moderate genetic advance of 19.25 per cent was observed for this trait. However this trait noticed low genetic advance (6.07).

4.1.2.2 Number of clusters per plant:

The High PCV (40.53 %) and GCV (38.06 %) were noticed for this trait. High heritability of 88.15 percent coupled with high GAM 73.60 per cent was observed for number of clusters per plant and showed low GA (7.68).

4.1.2.3 Number of flowers per cluster

The High PCV (24.86 %) and GCV (23.65 %) were observed for this trait. High heritability of 90.50 per cent coupled with high GAM 46.35 per cent and low GA (3.42) was observed for this trait.

4.1.2.4 Number of fruits per cluster

The high PCV (29.42 %) and GCV (23.30 %) were recorded for this trait. High heritability 62.68 per cent coupled with high genetic advance as per cent mean 37.99 per cent was observed for this trait. But this trait showed low genetic advance (1.54).

4.1.2.5 Number of fruits per plant

High genotypic (23.43 %) and phenotypic coefficient (23.46 %) of variability were observed for this trait with high heritability 99.70 per cent coupled with high genetic advance (96.86) and genetic advance as per cent mean (48.19 %) was also noticed for this trait.

4.1.2.6 Primary branches per plant

High genotypic and phenotypic coefficient of variability was recorded. The estimates of PCV and GCV were 27.10 and 24.45 per cent, respectively. High heritability 81.40 % but low GA (1.35) and high genetic advance as per cent mean (45.48 %) were observed for this trait.

Table 4.2: Estimation of genetic variability parameters of yield and yield related traits in segregating population (F₂) of cherry tomato

Sl. No	Characters	Mean of F ₂ ± SEM	Coefficient of variation		h ² (bs) (%)	GA	GAM (%)
			GCV (%)	PCV (%)			
1	Days to first flowering	31.57±0.211	9.93	10.56	88.49	6.07	19.25
2	Number of cluster per plant	10.44±0.268	38.06	40.53	88.15	7.68	73.60
3	Number of flowers per cluster	7.38±0.116	23.65	24.86	90.50	3.42	46.35
4	Number of fruits per cluster	4.01±0.075	23.30	29.42	62.68	1.54	37.99
5	Number of fruits per plant	81.00±1.35	23.43	23.46	99.70	96.86	48.19
6	Primary branches per plant	2.96±0.51	24.45	27.10	81.40	1.35	45.48
7	Secondary branches per plant	9.05±0.096	16.51	16.78	96.74	3.02	33.48
8	Average fruit weight (g)	62.5± 0.944	15.42	15.47	99.38	29.63	47.40
9	Number of locule per fruit	4.18±0.49	14.22	18.87	56.77	0.92	22.06
10	Plant height (cm)	116.11±0.99	14.38	14.53	97.93	31.78	29.31
11	Fruit width (cm)	4.03±0.37	14.46	14.65	97.43	11.86	29.41
12	Fruit length (cm)	3.64±0.32	13.19	13.83	90.90	9.43	25.90
13	Total soluble solids (Brix %)	5.85±0.07	13.74	17.94	58.70	1.26	21.69
14	pH	4.27±0.03	10.80	11.94	81.78	0.86	20.12
15	Pericarp thickness (mm)	2.99±0.05	22.33	23.95	86.87	1.28	42.87
16	Lycopene content (mg/100 g)	2.73±0.84	48.23	48.49	98.94	2.70	98.82
17	Ascorbic acid content (mg/100g)	4.98±0.06	18.21	18.67	95.15	1.86	36.59
18	Pulp content (%)	75.31±0.24	4.19	4.86	74.50	5.87	7.45
19	Fruit yield (g)	812.23±8.95	16.27	17.43	87.19	254.27	31.30

GCV = Genotypic coefficient of variation

PCV= Phenotypic coefficient of variation

h² (bs) = Broad sense heritability

GA = Genetic advance,

GAM = Genetic advance as percent mean

4.1.2.7 Secondary branches per plant

Moderate Genotypic and phenotypic coefficient of variability was observed. The estimates of PCV and GCV were 16.78 and 16.51 per cent, respectively. Recorded high heritability (96.74 %), whereas GA (3.02) was low; however, high genetic advance as per cent mean (33.48 %) was observed for this trait.

4.1.2.8 Average fruit weight

Moderate phenotypic and genotypic coefficient of variability was recorded with estimates of 15.47 and 15.42 per cent, respectively. High heritability 99.38 per cent coupled with high genetic advance as per cent mean 47.40 per cent was observed for this trait. And high GA (29.63) was noticed for this trait.

4.1.2.9 Number of locule per plant

Moderate PCV of 18.87 and GCV of 14.22 per cent were noticed. However high heritability 56.77 per cent coupled with high genetic advance as per cent mean 22.06 per cent but low genetic advance 0.92 was possessed by this trait.

4.1.2.10 Plant height

Moderate genotypic and phenotypic coefficient of variation was observed. The GCV and PCV for this trait were 14.38 and 14.53 per cent, respectively. High heritability 97.93 per cent coupled with high GA (31.78) and genetic advance as per cent mean (29.31 %) was observed for this trait.

4.1.2.11 Fruit width

Moderate genotypic and phenotypic coefficient of variations of 14.46 and 14.65 percent respectively was recorded. However, high heritability (97.43%) coupled with high genetic advance as percent mean (29.41 %) was observed for this trait. Whereas low genetic advance of 11.86 was noticed for fruit weight.

4.1.2.12 Fruit length

Moderate genotypic and phenotypic coefficient of variation was observed. The GCV and PCV estimates were 13.19 and 13.83 per cent, respectively. High heritability (90.90 %) coupled with high genetic advance as percent mean 25.90 was recorded for this trait. However, low Genetic advance (9.43) was observed for fruit length.

4.1.2.13 Total soluble solids

Moderate GCV (13.74 %) and PCV (17.94 %) high heritability (58.70 %) coupled with high genetic advance as per cent mean (21.69 %), but low genetic advance (1.26) was noticed for TSS.

4.1.2.14 pH content

The trait pH content noticed a moderate value of the genotypic and phenotypic coefficient of variation was noticed. The estimates of GCV and PCV were 10.80 and 11.94 per cent, respectively. High heritability (81.78 %) coupled with high genetic advance as per cent mean (20.12 %) was observed for this trait. However, this trait noticed low GA (0.86).

4.1.2.15 Pericarp thickness

High genotypic and phenotypic coefficient of variation was observed with estimates of 22.33 and 23.95 per cent, respectively along with high heritability (86.87 %) coupled with high genetic advance as per cent mean (42.87 %) was observed for this trait. However, this trait possessed very low genetic advance (1.28).

4.1.2.16 Lycopene content

The variability parameter like PCV and GCV were (48.49%) and (48.23%), High heritability (98.94 %) and GAM (98.82 %) was high for this trait. However, the genetic advance (2.70) was recorded very low.

4.1.2.17 Ascorbic acid content

Moderate genotypic and phenotypic coefficient of variation was recorded for ascorbic acid content which estimates of 18.21 and 18.67 per cent, respectively. High heritability (95.15 %) coupled with high genetic advance as per cent mean (36.59 %) was observed for this trait. However, the trait ascorbic acid possessed low genetic advance (1.86).

4.1.2.18 Pulp content

The magnitude of genetic variability parameters *viz.*, PCV, GCV, GA and GAM was noted low. The GCV and PCV were 4.19 and 4.86 per cent, respectively and GA and GAM estimate were 5.87 and 7.45 per cent, respectively. However, the heritability (74.50 %) of this was higher extent.

4.1.2.19 Fruit yield per plant

Moderate genotypic and phenotypic coefficient of variation was recorded. The GCV and PCV were 16.27 and 17.43 per cent, respectively. But this trait recorded



Plate 4.1: Variation observed for number of clusters per plant in segregating population (F₂) of cherry tomato



Plate 4.2: Variation observed for fruit shape, fruit size in segregating population (F₂) of cherry tomato

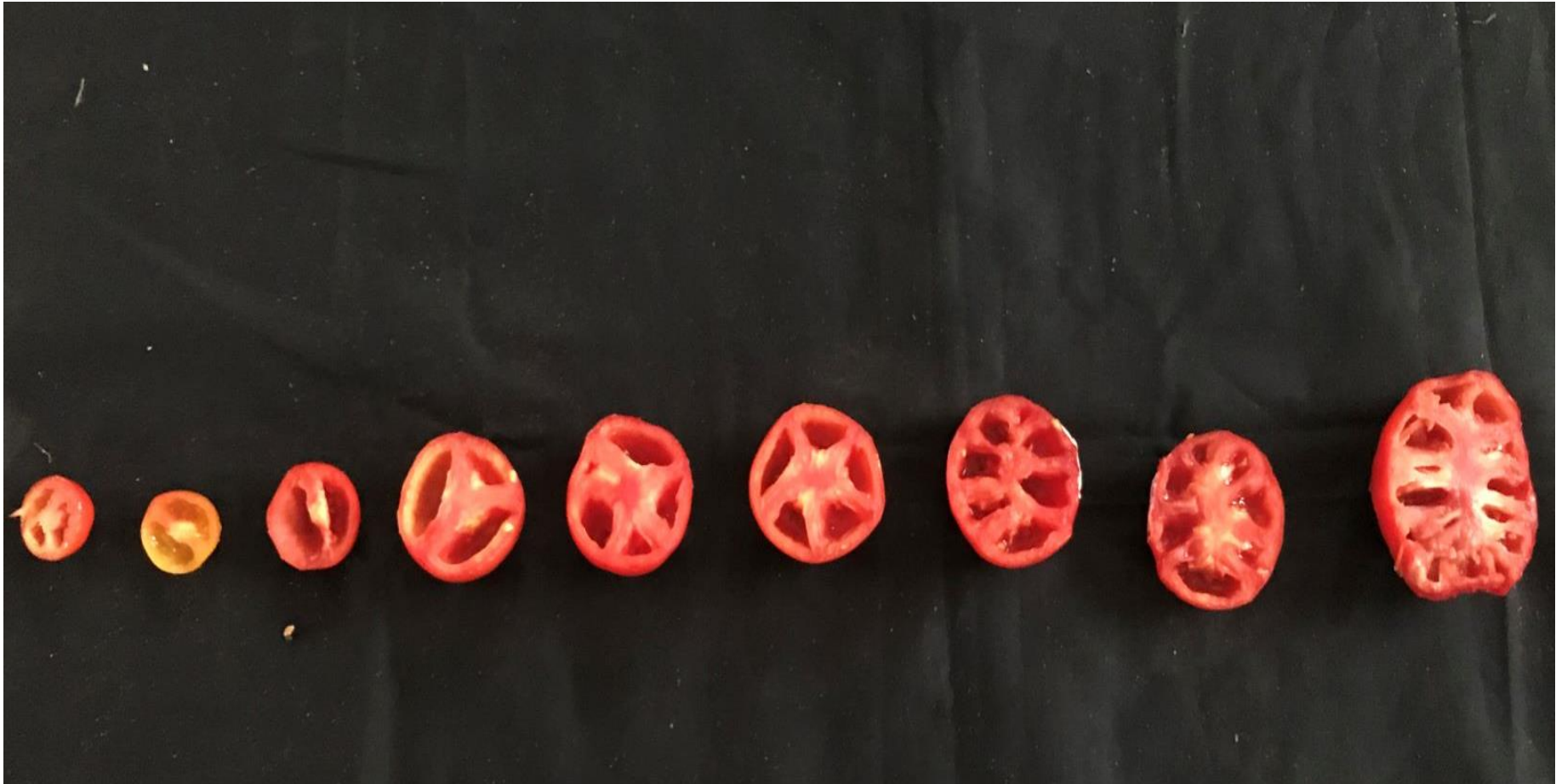


Plate 4.3: Variation observed for number of locules per fruit in segregating population (F₂) of cherry tomato

high heritability (87.19 %) coupled with high genetic advance (254.27) and genetic advance as per cent mean (31.30 %).

In the present study, all traits exhibited slightly high PCV than GCV, which might occur due to the interaction of the genotypes with the environment to some degree or other denoting environmental factors influencing the expression of these characters. Most of the traits showed high heritability coupled with high GAM this might be assigned to additive gene effects governing their inheritance and phenotypic selection for their improvement could be achieved by simple breeding methods.

4.2 To study nature and magnitude of association among yield traits through correlation and path analysis

The phenotypic correlation was worked out among nine yield and yield-related traits and four fruit biochemical traits to know the nature of association existing among the characters. The results are presented in Table 4.3 and Table 4.4. The result pertaining to correlation between fruit yield and other related characters are presented first followed by correlation among the characters.

4.2.1 Correlation of fruit yield with other morpho-physiological characters in segregating population of cherry tomato

Significant and positive association of fruit yield was noticed with average fruit weight (0.766), number of clusters per plant (0.148), number of fruits per plant (0.150), plant height (0.177), number of branches per plant (0.261) and fruit width (0.184). Days to first flowering (0.047) showed positive non-significant association. While the trait pulp content (-0.083) had a negative and non-significant association with fruit yield per plant.

4.2.2 Correlation among yield components in segregating population (F_2) of cherry tomato

4.2.2.1 Number of clusters per plant

Number of clusters per plant showed positive and significant correlation at phenotypic level with number of fruits per plant (0.760), plant height (0.165) and average fruit weight (0.169). It had a positive and non-significant association with fruit width (0.074), days to first flowering (0.009) and pulp content (0.045). Negative and non-significant association was observed for traits with number of branches (-0.035).

Table 4.3: Phenotypic correlation for yield and its related traits in segregating population (F₂) of cherry tomato

	X ₁	X ₂	X ₃	X ₄	X ₅	X ₆	X ₇	X ₈	X ₉
X ₁	1.000	0.760**	0.165**	-0.035	0.169**	0.074	0.045	0.009	0.148*
X ₂		1.000	0.126*	-0.022	0.089	0.026	0.056	0.098	0.150*
X ₃			1.000	0.033	0.113	0.032	-0.019	0.156*	0.177**
X ₄				1.000	0.224**	0.064	0.039	-0.038	0.261**
X ₅					1.000	0.148*	-0.078	0.044	0.766**
X ₆						1.000	-0.109	0.052	0.184**
X ₇							1.000	-0.020	-0.083
X ₈								1.000	0.047
X ₉									1.000

*Significant at 5% LOS , ** Significant at 1% LOS

X₁= No. of cluster per plant

X₂= No. of fruits per plant

X₃= Plant height (cm)

X₄= No. of branches per plant

X₅= Average fruit weight (g)

X₆= Fruit width (mm)

X₇= Pulp content (%)

X₈= Days to first flowering

X₉= Fruit yield per plant (g)

Table 4.4: Path coefficient analysis for yield and its related trait in segregation population (F₂) of cherry tomato

Traits	X ₁	X ₂	X ₃	X ₄	X ₅	X ₆	X ₇	X ₈
X ₁	-0.1184	-0.0900	-0.0196	0.0041	-0.0201	-0.0087	-0.0054	0.0011
X ₂	0.1269	0.1670	0.0211	-0.0037	0.0149	0.0043	0.0094	0.0164
X ₃	0.0149	0.0114	0.0904	0.0030	0.0102	0.0029	-0.0018	0.0141
X ₄	-0.0031	-0.0020	0.0030	0.0906	0.0203	0.0058	0.0036	-0.0035
X ₅	0.1239	0.0650	0.0825	0.1630	0.7292	0.1083	-0.0575	0.0323
X ₆	0.0051	0.0018	0.0022	0.0045	0.0103	0.0693	-0.0076	0.0036
X ₇	-0.0011	-0.0014	0.0005	-0.0009	0.0019	0.0026	-0.0241	0.0005
X ₈	0.0002	-0.0017	-0.0027	0.0007	-0.0008	-0.0009	0.0004	-0.0176
r value	0.1484*	0.1501*	0.1774**	0.2612**	0.7659**	0.1835**	-0.0829	0.0470

Residual effect: **0.612**, R square: **0.615**, r value= Correlation coefficient

X₁= No. of cluster per plant

X₅= Average fruit weight (g)

X₂= No. of fruits per plant

X₆= Fruit width (mm)

X₃= Plant height (cm)

X₇= Pulp content (%)

X₄= No. of branches per plant

X₈= Days to first flowering

4.2.2.2 Number of fruits per plant

Number of fruits per plant showed significant and positive correlation at phenotypic level with plant height (0.126) and showed positive and non-significant association with average fruit weight (0.089), fruit width (0.026) and pulp content (0.056). It negative non-significant association with number of branches (-0.022).

4.2.2.3 Plan height

Plant height showed significant and positive correlation at phenotypic level with average fruit weight (0.112) and days to first flowering (0.156), positive and non-significant correlation with number of branches (0.033), fruit width (0.032). It showed negative and non-significant correlation with pulp content (-0.019).

4.2.2.4 Number of branches

Number of branches showed positive and significant correlation at the phenotypic level, with average fruit weight (0.224) and non-significant correlation with fruit width (0.064) and pulp content (0.039). It had negative and non-significant association with days to first flowering (-0.038).

4.2.2.5 Average fruit weight

Average fruit weight showed positive and significant association at phenotypic level with fruit width (0.148) and positive non-significant association with days to first flowering (0.044). It had negative non-significant association with pulp content (-0.078).

4.2.2.6 Fruit width

Fruit width showed positive and non-significant association with days to first flowering (0.052) and negative non-significant association with pulp content (-0.109).

4.2.2.7 Pulp content

Pulp content showed negative non-significant association with days to first flowering (-0.020).

4.2.3 Path co-efficient analysis in segregating population of cherry tomato

It is important to establish the cause and effect relationships between yield and the yield enhancing components of the crop species that are amenable to the indirect selection approach for yield. The coefficients generated by path analysis measures the cause and effect relationships, that is, direct and indirect influence of, for instance, yield components as independent variables upon another character such as yield, as a dependent variable.

Path co-efficient analysis was carried out at phenotypic level taking the fruit yield per plant as a dependent character and the characters found significantly correlated with number of clusters per plant, number of fruits per plant, plant height, number of branches, average fruit weight and fruit width.

4.2.3.1 Direct effect of yield contributing characters on fruit yield per plant in segregating population of cherry tomato.

Five out of eight characters had positive and direct effect on plant yield viz., number of clusters per plant (0.1670), plant height (0.0904), number of branches per plant (0.0906), average fruit weight (0.7292) and fruit width (0.0693). While the characters viz., number of clusters per plant (-0.1184), pulp content (-0.0241) and days to first flowering (-0.0176) had negative direct effects on fruit yield per plant. Average fruit weight (0.7292) had highest positive direct effect, whereas days to flowering (-0.0176) had the highest negative direct effect on fruit yield per plant.

4.2.3.2 Indirect effect of yield contributing characters on fruit yield in the segregating population of cherry tomato.

4.2.3.2.1 Number of clusters per plant

The positive indirect effect of number of clusters per plant was exhibited by number of branches per plant (0.0041) and days to first flowering (0.0011). It showed indirect negative effect on fruit yield via number of fruits per plant (-0.0087), plant height (-0.0196), average fruit weight (-0.0201), fruit width (-0.0087) and pulp content (-0.0054)

4.2.3.2.2 Number of fruits per plant

The trait number of fruits per plant exhibited positive indirect effect on fruit yield exhibiting *via*. Number of clusters per plant (0.1269), plant height (0.0211), average fruit weight (0.0149), fruit width (0.0043), pulp content (0.0094) and days to first flowering (0.0164). However, it showed negative non-significant effect on number of branches per plant (-0.0037).

4.2.3.2.3 Plant height

The plant height trait exhibited the direct effect on fruit yield per plant exhibiting positive indirect effect *via*. Number of clusters per plant (0.0149), number fruits per plant (0.0114), number of branches per plant (0.0030), average fruit weight (0.0102), fruit width (0.0029) and days to first flowering (0.0141). It showed negative effect on pulp content (-0.0018).

4.2.3.2.4 Number of branches per plant

It had indirect and positive effect on plant height (0.0030), average fruit weight (0.0203), fruit width (0.0058) and pulp content (0.0036). However, it showed negative effect on number of clusters per plant (-0.0031), number of fruits per plant (-0.0020) and days to first flowering (-0.0035).

4.2.3.2.5 Average fruit weight

Positive indirect effect of average fruit weight with number of clusters per plant (0.1239), number of fruits per plant (0.0650), plant height (0.0825), number of branches per plant (0.1630), fruit width (0.1083) and days to first flowering (0.0323) was noticed. It showed negative effect on pulp content (-0.0575).

4.2.3.2.6 Fruit width

The indirect and positive effect on fruit yield was exhibited by number of clusters per plant (0.0051), number of fruits per plant (0.0018), plant height (0.0022), number of branches per plant (0.0045), average fruit weight (0.0103) and days to first flowering (0.0036). It showed negative effect on pulp content (-0.0076).

4.2.3.2.7 Pulp content

The indirect and positive effect on fruit yield was exhibited by plant height (0.0005), average fruit weight (0.0019), fruit width (0.0026) and days to first flowering (0.0005). It showed negative effect on number of clusters per plant (-0.0011), number of fruits per plant (-0.0014) and number of branches per plant (-0.0009).

4.2.3.2.8 Days to first flowering

The indirect and positive effect on fruit yield was exhibited by number of clusters per plant (0.0002), number of branches per plant (0.0007) and pulp content (0.0004). It showed negative effect on number of fruits per plant (-0.0017), plant height (-0.0027), average fruit weight (-0.0008) and fruit width (-0.0009).

4.3. To identify transgressive segregants for yield traits in cherry tomato

Many plant breeders have reported transgressive segregation in hybrid progenies and suggested transgressive segregation may be used as a positive tool in plant breeding. The conventional idea of hybridization is to develop a new hybrid derivative for recombination of desirable characteristics already observed in their parents. Perhaps a more appropriate approach is to consider the possibilities of using transgressive segregation.

Transgressive segregants are those genotypes, which surpassed the limits of both the parents in desirable direction for any of the characters in segregating generation, especially in the F₂ population. Such plants are produced by the accumulation of favorable genes from the parents into progenies as a consequence of segregation and recombination in segregating population results in the occurrence of transgressive segregants. Success in obtaining the desired transgressive segregants depends on getting genetic recombination between both linked and unlinked alleles (Briggs and Allard, 1953).

Keeping in the view of the importance of transgressive segregants, the present investigation was carried in F₂ generation in the inter-varietal cross of tomato and cherry tomato. Details of the transgressive segregants obtained from IIHR 2358 × Australian Red cross were briefly described. It leads to the production of progeny plants that out-yield their parents.

4.3.1 Transgressive segregants identified for number of fruits per plant in F₂ segregating generation of cross IIHR-2358 × Australian Red.

Transgressive segregants for number of fruits per plant were identified from the cross IIHR-2358 × Australian Red presented in Table 4.5. Among 250 F₂ population studied, plant number P-212 (369.81) and P-18 (354.73) exhibited the highest number of fruits per plant and showed 136.50 and 116.85 per cent performance over better parent Australian Red, followed by plant number P-176 (316.73) showed 102.55 per cent more than performance of over better parent Australian Red (152.64) and plant number P-138, P-112, P-215, P-105, P-135, P-6 and P-213 showed, more than 80 per cent performance over better parent Australian Red.

4.3.2 Transgressive segregants identified for plant height in F₂ segregating generation of cross IIHR-2358 × Australian Red.

Transgressive segregants for plant height were identified from the cross IIHR-2358 × Australian Red are presented in Table 4.6. Among 250 F₂ population studied, plant number P- 84 (142.30 cm) exhibited superior mean performance for plant height at maturity followed by plant number P-49 (136.80 cm), P-14 (136.50 cm), P-32 (135.00 cm), P-70 (133.00 cm) , P-87 (132.10 cm), P-17 (131.10 cm), P-53 (131.00 cm), P-20 (130.50 cm) and P-133 (130.27 cm) and these plant showed 32.09, 26.98, 26.70, 25.31, 23.45, 22.53, 21.69, 21.69, 21.14 and 20.92 per cent, respectively, performance over better parent Australian Red (105.00 cm).

Table 4.5: Transgressive segregants identified for number of fruits per plant in segregating generation (F₂) of cross IIHR-2358 × Australian Red

Sl. No.	Plant number	No. of fruits per plant	% increase over better parent
1	P-212	369.81**	136.50
2	P-18	354.73**	116.85
3	P-176	316.73**	102.55
4	P-138	305.85**	95.59
5	P-112	305.56**	95.40
6	P-215	301.81**	93.01
7	P-105	294.88**	88.58
8	P-135	294.75**	88.49
9	P-6	289.97**	85.44
10	P-213	288.65**	84.59
Checks (mean of parents)			
1	IIHR-2358	32.64	
2	Australian Red	152.64	
SEm	1.35		
CD @ 5 %	3.73		
CD @ 1 %	4.75		

* Significant over better parent at 5 % LOS

** Significant over better parent at 1 % LOS

Table 4.6: Transgressive segregants identified for plant height in segregating generation (F₂) of cross IIHR-2358 × Australian Red

Sl. No.	Plant number	Plant height(cm)	% increase over better parent
1	P-84	142.30**	32.09
2	P-49	136.80**	26.98
3	P-14	136.50**	26.70
4	P-32	135.00**	25.31
5	P-70	133.00**	23.45
6	P-87	132.10**	22.53
7	P-17	131.10**	21.69
8	P-53	131.00**	21.69
9	P-20	130.50**	21.14
10	P-133	130.27**	20.92
Checks (mean of parents)			
1	IIHR-2358	57.30	
2	Australian Red	105.00	
SEM	0.99		
CD @ 5 %	2.73		
CD @ 1 %	3.49		

* Significant over better parent at 5 % LOS

** Significant over better parent at 1 % LOS

4.3.3 Transgressive segregants identified for fruit width in F₂ segregating generation of cross IIHR-2358 × Australian Red.

Transgressive segregants for fruit width were identified from the cross IIHR-2358 × Australian Red are presented in Table 4.7. Among 250 F₂ population studied plant number P-176 (55.86 mm) exhibited superior mean performance for fruit width followed by plant number P-26 (54.32 mm), P-71 (53.41 mm), P-218 (52.86 mm), P-87 (49.41 mm), P-100 (49.05 mm), P-232 (48.76 mm), P-105 (48.66 mm), P-240 (48.50 mm) and P-35 (48.41 mm) and these plants showed 28.29, 24.75, 22.67, 21.40, 13.48, 12.65, 19.89, 11.75, 11.39 and 11.19 per cent performance over better parent IIHR-2358(34.61 mm) respectively.

4.3.4 Transgressive segregants identified for yield per plant in F₂ segregating generation of cross IIHR-2358 × Australian Red.

Transgressive segregants for fruit yield per plant were identified from the cross IIHR-2358 × Australian Red are presented in Table 4.8. Among 250 F₂ population studied plant number P-165 exhibited superior mean performance for yield per plant (1293.00 g) followed by plant number P-128 (1282.00 g), P-168 (1214.00 g), P-59 (1200.00 g), P-17 (1200.00 g), P-03 (1170.00 g), P-69 (1164.00 g), P-48 (1147.00 g), P-18 (1143.00 g) and P-41 (1135.00 g) and these plants showed 16.11 followed by 15.13, 9.02, 7.76, 7.76, 5.07, 4.53, 3.00, 2.64 and 1.93 per cent, respectively, performance over better parent IIHR-2358 (1088.80 g).

4.3.5 Transgressive segregants identified for number of clusters in F₂ segregating generation of cross IIHR-2358 × Australian Red.

Transgressive segregants for number of clusters per plant were identified from the cross IIHR-2358 × Australian Red are presented in Table 4.9. Among 250 F₂ population studied plant number P-26 (26.00) exhibited the highest number of clusters per plant followed by plant number P-39 (24.00), P-23 (23.00), P-91 (22.00), P-179 (21.00), P-02 (21.00) and P-11 (21.00), P-9 (20.00), P-19 (20.00) and P-176 (20.00) showed and these plant showed 71.73, 58.52, 51.92, 45.31, 38.71, and 32.10 per cent respectively performance over better parent Australian Red (14.40).

4.3.6 Transgressive segregants identified for average fruit weight in F₂ generation of cross IIHR-2358 × Australian Red.

Transgressive segregants for average fruit weight were identified from the cross IIHR-2358 × Australian Red are presented in Table 4.10. Among 250 F₂ population studied plant number P-59 (101.24 g) exhibited superior mean performance for average fruit weight followed by plant number P-128 (95.16 g), P-17

Table 4.7: Transgressive segregants identified for fruit width in segregating generation (F₂) of cross IIHR-2358 × Australian Red

Sl. No.	Plant number	Fruit width (mm)	% increase over better parent
1	P-176	55.86**	28.29
2	P-26	54.32**	24.75
3	P-71	53.41**	22.67
4	P-218	52.86**	21.40
5	P-87	49.41**	13.48
6	P-100	49.05**	12.65
7	P-232	48.76**	19.89
8	P-105	48.66**	11.75
9	P-240	48.50**	11.39
10	P-35	48.41**	11.19
Checks (mean of parents)			
1	IIHR-2358	34.52	
2	Australian Red	5.15	
SEM	0.37		
CD @ 5%	1.02		
CD @ 1%	1.33		

* Significant over better parent at 5 % los

** Significant over better parent at 1 % los

Table 4.8: Transgressive segregants identified for yield per plant in segregating generation (F₂) of cross IIHR-2358 × Australian Red

Sl. No.	Plant number	Yield per plant(g)	% increase over better parent
1	P-165	1293.00**	16.11
2	P-128	1282.00**	15.13
3	P-168	1214.00**	9.02
4	P-59	1200.00**	7.76
5	P-17	1200.00**	7.76
6	P-03	1170.00**	5.07
7	P-69	1164.00**	4.53
8	P-48	1147.00**	3.00
9	P-18	1143.00**	2.64
10	P-41	1135.00**	1.93
Checks (mean of parents)			
1	IIHR-2358	1088.80	
2	Australian Red	667.40	
SEM	8.95		
CD @ 5%	24.73		
CD @ 1%	31.54		

* Significant over better parent at 5 % LOS

** Significant over better parent at 1 % LOS

Table 4.9: Transgressive segregants identified for number of clusters in segregating generation (F₂) of cross IIHR-2358 × Australian Red

Sl. No.	Plant number	No. of clusters per plant	% increase over better parents
1	P-26	26.00**	71.73
2	P-39	24.00**	58.52
3	P-23	23.00**	51.92
4	P-91	22.00**	45.31
5	P-179	21.00**	38.71
6	P-02	21.00**	38.71
7	P-11	21.00**	38.71
8	P-09	20.00**	32.10
9	P-19	20.00**	32.10
10	P-176	20.00**	32.10
Checks (mean of parents)			
1	IIHR-2358	9.60	
2	Australian Red	14.40	
SEM	0.268		
CD @ 5 %	0.74		
CD @ 1 %	0.91		

* Significant over better parent 5 % LOS

** Significant over better parent 1 % LOS

Table 4.10: Transgressive segregants identified for average fruit weight in segregating generation (F₂) of cross IIHR-2358 × Australian Red

Sl. No.	Plant number	Average fruit weight (g)	% increase over better parents
1	P-59	101.24**	15.34
2	P-128	95.16**	8.42
3	P-17	94.56**	7.73
4	P-160	92.38**	5.25
5	P-48	92.28**	5.13
6	P-98	92.26**	5.16
7	P-160	92.17**	5.01
8	P-51	92.14**	4.98
9	P-158	92.07**	4.90
10	P-118	91.88**	4.68
Checks (mean of parents)			
1	IIHR-2358	85.16	
2	Australian Red	74.12	
SEM	0.944		
CD @ 5 %	2.61		
CD @ 1 %	3.31		

* Significant over better parent at 5 % LOS

** Significant over better parent at 1 % LOS

(94.56 g), P-160 (92.38 g), P-48 (92.28 g), P-98 (92.26 g), P-160 (92.17 g), P-51 (92.14 g), P-158 (92.07 g) and P-118 (91.88 g) and these plants showed 15.34 followed by 8.42, 7.73, 5.25, 5.13, 5.16, 5.01, 4.98, 4.90 and 4.68 per cent, respectively, performance over better parent IIHR 2358 (85.16 g).

4.3.7 List of high yielding plants were selected based on various yield attributing traits in F₂ segregating generation of cross IIHR-2358 × Australian Red.

High yielding transgressive segregants were selected based on various yield attributing traits in F₂ population are presented in Table 4.11. All plants were significantly different for fruit yield from the better parent. Among the selected plants, plant number P-165 (1293.00 g) and P-128 (1282.00g) exhibited highest fruit yield followed by plant number P-168 (1214.00 g), P- 59 (1200.00 g), P-17 (1200.00 g), P-3 (1170.00 g), P-64 (1164.00 g), P-48 (1147.00 g), P-18 (1143.00 g) and P-41 (1135.00 g) over the better parent IIHR 2358 (1088.80 g).

Table 4.11: List of high yielding plants were selected based on various yield attributing traits in segregating generation (F₂) of cross IIHR-2358 × Australian Red

Sl. No.	Plant number	Plant height (cm)	No. of cluster/plant	No. of fruits/plant	Average Fruit weight (g)	Yield per plant (g)
1	P-165	206.20**	11.00	206.83**	90.03**	1293.00**
2	P-128	104.60	8.00	248.91*	95.16**	1282.00**
3	P-168	92.65	17.00**	174.55**	94.99**	1214.00**
4	P-59	116.90**	18.00**	112.45	101.24**	1200.00**
5	P-17	131.10**	17.00**	155.11	94.56**	1200.00**
6	P-3	124.50**	21.00**	226.69**	91.00**	1170.00**
7	P-64	89.00	8.00	222.00**	75.26	1164.00**
8	P-48	127.00**	19.00**	198.24**	91.26**	1147.00**
9	P-18	123.67**	5.00	223.75**	91.54**	1143.00**
10	P-41	108.20*	5.00	192.87**	91.28**	1135.00**
P1	IIHR2358	57.30	9.60	32.64	85.16	1088.80
P2	Australian Red	105.00	14.40	152.64	74.12	667.40
Mean of F₂		116.11	10.44	81.00	62.50	812.23
CD @ 5 %		2.73	0.74	3.73	2.61	24.73
CD @ 1 %		3.49	0.94	4.75	3.31	31.54

* Significant over better parent at 5 % LOS

** Significant over better parent at 1 % LOS

DISCUSSION

V DISCUSSION

Plant breeders are continuously endeavoring to improve the genetic potential of yield and quality traits of tomato crop to meet the demands of an ever-increasing population of the world. The success of a crop improvement programme depends on the extent of variability existing in the population. Hence it is necessary to assess the quantum of genetic variability present in population.

Crop improvement depends upon the magnitude of genetic variability and the extent to which desirable characters are heritable. Genetic variability for yield and its related traits is essential in the base population for successful crop improvement.

The genetic variance of any quantitative trait is composed of additive variance (heritable) and non-additive variance and includes dominance and epistasis (non-allelic interaction). Therefore, it becomes necessary to partition the observed phenotypic variability into its heritable and non-heritable components with suitable parameters such as phenotypic and genotypic coefficient of variation, heritability and genetic advance (Mohammad *et al.*, 2015). Heritability determines how much of the phenotypic variability has a genetic origin and how much due to the influence of the environment, and therefore helps us select on a genetic basis. Genetic advance is another parameter on which the effectiveness of selection depends.

Correlation studies give information about the relative contribution of various component traits on fruit yield per plant and help in effective identification and selection of superior plants.

The present investigation was carried out to gather these information in F_2 population obtained from the selfing of F_1 hybrid which is derived from cross between cherry tomato (Australian Red) and tomato (IIHR-2358) provides all possible variations — segregating population (F_2) of cherry tomato which would be utilized for further improvement of tomato yield through an appropriate selection and sound breeding plan. Hence, selection with particular objectives in F_2 generation is most effective and selfing of those selected genotypes generation after generation helps to develop improved variety.

Hence, the present investigation was conducted to study the genetic variability, heritability and genetic advance, association and cause and effect for yield and its related traits. And the information obtained regarding variability parameters, correlation co-efficient and path coefficient is discussed under the following sub-headings.

- 5.1 To assess the genetic variability for yield and its related traits in segregating population of cherry tomato
- 5.2 To study nature and magnitude of association among yield traits through correlation and path analysis
- 5.3 To identify transgressive segregants for yield traits in cherry tomato

5.1 To assess the genetic variability for yield and its related traits in segregating population of cherry tomato

5.1.1 Range, skewness and kurtosis in the F₂ generation

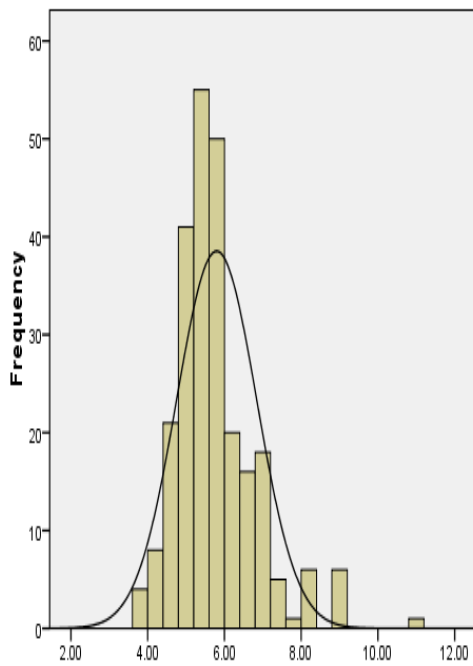
The study of distribution properties such as coefficients of skewness (third-degree statistic) and kurtosis (fourth-degree statistic) provides insight about the nature of gene action and number of genes controlling the traits (Robson, 1956). The skewed distribution of a trait, in general, suggests that the trait is under the control of non-additive gene action, especially epistasis and influenced by environmental variables (Pooni *et al.*, 1977; Kimberg and Bingham, 1998 and Roy, 2000).

The F₂ generation of cross IIHR-2358 × Australian Red exhibited a considerable amount of variability for all nineteen characters individually.

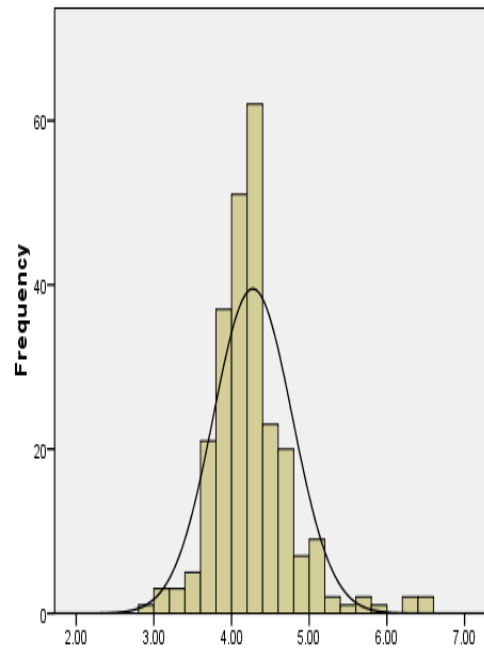
Traits showing skewed distribution indicates that genes controlling the character are predominantly dominant irrespective of enhancing or inhibiting effects on the expression of the trait. In general, the distribution pattern of F₂ generation suggested dominance and dominance based epistasis as the major causes for significant variation and asymmetrical distribution of the majority of the traits investigated in the present study.

The traits with leptokurtic and platykurtic distribution are controlled by fewer and a large number of genes. Kurtosis is negative or close to zero in the absence of gene interactions and is positive in the presence of gene interactions (Pooni *et al.*, 1977 and Choo and Reinbergs 1982). The inferences on the relative number of genes and nature of genetic control of different traits in F₂ generation of tomato cross are discussed below.

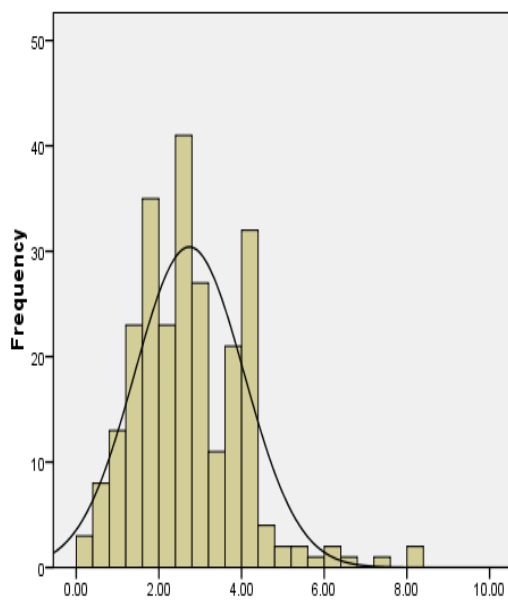
Out of nineteen fruit biochemical, morpho-physiological and yield attributing traits evaluated, twelve characters *viz.*, days to first flowering, number of flowers per plant, number of fruits per cluster, number of clusters per plant, primary branches, average fruit weight, number of locule per fruit, fruit diameter, pericarp thickness, lycopene content, ascorbic acid content and fruit yield per plant showed positive skewness with platykurtic distribution which is an evidence for involvement of



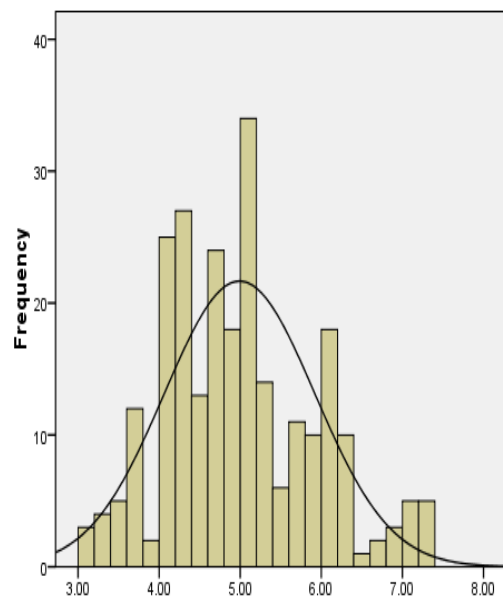
Total soluble solids



pH content

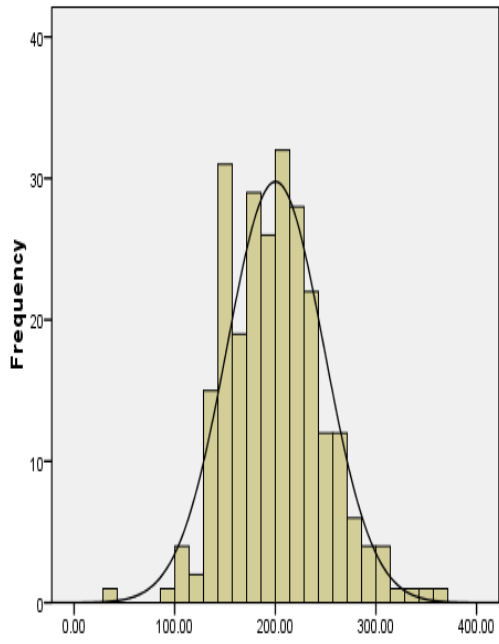


Lycopene content

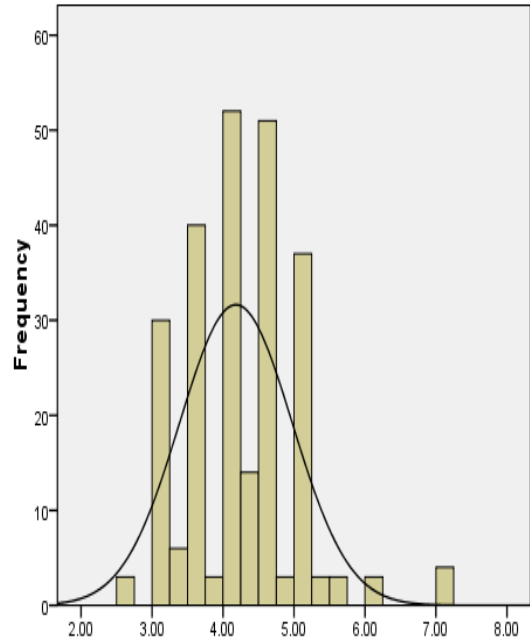


Ascorbic acid content

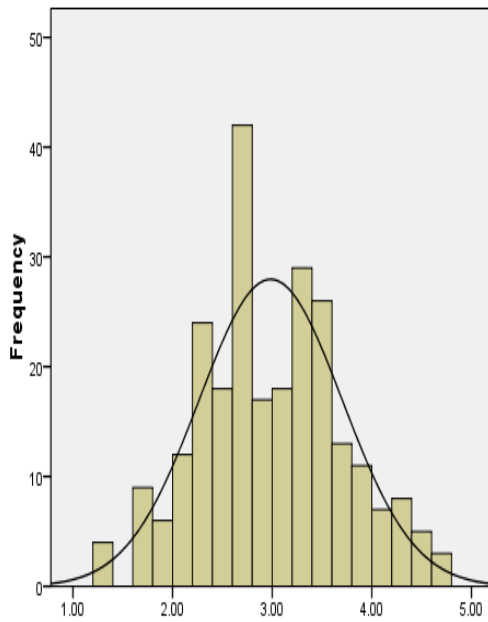
Fig. 5.1 Frequency distribution of total soluble solids (%), pH content, lycopene content and ascorbic acid content in F₂ generation of cross IHR-2358 × Australian Red



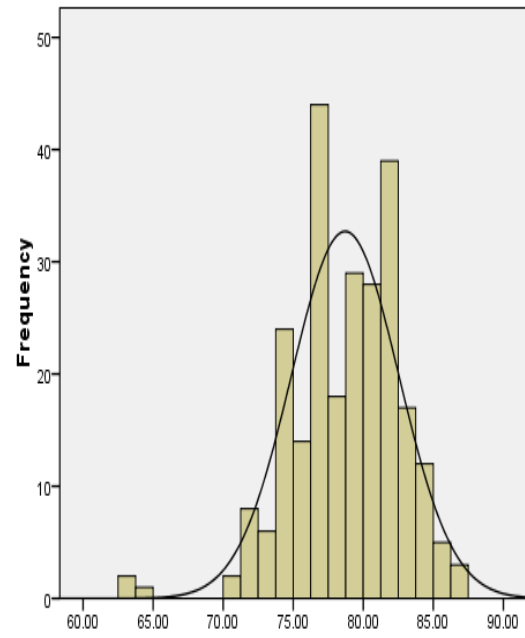
Number of fruits per plant



Number of locules per fruit



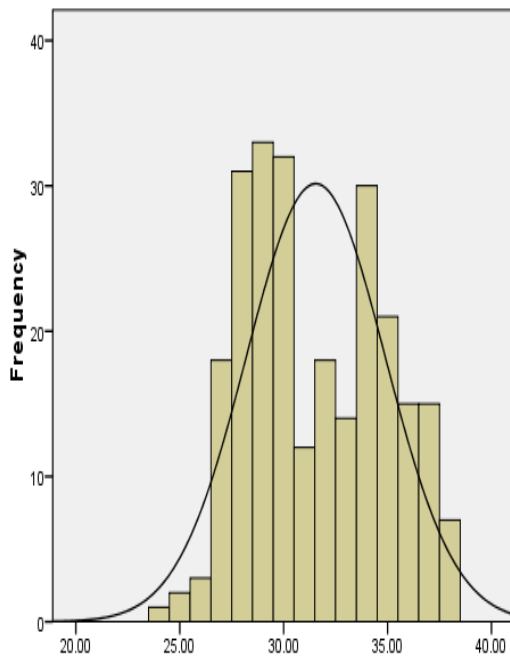
Pericarp thickness



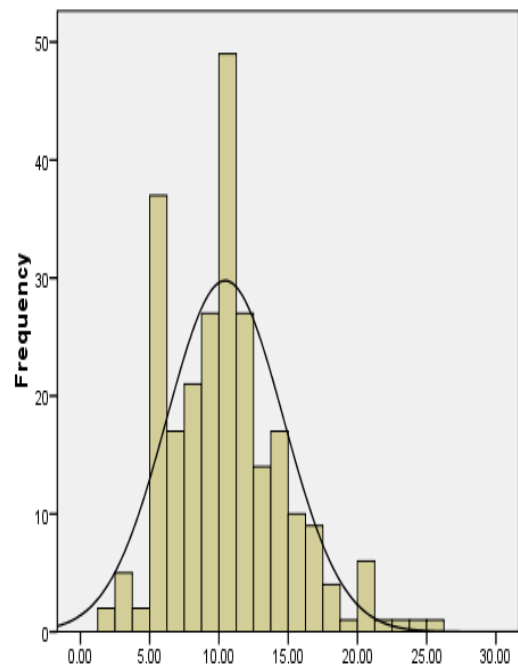
Pulp content

Mt
Std.

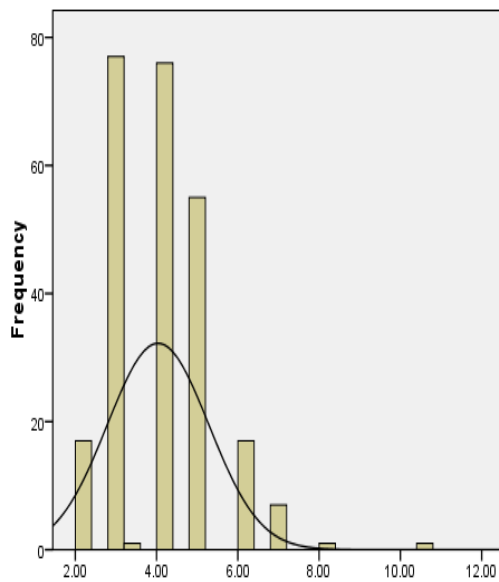
Fig.5.2 Frequency distribution of number of fruits per plant, number of locules per fruit, pericarp thickness and pulp content in F₂ generation of cross **IIHR-2358 × Australian Red**



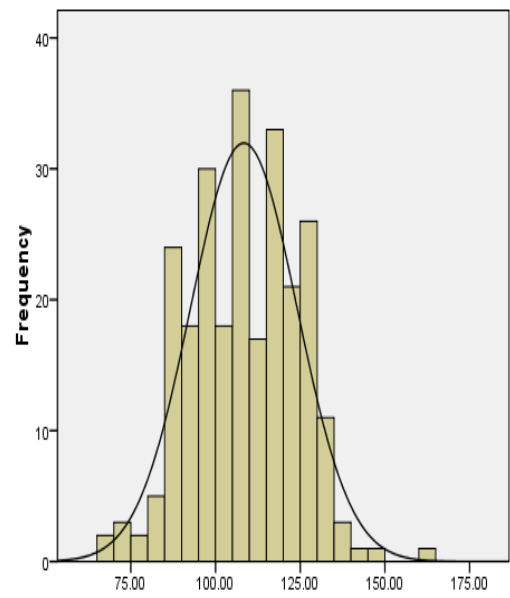
Days to first flowering



Number of clusters per plant

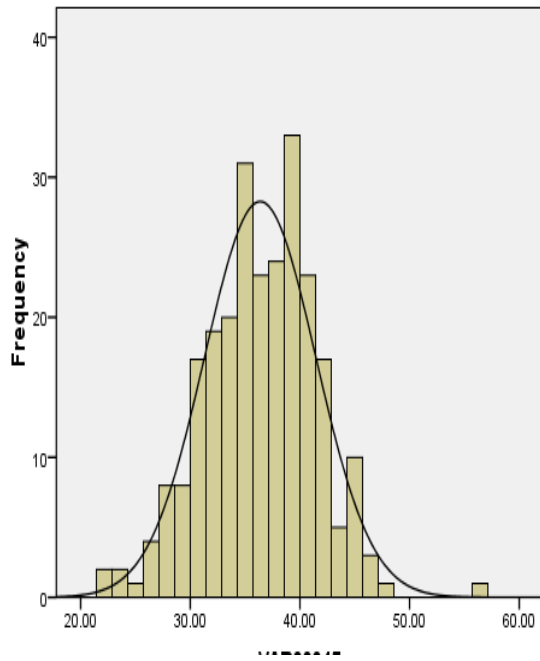


Number of fruits per cluster

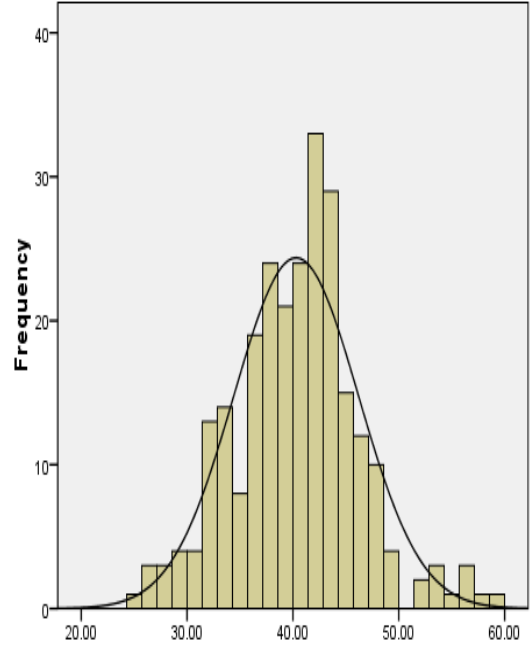


Plant height

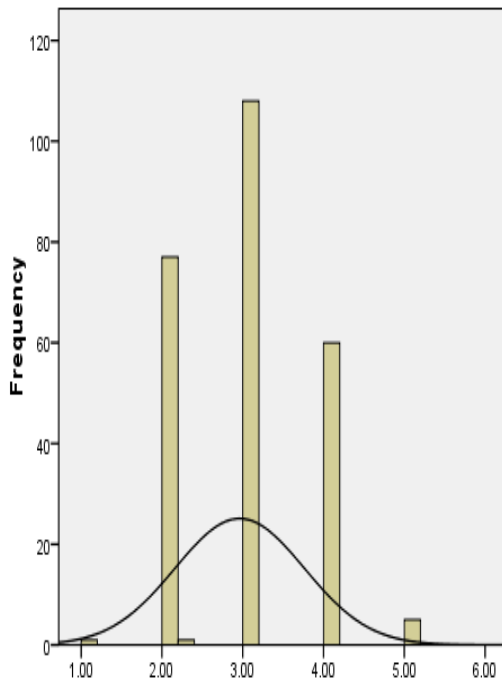
Fig. 5.3 Frequency distribution of days to first flowering, number of clusters per plant, number of fruits per cluster and plant height in F₂ generation of cross IIHR-2358×Australian Red



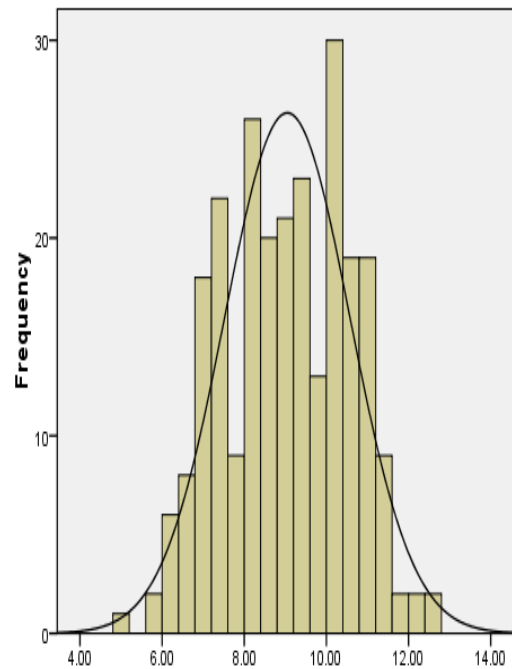
Fruit length



Fruit width

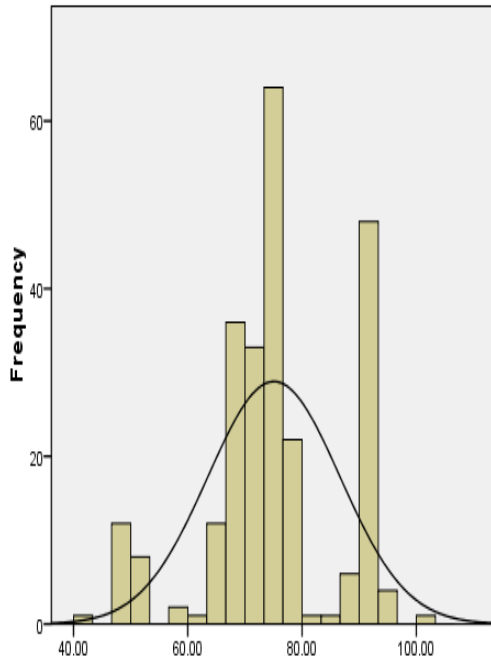


Primary branches per plant

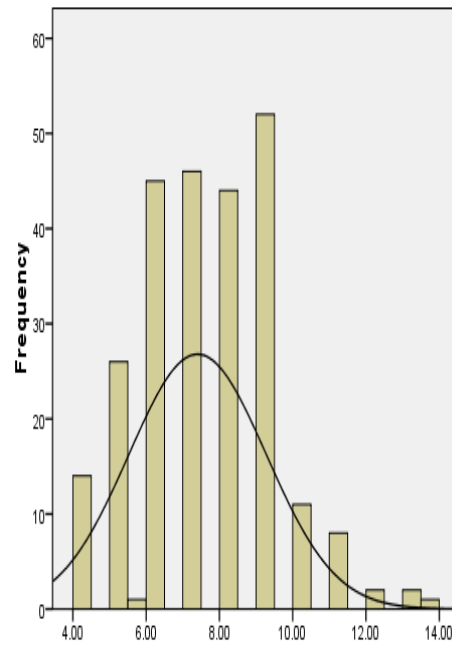


Secondary branches per plant

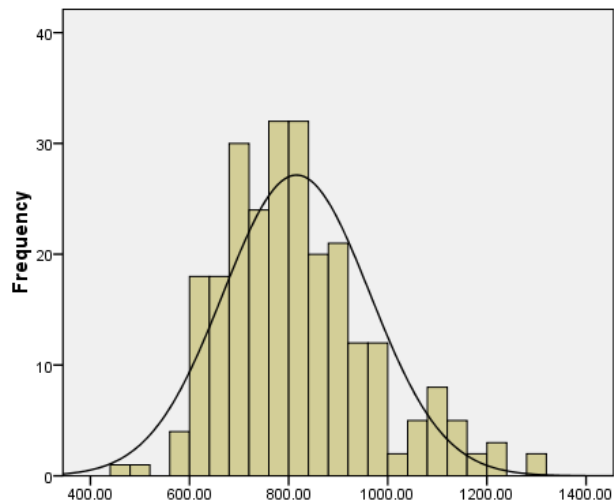
Fig.5.4 Frequency distribution of the fruit length, fruit width, primary branches per plant and secondary branches per plant in F₂ generation of cross IIHR-2358×Australian Red.



Average fruit weight



Number of flowers per cluster



Fruit yield per plant

Fig.5.5 Frequency distribution of average fruit weight, number of flowers per cluster and fruit yield per plant in F₂ generation of cross IIHR-2358×Australian Red

moderate number of genes among which equal frequency of genes had increasing and decreasing effects with complementary type of epistasis on the expression of the traits

Negatively skewed and platykurtic distribution was exhibited by five characters *viz.*, secondary branches, plant height, fruit length and pulp content indicates the involvement of a large number of dominant genes with a majority of them having increasing effects and duplicate type of epistasis in the inheritance of these traits. This kind of distribution of character will help to protect the individual plant from deleterious alleles arising from existing variability (Roy, 2000).

Three traits such as number of fruits per plant, TSS content and pH content showed leptokurtic and positively skewed distribution suggested the involvement of a relatively fewer number of segregating genes with the majority of them having decreasing effects and dominance based complementary type of interaction in their inheritance. Traits with positively skewed distribution require an intense selection from the available variability to maximize the genetic gain (Roy, 2000). These results are in agreement with the findings of Yogendra (2011).

Variability is an essential requirement for cherry tomato crop improvement. The breeder should have a large number of variable populations to begin breeding activities. The most important economic character in tomato is fruit yield. Other supporting characters influencing the fruit yield and yield itself are governed by polygenes and are quantitatively inherited (Hayes *et al.*, 1955). Since the selection is based on phenotypic observations, their reflection on genotypic value may not hold good unless observation on quantitative traits are subjected and interpreted according to statistical procedures, as fruit yield in tomato is much influenced by environmental factors. Therefore, parameters like the coefficient of variation, heritability and genetic advance as per cent mean, etc. for different traits in cherry tomato have been computed to draw some valid inferences from the F₂ generation studied in the present investigation.

In the present study for all traits except for locules per fruit phenotypic coefficient of variation (PCV) agreed closely with the genotypic coefficient of variation (GCV). This result is in agreement with the finding of Pemba *et al.* (2014). The magnitude of the phenotypic coefficient of variation was higher than genotypic coefficient of variation for all the characters which might be due to the interaction of the genotypes with the environment to some extent or other denoting environmental factors influencing the expression of these characters. This result is in accordance with earlier findings Islam *et al.* (2012), Renuka *et al.* (2012), Adhi *et al.* (2013), Bilal *et al.* (2017), Sunil *et al.* (2016), Mahantagouda *et al.* (2017a), Mahesh *et al.* (2017) and Priyanka *et al.* (2017). Very narrow differences were observed between the genotypic coefficient of variation (GCV) and phenotypic coefficient of variation

(PCV) for all the traits except for TSS, indicating that most of the traits were less influenced by environmental factors for their phenotypic expression. This observation is in agreement with Mahantagouda *et al.*, (2017a).

The low estimate of GCV and PCV was observed for pulp content, whereas days to first flowering showed low GCV and moderate PCV. Low estimate of GCV and PCV indicates a narrow range of variability and selection based on these traits would not be rewarding. This result is in agreement with the finding of Prema *et al.* (2011).

Moderate genotypic and phenotypic coefficient of variation had shown by traits like secondary branches per plant, average fruit weight, number of locules per fruit, plant height, fruit width, fruit length, total soluble solids, pH, Ascorbic acid content and fruit yield, indicating the moderate genetic variability for this trait. This result is in agreement with the finding of Prema *et al.* (2011), Renuka *et al.* (2012), Adhi *et al.* (2013), Amarjeet *et al.* (2016), Arun *et al.* (2016), Sunil *et al.* (2016) Mahantagouda *et al.* (2017a), Mahesh *et al.* (2017), Arvind *et al.* (2017), Priyanka *et al.* (2017) and Rakesh *et al.* (2018)

The higher estimate of the genotypic and phenotypic coefficient of variation was observed for traits like number of cluster per plant, number of flowers per plant, number of fruits per plant, number of primary branches per plant, pericarp thickness and lycopene content. This result is in accordance with the results reported by Prema *et al.* (2011), Islam *et al.* (2012), Renuka *et al.* (2012), Patel *et al.* (2013), Adhi *et al.* (2013), Neeraj *et al.* (2015a), Ravindra *et al.* (2015), Amarjeet *et al.* (2016), Bilal *et al.* (2017), Mahesh *et al.* (2017) and Arvinda *et al.* (2017). Higher GCV and PCV indicate a wide range of variation for these traits and are less influenced by environmental variation. These traits provide better scope for improvement through selection.

High heritability was observed for the traits like number of clusters per plant, number of fruits per cluster, number of fruits per plant, primary branches per plant, secondary branches per plant, average fruit weight, fruit width, fruit length, plant height, ascorbic acid, pericarp thickness, fruit yield per plant. Moderate heritability was observed for the traits like TSS, number of locules per fruit. The traits showing high heritability in broad sense indicates these traits are least influenced by the environmental effects, the selection for improvement of such traits may not be useful, because broad sense heritability is based on total genetic variance which includes both fixable (additive) and non-fixable (dominance and epistasis) variance. This result is in agreement with findings of Renuka *et al.* (2012), Adhi *et al.* (2013), Sunil *et al.* (2016), Amarjeet *et al.* (2016), Arvind *et al.* (2017) and Mamatha *et al.* (2017).

Estimates of genetic advance help to predict the extent of improvement that can be achieved by improving the different characters. High GAM was observed for traits like number of clusters per plant, number of flowers per cluster, number of fruits per clusters, number of fruits per plant, primary branches per plant, secondary branches per plant, average fruit weight, number of locule per fruit, plant height, fruit width, fruit length, TSS, pH, pericarp thickness, lycopene content, ascorbic acid and fruit yield per plant. Whereas days to first flowering showed, moderate GAM and pulp content showed low GAM. High GAM indicates that traits are governed by additive genes and selection will be rewarding for improvement of such trait, low GAM indicates that traits are governed by non-additive genes and heterosis breeding may be useful. This result is in agreement with findings of Ravindra *et al.* (2015), Sunil *et al.* (2016) for high GAM. And for low GAM agrees with finding of Patel *et al.* (2013), Manna and Paul (2012a), Neeraj *et al.* (2015a), Arvind *et al.* (2017) and Mahantagouda *et al.* (2017a).

High heritability coupled with high GAM indicates the presence of additive gene action and these traits can be improved through a simple breeding programme. This result is in agreement with findings of Prema *et al.* (2011), Renuka *et al.* (2012) and Pemba *et al.* (2014).

5.2 To study nature and magnitude of association among yield traits through correlation and path analysis

Knowledge of correlation between yield and its contributing characters are the basic and foremost endeavor to find out guidelines for plant selection. Partitioning of total correlation into direct and indirect effect by path coefficient analysis helps in making the selection more effective. The existing relationships between characters are generally determined by the genotypic, phenotypic correlations. However, the correlation coefficient between two characters does not necessarily imply a cause and effect relationship. The existence of correlation may be attributed to the presence of linkage or pleiotropic effect of genes or physiological and development relationship or environmental effect or in combination of all.

The basic objective of most of the crop improvement programme is to realize a marked improvement in crop yield. But yield is a complex character which is controlled by association of various characters. Thus, information on the association of yield attributes and their direct and indirect effects on fruit yield is of paramount significance. Hence, path analysis is of much importance in any plant breeding program.

The major advantage of path analysis is that it permits the partitioning of the correlation coefficient into its components, one component being the path coefficient

that measures the direct effect of a predictor variable upon its response variable and the second component being the indirect effect(s) of a predictor variable on the response variable through another predictor variable (Dewey and Lu, 1959). Keeping the stated concepts in mind, an attempt was made to understand the study of correlation and path coefficient analysis of yield attributing traits in 250 segregating population (F_2) of cross IIHR 2358 and Australian red and the results were discussed under following subheadings.

5.2.1 Correlation of fruit yield per plant and its related traits in F_2 generation of cross IIHR 2358 \times Australian Red.

Yield is quantitative character. Hence, its association with other traits is important. In the present study fruit yield per plant had significant and positive association with number of clusters per plant, number of fruits per plant, plant height, number of branches, average fruit weight and fruit width. This result as in agreement with previous research findings of Islam *et al.* (2010), Ghosh *et al.* (2010), Manna and Paul (2012b), Prakash and Vijay, (2015), Naveen *et al.* (2017), Neeraj *et al.* (2015b) and Meera *et al.* (2018). Hence, indirect selection for fruit yield could be effectively done through direct selection of yield component characters as indicated above.

Studies on the relationship of fruit yield with other yield components revealed that fruit length and pulp content had negative and significant association with fruit yield at phenotypic level. The results are confirmed to the findings of Monamodi *et al.* (2013).

Number of fruits per plant showed significant and positive correlation at phenotypic level with plant height and showed positive and non-significant association with average fruit weight, fruit width and pulp content. It had negative non-significant association with number of branches. This observation is in agreement with findings of Harun (2015), Renuka *et al.* (2017) for positive and significant association and agreement with Meera *et al.* (2018) for negative non-significant association.

Fruit width showed positive significant association with days to first flowering. This result is in agreement with findings of Ghosh *et al.* (2010) and Meera *et al.* (2018) and showed negative and non-significant association with pulp content this is in agreement with the finding of Ullah *et al.* (2015).

Plant height showed positive and significant correlation at phenotypic level with average fruit weight and positive and non-significant correlation with number of branches and fruit width. This observation is in agreement with the finding of Meera *et al.* (2018). It showed negative and non-significant correlation with pulp content; this is in agreement with findings of Islam *et al.* (2010).

Number of branches showed positive and non-significant association at phenotypic level with average fruit weight, fruit width and pulp content. This result is in agreement with findings of Islam *et al.* (2010). It had negative and non-significant association with days to first flowering.

Pulp content showed positive and non-significant association with number of clusters per plant, number of fruits per plant and number of branches. It had negative and significant association with fruit width and negative non-significant association with plant height, average fruit weight and days to first flowering. This result is in agreement with findings of Ullah *et al.* (2015).

5.2.2 Path Analysis of fruit yield and its related traits in F₂ generation of the cross, IIHR 2358 × Australian Red.

The path coefficient analysis suggested by Dewey and Lu (1959) specified the effective measure of direct and indirect causes of association and also depicted the relative importance of each factor involved in contributing to the final product that is yield. In the present study, the path coefficient analysis was done at the phenotypic level, and these results are discussed below.

Phenotypic path coefficient analysis had showed that yield related characters *viz.*, number of clusters per plant, plant height, number of branches per plant, average fruit weight and fruit width exhibited positive direct effect on fruit yield at phenotypic level (Table 5). Indicating the selection of these traits provides the basis for selection of superior genotype. Similar results of positive direct effect on fruit yield also reported by Ghosh *et al.* (2010), Kaushal *et al.* (2017) and Meera *et al.* (2018).

Highest negative direct effective was exhibited by number of cluster per plant. Even though the direct effect of this trait is negative, it seems to be the most potential trait for improving fruit yield per plant *via*, other traits. This result is in agreement with findings of Ghosh *et al.* (2010) and Rajashekar *et al.* (2013).

The highest positive indirect effect was observed for number of branches per plant followed by number of fruits per plant. These traits might be recognized as the most important components traits for selecting fruit yield per plant. This result is in accordance with findings of Islam *et al.* (2010), Rajasekhar *et al.* (2013) and Meena *et al.* (2015).

5.3 To identify transgressive segregants for yield traits in cherry tomato

The present investigation leads to the identification of superior promising individual plants in F₂ segregating generation in the cross, IIHR-2358×Australian Red. The significant superior performance of segregants due to the contribution of

component characters. Top ten plants have been identified based on various yield attributing traits like plant height, number of clusters per plant, number of fruits per plant, average fruit weight. Among 250 segregating population (F_2), P-212 (369.81) exhibited highest fruits per plant, P-84 (142.30 cm) showed highest plant height, P-176 (56.86 mm) exhibited highest fruit width, P-26 (26.00) showed higher clusters per plant and P- 59 (101.24 g) showed the highest average fruit weight. These plants showed 136.50, 32.09, 28.29, 71.73, 15.34 per cent, respectively, increase over the better parent.

Among segregating plants P-165(1293.00g) exhibited the highest fruit yield per plant which is significantly differing from better parent IIHR 2358. This indicates that the parents possess different alleles and genes governing respective characters from which it could be inferred that there is a lot of scopes to bring in beneficial alleles into a single genotype through vigorous selection and handling of these segregants evaluating the segregates for different characters along with selection for yield to arrive at a desirable plant type through selection in later generations.

Conclusion

The traits studied in segregating population (F_2) had a wide range of variability such as high range, skewness, kurtosis, PCV, GCV, h^2 and GAM. Thus, they could be considered for making selection. Out of nineteen fruit biochemical, morpho-physiological and yield attributing traits evaluated, twelve characters *viz.* days to first flowering, number of clusters per plant, number of flowers per plant, number of fruits per cluster, primary branches, average fruit weight, number of locule per fruit, fruit diameter, pericarp thickness, lycopene content, ascorbic acid and yield per plant showed positive skewness with platykurtic distribution. Four traits *viz.*, secondary branches, plant height, fruit length and pulp content negative skewness with the platykurtic distribution. Three traits such as number of fruits per plant, TSS and pH showed leptokurtic and positively skewed distribution. Traits with positively skewed distribution require an intense selection from the available variability to maximize the genetic gain. All traits showed high to moderate estimate of genotypic and phenotypic coefficient of variation except for pulp content; this indicates the possibility of obtaining higher to moderate selection response for these traits. Most of the traits showed high heritability coupled with high GAM except for the traits like days to first flowering, number of locules per fruit, total soluble solids and pulp content. Thus, these traits are probably controlled by additive gene action which is very useful in phenotypic selection. The preceding discussion on path coefficient analysis has clearly demonstrated that number of fruits per plant, plant height, number of branches per plant, average fruit weight and fruit width had an effect on fruit yield per plant. Direct selection of these traits would be helpful in increasing the fruit yield per plant in cherry tomato through selection. The identified superior transgressive segregants (P-165, P-128, P-168, P-59 and P-17) can be evaluated for further generation and can be used as parents in hybridization programme and can be forwarded for stabilization.

Future line of work

1. The identified superior genotypes (P-165, P-128, P-168, P-59 and P-17) should be advanced to next generation (F_3) and best-performing genotypes after stabilization can be utilized in hybridization programme or proposed for direct release.
2. Genotypes identified can be screened for biotic and abiotic stress and further confirmed with molecular markers.
3. Genotypes showing the best performance in particular character (quality) can be used as a donor parent in hybridization.

SUMMARY

VI SUMMARY

In the present investigation, the assessment of genetic variability was undertaken with the 250 segregating population (F_2) of cross IIHR 2358 \times Australian red. The experiment was conducted ZAHRS, Navule, Shivamogga during 2018. The objectives were to assess genetic variability, to study the nature and magnitude of association among yield and its attributing traits, identification of transgressive segregants for yield and some yield attributing traits. The results of the study and the conclusion drawn from the experiment are summarized below.

Out of nineteen fruit biochemical, morpho-physiological and yield attributing traits evaluated, twelve characters *viz.* days to first flowering, number of clusters per plant, number of flowers per plant, number of fruits per cluster, primary branches, average fruit weight, number of locule per fruit, fruit diameter, pericarp thickness, lycopene content, ascorbic acid and yield per plant showed positive skewness with platykurtic distribution. Four traits *viz.*, secondary branches, plant height, fruit length, and pulp content showed negative skewness with the platykurtic distribution. Three traits such as number of fruits per plant, TSS and pH showed leptokurtic and positively skewed distribution. Traits with positively skewed distribution require an intense selection from the available variability to maximize the genetic gain.

The segregating population had a wide range of variation for all the traits studied. The magnitude of PCV was higher than GCV for all the characters. The traits like number of cluster per plant, number of flowers per plant, number of fruits per plant, primary branches per plant, pericarp thickness and lycopene content had shown higher estimate of genotypic and phenotypic coefficient of variation whereas the traits like secondary branches per plant, average fruit weight, number of locules per fruit, plant height, fruit width, fruit length, total soluble solids, pH, Ascorbic acid content and fruit yield had shown moderate genotypic and phenotypic coefficient of variation. The trait pulp content had shown a low estimate of GCV and PCV. The higher estimate of GCV and PCV for traits indicates the sensitiveness of trait for selection.

Most of the traits had shown high heritability coupled with high genetic advance as percent mean except for the traits like days to first flowering, number of locule per fruit, total soluble solids and pulp content. It reveals that broad genetic base and these traits are under control of additive genes. Hence, simple and early generation selection schemes would be effective for improvement of these traits.

In the present study, fruit yield had a significant and positive phenotypic association with number of clusters per plant, number of fruits per plant, plant height, number of branches, average fruit weight and fruit width. Indirect selection for fruit

yield could be effectively done through direct selection of traits showing positive and significant difference with fruit yield.

Number of fruits per plant showed significant and positive correlation at phenotypic level with plant height and showed positive and nonsignificant association with average fruit weight, fruit width and pulp content. Number of fruits per plant showed negative significant association with fruit length and negative non-significant association with number of branches. Fruit width showed positive significant association with days to first flowering. Plant height showed positive and significant correlation at phenotypic level with average fruit weight and positive and non-significant correlation with number of branches and fruit width. Number of branches showed positive and non-significant at phenotypic level with average fruit weight, fruit width and pulp content. Pulp content showed positive and non-significant association with number of clusters per plant, number of fruits per plant and number of branches.

In the present study, the path coefficient analysis had shown that yield related characters *viz.*, number of clusters per plant, plant height, number of branches per plant, average fruit weight and fruit width exhibited positive direct effect on fruit yield at the phenotypic level.

Number of clusters per plant had indirect and positive effect on fruit yield was exhibited by number of branches per plant and days to first flowering. Plant height showed indirect and positive effect on fruit yield was exhibited by number of cluster per plant, number of branches per plant, average fruit weight, fruit width and days to first flowering. Number of branches per plant showed indirect and positive effect on fruit yield was exhibited by plant height, average fruit weight, fruit width and pulp content and showed negative effect on number of cluster per plant, number of fruits per cluster and days to first flowering.

Average fruit weight had indirect and positive effect on fruit yield was exhibited by number of clusters per plant, number of fruits per cluster, plant height, number of branches per plant, fruit width and days to first flowering. Fruit width had indirect and positive effect on fruit yield was exhibited by number of clusters per plant, number of fruits per cluster, plant height, number of branches per plant, average fruit weight and days to first flowering.

Pulp content showed indirect and positive effect on fruit yield was exhibited by plant height, average fruit weight, fruit width and days to first flowering. It showed negative effect on number of clusters per plant, number of fruits per plant and number of branches per plant. Days to first flowering showed indirect and positive effect on fruit yield was exhibited by number of clusters per plant, number of branches per

plant and pulp content. It showed negative effect on number of fruits per plant, plant height, average fruit weight and fruit width.

High yielding transgressive segregants have been identified based on various yield attributing traits over the better parent. Plant number 165 showed had the highest yield, followed by plant 128, 168, 59, 17, 03, 64, 48, 18, 41. These plants are significantly different for fruit yield from better parent whereas for other yield attributing like plant height, number of cluster per plant, number of fruits per plant, average fruit weight. Some plant had shown on par with better parent and some plants had significantly different from the better parent.

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APPENDICES

VIII APPENDICES

Appendix I. Monthly meteorological data for the year 2018 and the mean of past 31 years (1986-2017) recorded at the meteorological observatory, Zonal Agricultural and Horticultural Research Station, Navile, Shivamogga, Karnataka.

Month	Rainfall (mm)			Mean temperature (°C)						Mean relative humidity (%)			Sunshine hours			Rainy days	
	N	A	D	Maximum			Minimum			N	A	D	N	A	D	N	A
				N	A	D	N	A	D								
January	0.4	0	-0.40	31.2	32.1	0.9	17.1	15.3	-1.8	59	57	-2	9	8.73	-0.27	0	0
February	0.2	0	-0.20	33.4	33.6	0.2	17.7	16.5	-1.2	57	45	-12	9	8.71	-0.29	0	0
March	3.2	7.6	4.40	35.8	36	0.2	21	20	-1	54	53	-1	7.1	3.77	-3.33	0	1
April	44.2	62.4	18.20	36.4	36.7	0.3	22.1	22.7	0.6	60	64	4	8	7.84	-0.16	3	4
May	72.2	154	81.80	34.7	34.3	-0.4	22.7	22.1	-0.6	66	70	4	7.4	6.95	-0.45	4	12
June	115.6	145	29.40	29.5	29.2	-0.3	21.5	21.7	0.2	70	85	15	3.2	2.32	-0.88	10	12
July	199.8	154.2	-45.60	27.7	28	0.3	21.2	21.5	0.3	84	87	3	2.6	2.09	-0.51	14	21
August	139.7	174.2	34.50	27.7	27.4	-0.3	22.3	21.3	-1	84	88	4	4.3	3.47	-0.83	14	19
September	105.4	82.4	-23.00	29.3	31.1	1.8	22	20.5	-1.5	80	75	-5	4.8	7.45	2.65	7	5
October	140.1	134.8	-5.30	30.2	31.5	1.3	21.8	19.8	-2	77	70	-7	6.5	7.92	1.42	7	5
November	41	5.2	-35.80	30	31.4	1.4	19.3	17.7	-1.6	69	64	-5	7.2	8.07	0.87	3	1
December	10.7	3.6	-7.10	29.9	31.2	1.3	17.8	17.2	-0.6	62	66	4	8.5	7.75	-0.75	1	0
Total	872.5	923.4	-	-	-	-	-	-	-	-	-	-	-	-	-	64	80

Note: Total rainfall during the calendar year (January to December) = 872.5 mm (Normal), 923.4 mm (Actual)

A: Actual for the year 2018 N: Normal for previous 31 years (1986-2017) D: Deviation (A-N)

Appendix II. Mean performance of all nineteen traits of all segregating population (F₂) of cross IHR 2358× Australian red including checks.

Plt. No.	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19
1	37.00	2.00	8.00	6.00	2.00	6.00	48.30	3.00	4.20	3.62	3.70	4.35	3.11	36.71	35.72	77.42	112.50	159.69	715.00
2	25.00	21.00	6.00	4.00	2.00	7.00	68.50	4.15	5.10	3.12	3.90	4.12	3.46	45.15	40.06	79.35	130.00	186.02	665.00
3	26.00	5.00	4.00	5.00	3.00	8.00	91.00	4.50	6.00	4.13	8.37	5.32	1.61	42.61	40.36	80.34	124.50	226.69	1170.00
4	28.00	13.00	6.00	3.00	4.00	11.00	78.27	2.60	5.12	4.39	1.82	4.81	2.67	43.28	37.26	84.51	104.00	208.18	820.00
5	33.00	12.00	8.00	4.00	3.00	6.00	48.50	4.00	3.91	4.16	3.45	4.47	3.57	40.29	35.67	82.63	123.10	180.10	745.00
6	29.00	7.00	7.00	5.00	3.00	9.00	50.27	3.10	4.25	4.51	3.40	4.10	2.60	42.38	35.16	79.56	126.60	173.76	760.00
7	32.00	9.00	9.00	6.00	4.00	8.00	79.75	3.60	6.41	4.26	4.84	6.02	2.30	41.33	34.65	79.95	90.00	248.81	835.00
8	27.00	11.00	4.00	5.00	4.00	7.00	50.29	5.13	4.37	4.30	4.42	4.86	2.73	33.45	27.33	79.43	127.33	162.57	703.00
9	31.00	20.00	5.00	3.00	2.00	9.06	68.30	4.26	5.12	3.91	6.78	4.12	2.83	38.01	32.74	74.36	124.00	156.60	662.00
10	36.00	3.00	7.00	4.00	2.00	9.17	49.37	3.19	5.80	4.25	2.63	5.02	2.76	28.92	33.56	77.27	126.50	145.18	752.00
11	34.00	21.00	5.00	3.00	3.00	8.64	90.27	3.70	4.81	4.15	7.31	3.06	1.70	45.27	38.47	77.34	128.60	138.53	947.00
12	37.00	10.00	9.00	5.00	3.00	9.27	78.07	4.31	5.24	4.06	1.28	4.06	1.89	38.72	37.16	76.39	118.90	157.20	813.00
13	28.00	6.00	4.00	3.00	4.00	9.00	48.36	5.13	5.67	4.22	6.38	4.92	3.45	42.01	40.64	82.81	116.50	206.69	791.00
14	33.00	10.00	5.00	2.00	3.00	11.25	68.72	4.29	5.27	4.62	4.81	5.16	3.98	46.40	37.58	79.21	136.50	239.42	687.00
15	27.00	3.00	7.00	4.00	2.00	11.06	49.37	5.00	4.21	4.37	5.66	4.67	3.41	31.35	31.77	81.00	102.50	146.40	771.00
16	26.00	17.00	4.00	2.00	4.00	6.18	75.29	5.13	5.64	4.76	8.39	4.09	1.20	43.16	42.70	81.12	123.40	176.52	809.00
17	38.00	17.00	11.00	8.00	5.00	6.29	94.56	4.06	5.57	3.52	3.61	4.28	2.18	36.24	36.29	85.13	131.10	155.11	1200.00
18	35.00	5.00	7.00	4.00	4.00	7.14	91.54	3.50	4.42	4.76	2.25	5.34	2.70	41.90	36.97	79.85	123.67	223.75	1143.00
19	24.00	20.00	9.00	4.00	3.00	6.79	76.27	4.00	6.75	4.35	4.66	6.12	2.04	34.23	30.49	80.45	103.70	209.49	808.00
20	34.00	13.00	8.00	4.00	4.00	8.16	91.27	5.16	5.96	4.16	1.23	5.87	2.62	33.56	28.92	80.23	130.50	197.00	992.00
21	32.00	7.00	6.00	3.00	4.00	9.07	48.27	4.03	6.42	3.96	1.28	4.19	2.29	32.56	31.71	81.45	116.80	136.43	706.00
22	37.00	4.00	9.00	5.00	3.00	9.50	78.29	4.21	5.74	3.79	0.98	4.06	2.16	42.86	39.26	78.66	128.80	174.01	824.00
23	29.00	23.00	7.00	3.00	2.00	11.01	78.19	4.50	4.93	4.06	3.42	4.16	3.49	38.16	35.54	83.45	127.60	158.75	819.00
24	28.00	12.00	10.00	5.00	2.00	10.67	49.67	3.29	7.76	4.19	3.34	3.19	1.61	42.90	45.15	79.61	99.50	136.85	780.00
25	35.00	15.00	8.00	4.00	3.00	7.29	90.27	3.51	6.25	4.32	3.45	3.79	3.01	40.26	37.19	63.17	130.80	152.59	961.00

26	30.00	11.00	6.00	4.00	3.00	8.26	76.16	4.06	5.47	4.29	1.87	4.19	2.73	54.32	39.49	82.97	120.68	227.60	863.00
27	32.00	16.00	5.00	2.00	2.00	9.18	75.19	4.61	6.10	4.46	2.05	4.36	1.81	38.73	35.16	77.64	105.60	168.86	816.00
28	37.00	14.00	9.00	3.00	2.00	10.00	79.24	4.00	5.50	3.97	1.67	4.02	3.28	37.29	38.16	83.67	103.30	149.91	830.00
29	35.00	12.00	6.00	3.00	4.00	11.22	41.29	3.10	5.00	5.74	1.56	4.96	2.53	38.19	33.46	74.36	109.40	189.42	563.00
30	29.00	6.00	4.00	2.00	5.00	11.47	49.19	4.50	6.00	4.22	2.13	4.21	2.50	38.29	37.26	74.16	89.50	161.20	729.00
31	36.00	12.00	8.00	4.00	4.00	10.39	68.50	5.00	5.00	4.39	0.87	5.16	3.37	42.46	40.99	87.13	118.30	219.09	655.00
32	37.00	17.00	9.00	5.00	3.00	10.75	90.27	4.50	6.00	4.58	0.21	4.67	2.33	40.28	35.56	80.22	135.00	188.11	1109.00
33	34.00	10.00	7.00	4.00	4.00	11.46	76.19	4.50	6.40	4.36	1.28	4.31	2.75	39.57	34.50	75.64	116.38	170.55	873.00
34	32.00	14.00	5.00	3.00	3.00	9.26	49.27	5.12	8.20	4.62	1.44	3.27	2.72	40.38	35.62	81.32	119.50	132.04	754.00
35	27.00	7.00	4.00	2.00	2.00	9.37	90.17	4.00	8.00	5.01	1.94	3.20	2.91	48.41	34.57	63.98	109.00	154.91	1090.00
36	33.00	9.00	5.00	3.00	2.00	10.28	67.27	5.00	5.40	3.77	0.69	4.60	2.36	37.64	30.16	76.84	121.60	173.14	647.00
37	35.00	8.00	7.00	4.00	2.00	6.97	77.19	4.50	6.40	5.43	1.25	4.20	2.98	35.61	28.94	77.36	108.70	149.56	852.00
38	28.00	5.00	6.00	3.00	3.00	7.29	47.26	4.61	5.40	5.78	1.93	4.15	3.50	43.16	30.11	80.41	130.26	179.11	749.00
39	36.00	24.00	5.00	3.00	4.00	7.09	80.76	3.50	6.00	4.72	1.66	5.16	3.26	37.93	35.83	80.26	114.25	195.72	863.00
40	34.00	10.00	9.00	5.00	3.00	8.64	70.24	5.00	6.40	4.12	0.37	5.02	2.05	38.42	33.45	81.65	108.20	192.87	680.00
41	36.00	5.00	4.00	2.00	3.00	8.69	91.26	4.21	5.80	5.23	1.73	5.17	1.75	39.16	36.38	76.34	123.38	202.46	1136.00
42	30.00	12.00	6.00	4.00	3.00	10.67	90.57	4.00	7.50	4.87	1.65	4.21	1.83	36.14	32.46	71.75	111.57	152.15	963.00
43	30.00	11.00	5.00	2.00	2.00	11.07	48.29	3.50	4.80	4.52	0.53	4.92	1.61	31.66	39.17	87.45	121.10	155.77	738.00
44	28.00	15.00	7.00	3.00	2.00	8.89	68.29	3.00	6.80	4.43	0.69	4.63	1.97	40.63	32.69	76.69	118.50	188.12	621.00
45	34.00	14.00	8.00	4.00	2.00	8.16	49.00	5.17	5.40	4.29	1.22	5.16	1.37	28.29	23.46	71.57	119.00	145.98	742.00
46	37.00	17.00	11.00	6.00	3.00	8.47	75.19	3.61	5.60	3.72	0.86	5.09	2.30	36.16	33.18	82.49	125.31	184.05	836.00
47	30.00	10.00	9.00	5.00	4.00	9.16	67.89	3.50	6.00	4.59	0.52	4.19	3.49	32.81	28.16	83.64	102.50	137.47	650.00
48	29.00	19.00	7.00	3.00	3.00	9.27	91.28	4.03	6.00	3.92	1.95	4.68	2.76	42.36	34.16	75.52	127.00	198.24	1147.00
49	28.00	16.00	9.00	4.00	3.00	10.37	90.27	4.00	6.00	3.73	0.39	4.57	2.69	36.51	33.46	79.62	136.80	166.85	941.00
50	34.00	5.00	5.00	4.00	4.00	10.69	70.24	3.63	7.00	4.02	3.19	5.06	2.47	45.86	40.16	76.51	69.00	232.05	680.00
51	28.00	16.00	7.00	5.00	3.00	9.37	92.14	4.50	5.10	3.94	2.66	4.64	3.12	42.25	38.95	77.16	102.60	196.04	1107.00

52	30.00	12.00	9.00	4.00	3.00	9.58	67.12	3.00	5.30	3.78	2.49	4.37	3.77	38.27	45.61	82.14	123.00	167.24	614.00
53	27.00	14.00	7.00	3.00	4.00	10.37	90.27	4.31	6.00	4.25	1.32	5.91	2.94	46.19	42.29	79.62	131.00	272.98	968.00
54	36.00	17.00	8.00	2.00	2.00	11.67	90.08	3.00	6.00	3.97	2.69	4.69	3.29	35.17	31.82	75.21	105.90	164.95	910.00
55	34.00	10.00	9.00	5.00	2.00	11.06	75.21	4.50	5.40	3.94	5.29	4.86	3.36	43.65	41.10	80.16	97.00	212.14	838.00
56	37.00	7.00	4.00	3.00	3.00	10.67	50.16	3.50	5.00	3.78	1.82	4.23	2.18	40.39	37.61	78.31	84.60	170.85	763.00
57	28.00	8.00	7.00	4.00	2.00	10.38	51.29	4.16	5.20	3.66	1.66	4.96	2.35	40.44	35.19	81.24	73.57	200.58	754.00
58	29.00	11.00	9.00	4.00	3.00	9.67	77.29	4.06	9.00	4.06	1.94	7.21	3.49	38.58	40.13	75.26	126.87	278.16	894.00
59	35.00	18.00	8.00	5.00	2.00	8.37	101.24	4.50	4.80	4.17	2.66	3.19	2.88	35.25	30.39	81.26	116.90	112.45	1200.00
60	30.00	9.00	7.00	3.00	4.00	6.79	70.04	3.75	6.00	4.25	2.96	5.16	1.86	42.79	42.58	79.64	129.30	220.80	800.00
61	38.00	6.00	9.00	5.00	4.00	6.50	71.29	3.25	5.00	6.43	1.25	4.19	3.14	43.76	42.36	78.41	109.40	183.35	816.00
62	36.00	12.00	6.00	3.00	3.00	7.16	72.40	3.07	7.00	4.19	3.66	6.12	3.10	46.29	37.58	77.19	163.30	283.29	885.00
63	29.00	9.00	8.00	4.00	2.00	7.24	69.27	4.00	4.80	3.68	4.05	4.12	1.78	42.90	45.19	80.13	94.50	176.75	669.00
64	27.00	8.00	9.00	3.00	2.00	7.29	75.26	3.50	6.00	4.29	3.94	5.46	3.36	40.66	39.85	85.17	89.00	222.00	762.00
65	36.00	26.00	11.00	6.00	3.00	7.05	73.19	5.12	6.80	3.85	3.67	5.86	2.96	44.58	40.18	84.12	127.20	261.24	801.00
66	37.00	7.00	7.00	2.00	3.00	7.19	67.19	4.16	5.10	4.14	3.92	4.68	3.26	45.19	43.67	80.34	104.90	211.49	643.00
67	38.00	7.00	8.00	4.00	3.00	7.06	90.04	2.50	5.80	3.92	4.27	5.39	3.39	45.48	38.67	84.52	73.57	245.14	906.00
68	29.00	6.00	9.00	4.00	2.00	7.17	74.29	4.50	5.40	4.32	4.38	4.29	2.57	33.86	30.65	82.63	109.00	145.26	822.00
69	38.00	8.00	8.00	5.00	2.00	8.29	91.27	4.30	4.60	4.21	3.05	4.16	3.44	43.19	38.73	77.19	121.00	179.67	1164.00
70	31.00	14.00	6.00	3.00	2.00	8.50	89.27	4.00	5.00	4.38	4.23	4.23	3.30	42.86	39.28	78.64	133.00	181.30	901.00
71	37.00	8.00	7.00	4.00	4.00	7.39	91.29	5.00	4.80	4.29	1.95	3.47	3.96	53.41	39.09	80.13	119.60	185.33	1089.00
72	38.00	12.00	6.00	3.00	4.00	8.16	77.26	3.12	5.20	4.30	1.26	4.96	4.28	45.19	38.76	84.19	91.63	224.14	890.00
73	30.00	5.00	8.00	4.00	5.00	9.21	52.99	3.21	5.40	3.95	5.26	5.07	3.76	47.07	38.89	76.24	80.75	238.64	770.00
74	29.00	13.00	9.00	5.00	4.00	10.38	70.29	4.50	7.00	4.02	2.51	6.29	2.94	38.16	35.62	75.14	106.30	240.03	801.00
75	37.00	6.00	8.00	4.00	3.00	11.09	51.16	4.19	6.12	3.94	1.82	5.92	2.73	41.71	40.03	79.16	123.70	246.92	763.00
76	25.00	12.00	11.00	7.00	2.00	12.07	72.89	3.50	4.80	4.38	1.86	4.26	2.31	41.15	40.89	81.42	119.30	175.30	792.00
77	38.00	18.00	7.00	5.00	2.00	9.38	69.27	5.50	7.00	4.12	1.58	6.12	2.71	35.46	33.14	83.41	125.13	217.02	698.00

78	37.00	8.00	8.00	4.00	2.00	8.29	76.29	4.00	5.00	4.29	2.54	4.87	2.76	38.29	34.77	77.24	106.40	186.47	885.00
79	27.00	12.00	7.00	3.00	3.00	10.96	89.94	4.50	6.10	3.96	4.09	5.19	2.68	58.52	44.30	73.45	98.60	303.72	991.00
80	36.00	5.00	5.00	3.00	3.00	10.37	77.29	5.20	5.00	3.87	4.26	4.17	2.25	36.49	35.26	86.31	115.70	152.16	852.00
81	28.00	9.00	6.00	4.00	2.00	9.26	67.16	6.00	5.00	3.25	4.12	4.06	3.38	47.39	42.28	78.41	128.60	192.40	674.00
82	29.00	7.00	7.00	3.00	2.00	9.78	74.29	4.00	8.00	4.09	2.65	7.13	4.03	36.25	34.25	63.52	121.65	258.46	719.00
83	35.00	13.00	8.00	4.00	4.00	8.19	74.39	4.50	5.80	4.04	3.92	4.69	3.64	47.15	39.75	73.46	127.80	221.13	768.00
84	34.00	14.00	9.00	5.00	2.00	8.27	88.29	3.21	5.40	4.73	3.05	5.06	4.67	42.19	38.64	74.19	142.30	213.48	904.00
85	37.00	17.00	7.00	4.00	2.00	10.65	69.21	3.00	5.20	3.97	2.85	5.17	2.89	41.87	35.79	71.21	107.00	216.47	693.00
86	28.00	8.00	8.00	3.00	3.00	10.38	65.19	4.36	6.00	4.29	3.76	5.83	3.81	43.10	37.36	70.28	85.00	251.27	640.00
87	29.00	10.00	9.00	3.00	3.00	10.76	68.59	5.00	6.00	4.52	2.05	5.27	2.94	49.41	36.07	74.23	132.10	260.39	684.00
88	38.00	9.00	7.00	4.00	4.00	11.06	89.14	4.00	5.20	4.24	4.05	4.86	2.95	47.89	42.35	76.31	97.13	232.75	955.00
89	27.00	12.00	6.00	5.00	2.00	11.45	75.29	4.50	5.30	4.56	1.92	4.79	3.47	45.16	44.37	77.29	80.75	216.32	745.00
90	36.00	13.00	7.00	5.00	4.00	10.87	75.83	4.50	5.00	4.90	2.56	4.29	3.66	43.69	42.25	81.26	127.00	187.43	789.00
91	35.00	22.00	9.00	4.00	4.00	9.68	91.28	4.50	4.20	4.16	2.48	4.18	1.91	38.46	31.26	80.17	126.20	160.76	1032.00
92	37.00	8.00	10.00	6.00	3.00	9.89	73.21	3.00	5.80	4.69	2.13	4.13	2.70	32.29	28.27	82.26	118.60	133.36	721.00
93	30.00	10.00	12.00	7.00	3.00	8.06	91.57	5.00	6.30	4.21	1.89	5.19	3.26	42.04	36.82	81.36	129.00	218.19	1054.00
94	34.00	11.00	9.00	6.00	2.00	6.19	75.76	4.31	4.90	4.36	1.04	4.08	3.95	36.81	33.92	74.36	101.30	150.18	781.00
95	33.00	13.00	5.00	4.00	2.00	6.89	73.54	5.16	4.40	4.00	3.72	4.17	3.79	41.45	38.68	81.57	95.80	172.85	705.00
96	32.00	12.00	6.00	3.00	1.00	7.29	69.28	5.66	6.00	4.29	2.16	5.17	2.73	25.92	26.94	82.19	106.80	134.01	691.00
97	34.00	10.00	8.00	3.00	2.00	7.28	91.28	4.00	6.20	4.43	2.54	5.29	2.27	43.69	37.19	84.36	113.10	231.12	1076.00
98	28.00	13.00	7.00	5.00	4.00	10.06	92.26	3.50	6.20	3.68	2.31	5.24	2.47	40.69	37.52	74.31	111.80	213.22	1124.00
99	32.00	13.00	6.00	3.00	4.00	9.28	74.29	3.50	5.40	4.38	4.07	4.87	2.77	43.28	40.10	71.36	96.00	210.77	863.00
100	36.00	8.00	11.00	7.00	3.00	10.39	87.49	4.16	5.30	3.26	4.18	4.68	1.69	49.05	41.90	71.58	105.70	229.55	920.00
101	35.00	5.00	5.00	3.00	3.00	11.07	75.25	4.50	6.00	3.84	1.54	5.29	2.18	40.56	43.32	77.46	96.80	214.56	743.00
102	31.00	8.00	9.00	4.00	2.00	10.67	90.06	4.91	6.40	4.14	1.32	5.68	2.78	45.50	37.94	79.63	117.60	258.44	972.00
103	36.00	14.00	10.00	6.00	2.00	10.51	75.29	3.16	7.00	4.29	2.44	6.39	3.33	37.76	34.01	78.00	107.50	241.29	873.00

104	35.00	11.00	9.00	5.00	4.00	10.06	69.28	3.50	6.00	4.45	1.23	5.78	3.06	41.54	40.89	79.16	93.60	240.10	692.00
105	34.00	14.00	8.00	4.00	4.00	11.69	72.46	4.30	6.30	4.72	1.83	6.06	3.59	48.66	37.05	77.19	92.50	294.88	841.00
106	37.00	10.00	9.00	4.00	3.00	11.07	76.24	4.50	5.60	4.16	2.35	5.19	3.46	55.87	41.38	72.16	97.00	289.97	793.00
107	34.00	18.00	8.00	5.00	3.00	10.00	67.19	3.00	6.00	4.25	2.66	5.47	3.83	42.34	41.73	74.19	149.00	231.60	662.00
108	35.00	11.00	6.00	3.00	3.00	10.37	74.19	5.00	7.00	3.96	0.78	6.12	4.41	38.48	33.30	78.19	105.60	235.50	896.00
109	36.00	9.00	10.00	6.00	2.00	10.28	91.23	3.50	5.00	3.16	2.26	4.97	4.22	42.90	45.15	77.24	128.20	213.21	932.00
110	32.00	13.00	12.00	7.00	2.00	10.06	73.27	4.12	5.50	4.77	0.89	5.19	3.51	37.84	36.66	76.31	117.60	196.39	720.00
111	34.00	9.00	7.00	3.00	3.00	9.27	65.21	4.00	4.80	3.59	2.03	4.21	2.80	56.37	46.59	74.29	89.00	237.32	602.00
112	33.00	12.00	8.00	4.00	3.00	9.57	69.88	5.26	11.00	4.29	0.79	7.06	3.39	43.28	39.53	74.39	91.63	305.56	697.00
113	33.00	11.00	9.00	3.00	2.00	9.64	77.29	3.15	7.40	4.13	1.38	4.29	3.07	47.37	44.00	81.36	86.60	203.22	784.00
114	31.00	9.00	8.00	4.00	2.00	8.06	90.27	4.50	4.80	2.82	2.07	4.26	3.83	34.69	33.58	82.14	128.20	147.78	900.00
115	30.00	12.00	7.00	3.00	2.00	6.89	68.00	7.00	5.40	6.43	0.95	4.75	3.94	37.38	32.44	84.27	107.90	177.56	663.00
116	35.00	9.00	8.00	4.00	3.00	7.14	76.49	3.50	5.00	4.43	4.09	4.29	2.25	47.05	34.27	79.63	103.80	201.84	796.00
117	32.00	12.00	9.00	3.00	3.00	7.45	76.19	4.00	6.00	4.17	2.45	5.16	3.34	40.13	39.88	74.16	98.60	207.07	889.00
118	34.00	14.00	10.00	5.00	4.00	8.65	91.88	4.00	5.60	4.48	1.08	4.96	3.32	32.11	27.55	78.26	118.90	159.27	1093.00
119	37.00	10.00	13.00	6.00	3.00	8.29	89.97	7.00	6.20	4.65	1.95	6.07	3.65	41.83	38.08	74.96	76.90	253.91	957.00
120	29.00	12.00	9.00	4.00	3.00	8.79	75.19	3.50	5.90	4.29	0.68	4.90	4.27	43.25	32.84	75.64	117.20	211.93	760.00
121	30.00	14.00	7.00	5.00	4.00	6.97	90.27	3.50	5.40	4.28	1.03	4.27	4.20	46.92	38.53	78.34	108.30	200.35	925.00
122	28.00	8.00	6.00	3.00	2.00	7.56	91.08	4.50	5.70	3.71	0.89	5.16	1.63	38.85	34.81	77.27	129.40	200.47	1096.00
123	34.00	5.00	8.00	2.00	3.00	7.29	90.67	3.50	6.00	4.43	1.94	5.04	3.45	36.68	35.72	81.63	130.20	184.87	981.00
124	29.00	13.00	9.00	6.00	2.00	7.45	76.49	4.50	4.90	4.87	1.84	4.21	3.59	25.43	21.43	82.64	107.20	107.06	796.00
125	31.00	16.00	5.00	4.00	3.00	7.19	72.28	3.00	4.80	4.27	1.68	4.60	2.98	42.03	35.13	79.16	129.20	193.34	861.00
126	31.00	12.00	7.00	6.00	3.00	7.26	75.46	3.00	5.00	3.52	2.93	4.27	3.94	36.44	32.84	80.16	88.00	155.60	754.00
127	28.00	14.00	8.00	3.00	4.00	8.29	76.02	4.50	6.30	3.73	4.07	5.16	2.58	42.18	38.78	81.37	106.00	217.65	884.00
128	29.00	8.00	6.00	3.00	2.00	9.16	95.16	3.06	5.60	3.79	3.88	5.19	4.10	47.96	40.17	77.68	104.60	248.91	1282.00
129	27.00	11.00	9.00	3.00	2.00	5.14	76.29	3.50	4.60	4.09	1.89	4.06	4.44	47.31	42.15	72.68	117.00	192.08	886.00

130	28.00	14.00	6.00	3.00	4.00	6.79	90.54	4.50	7.00	3.15	1.65	6.29	2.61	38.97	35.34	73.64	127.00	245.12	901.00
131	35.00	5.00	7.00	4.00	3.00	8.16	72.46	5.00	5.00	4.87	0.79	4.36	2.62	41.80	40.71	77.46	119.00	182.25	826.00
132	33.00	9.00	9.00	5.00	3.00	8.29	72.16	4.00	6.80	5.16	1.88	5.74	3.24	37.54	30.30	75.81	107.50	215.48	739.00
133	29.00	5.00	8.00	4.00	4.00	8.19	74.94	4.00	7.00	3.68	1.65	6.27	3.41	33.56	28.96	80.24	130.27	210.42	872.00
134	32.00	8.00	9.00	5.00	2.00	8.74	69.79	3.50	5.40	3.92	1.84	5.12	4.05	39.73	35.66	81.47	116.50	203.42	693.00
135	27.00	10.00	6.00	3.00	3.00	7.69	90.13	4.50	6.20	4.22	1.89	6.34	3.90	46.49	40.02	79.61	119.20	294.75	1058.00
136	28.00	11.00	5.00	3.00	3.00	7.88	74.27	3.50	5.40	3.96	2.52	5.27	2.95	37.44	35.12	74.36	115.50	197.31	845.00
137	29.00	11.00	7.00	4.00	2.00	7.65	90.21	3.50	6.20	3.96	3.67	6.13	2.69	46.21	44.46	76.39	94.60	283.27	977.00
138	35.00	9.00	8.00	5.00	2.00	8.93	69.89	4.00	9.00	4.10	3.09	7.06	3.24	43.32	44.46	78.53	92.13	305.84	699.00
139	34.00	14.00	9.00	6.00	3.00	10.29	75.19	4.00	5.00	3.60	4.12	4.68	3.49	53.41	44.51	80.44	104.00	249.96	797.00
140	28.00	12.00	6.00	5.00	3.00	11.03	75.19	4.00	5.00	4.12	4.06	4.23	3.44	41.97	38.00	79.66	85.00	177.53	834.00
141	30.00	13.00	4.00	3.00	4.00	10.59	78.16	4.50	5.60	3.85	3.85	4.76	3.38	31.21	28.48	79.62	114.00	148.56	794.00
142	29.00	10.00	6.00	3.00	4.00	9.76	91.56	3.16	7.00	3.94	2.54	6.21	2.64	36.52	30.74	81.32	123.00	226.79	963.00
143	34.00	17.00	5.00	4.00	3.00	8.46	70.06	4.00	6.60	3.76	2.87	6.13	2.60	40.65	35.04	82.34	110.40	249.18	700.00
144	28.00	8.00	7.00	5.00	3.00	8.79	68.78	5.13	5.20	4.46	3.14	4.23	2.05	35.79	28.13	85.17	117.80	151.39	609.00
145	30.00	10.00	9.00	4.00	3.00	9.17	74.19	4.16	5.80	4.12	3.54	3.64	2.83	29.84	28.58	75.16	120.00	108.62	748.00
146	27.00	9.00	10.00	6.00	2.00	9.06	75.39	4.50	6.00	4.29	4.08	4.67	2.48	43.69	40.26	74.63	103.00	204.03	835.00
147	31.00	8.00	7.00	3.00	2.00	8.46	67.29	3.49	4.40	4.39	1.76	4.42	2.74	30.34	22.98	73.41	99.20	134.10	639.00
148	32.00	6.00	9.00	5.00	2.00	8.17	73.94	3.06	5.00	4.19	1.08	3.67	2.68	25.85	21.43	82.65	104.00	94.87	765.00
149	29.00	5.00	8.00	7.00	4.00	9.06	76.19	4.29	5.40	4.44	0.93	4.67	3.63	27.03	25.34	76.33	86.90	126.23	833.00
150	33.00	11.00	6.00	5.00	3.00	11.02	75.93	5.29	4.20	4.46	3.20	3.75	2.37	36.44	32.84	77.85	110.40	136.65	793.00
151	28.00	10.00	5.00	4.00	3.00	10.75	91.68	4.50	4.80	4.35	2.98	3.45	3.60	43.36	39.60	74.25	112.80	149.59	929.00
152	29.00	9.00	7.00	3.00	3.00	11.09	67.50	3.16	5.40	3.87	2.65	4.16	2.66	42.22	38.40	81.48	107.60	175.64	628.00
153	30.00	3.00	8.00	5.00	4.00	9.36	74.01	4.06	5.10	5.16	3.26	4.42	3.11	43.91	38.17	80.39	124.20	194.08	769.00
154	34.00	8.00	7.00	3.00	4.00	9.78	77.19	3.19	4.60	5.06	2.43	4.53	3.36	37.54	30.36	74.36	116.90	170.06	876.00
155	35.00	12.00	6.00	4.00	5.00	8.46	92.17	4.50	6.20	5.17	4.07	4.65	1.22	33.56	28.96	79.64	115.20	156.05	1120.00

156	36.00	11.00	8.00	4.00	3.00	8.06	72.19	5.01	5.20	3.93	4.29	3.75	1.30	39.47	35.76	81.34	111.80	148.01	716.00
157	32.00	5.00	9.00	5.00	3.00	8.47	75.98	4.29	7.00	4.09	2.17	4.47	3.10	40.81	34.92	76.38	98.60	182.42	824.00
158	33.00	10.00	11.00	6.00	2.00	8.64	92.07	4.67	5.00	4.07	2.73	4.73	4.51	44.30	37.32	82.47	97.00	209.54	982.00
159	35.00	14.00	8.00	4.00	4.00	10.38	73.95	3.29	5.20	4.63	3.41	5.06	3.30	40.95	34.56	85.26	112.00	207.21	736.00
160	34.00	3.00	6.00	4.00	2.00	11.06	92.38	3.56	6.30	4.19	3.72	5.16	3.55	34.65	30.11	76.84	120.60	178.79	962.00
161	30.00	11.00	7.00	5.00	3.00	10.38	78.26	4.51	6.00	4.10	4.15	4.66	4.13	31.56	28.93	71.57	89.50	147.07	858.00
162	30.00	16.00	4.00	3.00	3.00	9.64	66.28	5.26	5.60	4.16	4.00	5.09	3.80	42.39	40.84	76.32	105.10	215.77	629.00
163	29.00	14.00	5.00	3.00	3.00	9.37	72.99	4.29	4.80	3.92	4.21	4.82	4.63	38.93	39.33	78.69	116.00	187.64	750.00
164	29.00	10.00	9.00	4.00	3.00	8.64	95.86	4.19	5.80	4.23	2.17	6.23	3.81	43.15	38.60	82.64	86.90	268.82	1293.00
165	30.00	11.00	7.00	5.00	3.00	8.16	90.03	5.06	5.20	5.03	1.09	5.14	3.35	40.24	35.28	80.16	95.60	206.83	1053.00
166	31.00	9.00	6.00	3.00	4.00	7.16	69.24	4.50	5.80	3.69	1.21	5.22	3.43	42.38	33.69	79.64	127.50	221.22	691.00
167	34.00	3.00	4.00	2.00	2.00	7.34	79.69	3.50	5.40	4.24	2.23	4.74	4.50	45.12	38.94	77.41	124.00	213.87	883.00
168	29.00	17.00	5.00	3.00	2.00	7.39	94.99	3.50	5.70	4.85	1.11	4.81	4.45	36.29	29.45	76.81	92.65	174.55	1214.00
169	27.00	9.00	6.00	3.00	3.00	8.13	74.99	5.00	5.20	5.19	2.45	4.27	3.07	29.68	26.45	77.68	85.75	126.73	815.00
170	29.00	12.00	8.00	4.00	3.00	9.06	75.96	4.00	6.80	5.06	2.76	6.06	3.69	31.67	30.55	82.94	68.92	191.92	826.00
171	28.00	7.00	9.00	4.00	3.00	9.08	76.69	4.00	6.00	4.91	2.65	4.72	2.70	42.40	35.55	83.16	74.75	200.13	791.00
172	29.00	9.00	11.00	6.00	3.00	10.37	91.06	7.06	7.00	4.93	4.13	4.82	2.12	39.62	34.30	73.38	90.75	190.97	950.00
173	33.00	10.00	8.00	5.00	4.00	11.09	77.16	4.50	7.20	3.76	3.65	6.13	2.65	37.99	33.46	77.32	115.50	232.88	863.00
174	30.00	9.00	6.00	4.00	4.00	12.67	90.06	5.00	9.00	4.20	3.30	5.80	3.53	35.21	35.61	77.48	106.30	204.22	927.00
175	28.00	11.00	9.00	5.00	3.00	10.46	69.86	6.12	8.10	4.68	2.82	5.26	3.96	41.18	42.50	82.64	112.30	216.61	694.00
176	31.00	20.00	7.00	3.00	3.00	9.47	77.29	5.12	5.60	3.97	1.74	5.67	4.34	55.86	42.59	81.43	97.00	316.73	824.00
177	29.00	5.00	6.00	2.00	2.00	6.76	67.16	4.53	9.00	4.16	2.22	5.91	2.74	45.50	38.85	82.54	118.60	268.91	633.00
178	28.00	6.00	8.00	4.00	4.00	7.83	72.19	4.50	5.00	4.07	4.13	5.76	2.56	42.03	37.79	76.38	103.60	242.09	712.00
179	27.00	21.00	5.00	3.00	4.00	8.56	77.93	3.91	5.60	4.59	4.05	5.37	3.03	39.42	33.70	79.68	111.75	211.69	868.00
180	34.00	12.00	7.00	5.00	3.00	9.46	73.26	4.13	4.80	3.38	2.17	4.87	3.23	31.92	33.76	81.87	96.80	155.45	760.00
181	33.00	8.00	9.00	4.00	2.00	9.79	92.07	4.50	6.30	4.19	4.17	4.19	3.54	44.94	43.54	76.38	85.00	188.30	1116.00

182	27.00	8.00	6.00	3.00	2.00	10.23	91.74	4.00	6.00	4.63	3.00	4.67	3.26	34.01	30.73	77.89	109.40	158.83	956.00
183	28.00	17.00	5.00	4.00	3.00	10.76	72.66	3.19	4.60	4.26	3.06	4.38	2.87	34.24	31.86	84.52	93.50	149.97	717.00
184	30.00	12.00	8.00	3.00	3.00	10.85	77.06	3.50	5.00	4.36	3.69	5.26	2.73	27.30	26.89	81.26	120.90	143.60	850.00
185	28.00	7.00	9.00	5.00	3.00	10.06	65.99	4.19	5.30	4.52	3.89	4.70	4.25	46.12	40.44	84.19	85.69	216.76	626.00
186	28.00	13.00	5.00	3.00	4.00	11.29	90.00	5.00	6.00	5.16	1.91	6.28	2.94	43.15	39.22	72.48	82.34	270.98	900.00
187	30.00	10.00	6.00	4.00	4.00	11.07	59.50	4.50	5.40	5.29	3.57	5.91	1.78	39.33	41.75	81.49	79.89	232.44	456.00
188	29.00	18.00	4.00	3.00	3.00	10.75	75.29	4.50	4.80	4.75	3.64	5.15	4.70	38.24	36.15	83.67	90.17	196.94	809.00
189	28.00	10.00	7.00	5.00	2.00	7.29	71.99	3.50	5.40	4.19	4.27	6.16	3.53	43.92	34.99	83.95	86.29	270.55	708.00
190	31.00	10.00	9.00	4.00	2.00	7.28	62.19	3.00	6.00	4.07	4.26	4.57	4.27	40.18	36.44	80.22	103.00	183.62	509.00
191	34.00	7.00	6.00	3.00	2.00	7.06	66.02	5.00	6.40	4.77	4.08	5.35	3.67	43.96	39.66	84.29	116.20	235.19	638.00
192	32.00	5.00	8.00	4.00	3.00	6.19	75.16	7.06	6.60	3.96	4.22	5.66	4.22	44.21	41.26	81.37	96.00	250.23	780.00
193	30.00	12.00	9.00	5.00	3.00	6.29	67.21	5.16	5.00	4.37	3.97	6.07	3.34	41.90	36.97	82.57	87.70	254.33	635.00
194	34.00	7.00	6.00	3.00	4.00	6.54	72.56	4.29	4.80	4.14	4.54	5.47	2.84	33.27	32.66	79.38	117.00	181.99	763.00
195	30.00	10.00	9.00	5.00	3.00	10.29	75.21	4.16	5.40	4.26	4.37	6.14	3.44	38.46	31.66	79.52	107.90	236.14	857.00
196	29.00	9.00	8.00	5.00	4.00	10.34	67.85	3.26	5.00	4.09	4.25	5.82	3.23	33.70	29.20	81.48	86.00	196.13	660.00
197	32.00	12.00	6.00	3.00	4.00	11.47	90.43	4.80	7.00	4.64	1.57	7.25	2.43	32.69	33.31	82.14	119.00	237.00	905.00
198	30.00	16.00	9.00	4.00	3.00	12.09	72.49	5.00	6.80	4.18	6.27	5.47	4.04	32.20	30.74	81.47	98.30	176.13	748.00
199	29.00	7.00	8.00	5.00	2.00	9.26	75.29	6.13	5.20	4.39	3.67	5.74	2.80	39.02	34.71	76.65	95.60	223.97	828.00
200	34.00	9.00	7.00	4.00	2.00	9.08	75.14	5.19	7.20	4.13	4.76	6.07	2.27	31.65	31.44	79.52	89.30	192.12	805.00
201	30.00	6.00	6.00	3.00	3.00	8.16	64.89	4.16	7.00	4.61	2.05	5.87	3.24	35.91	36.62	74.28	96.20	210.79	657.00
202	33.00	9.00	9.00	4.00	3.00	7.89	72.81	4.50	6.00	4.39	2.58	7.24	2.26	33.86	30.65	76.19	100.50	245.15	718.00
203	32.00	6.00	5.00	3.00	4.00	6.65	75.96	4.50	5.00	4.67	1.28	5.49	2.49	42.25	40.19	76.38	112.90	231.95	788.00
204	29.00	5.00	6.00	5.00	5.00	7.29	64.72	3.50	5.40	4.27	1.76	6.17	3.29	44.17	41.11	77.19	96.80	272.53	651.00
205	35.00	7.00	7.00	2.00	4.00	7.45	71.99	3.60	5.00	4.29	2.76	6.42	3.69	43.15	41.67	74.86	98.50	277.02	706.00
206	28.00	9.00	9.00	3.00	3.00	7.68	65.49	3.50	4.00	4.19	1.37	5.17	3.59	40.09	41.00	78.45	106.00	207.27	624.00
207	28.00	13.00	10.00	4.00	3.00	7.39	73.59	5.00	5.00	4.29	1.47	5.83	2.36	31.74	32.29	81.47	94.90	185.04	754.00

208	27.00	10.00	13.00	6.00	3.00	7.41	90.23	4.50	5.50	4.47	2.64	6.17	2.67	33.44	32.28	79.54	114.00	206.32	1060.00
209	29.00	6.00	10.00	5.00	2.00	8.19	90.57	4.00	4.20	3.96	1.45	5.61	2.46	59.08	44.92	77.28	90.60	331.44	935.00
210	32.00	15.00	9.00	4.00	4.00	8.29	76.98	4.00	6.00	4.49	2.68	5.18	2.40	45.79	36.49	81.29	86.70	237.19	889.00
211	33.00	8.00	6.00	3.00	3.00	10.29	72.98	3.00	5.40	4.37	2.75	5.71	2.26	47.41	43.54	82.28	119.00	270.71	720.00
212	30.00	9.00	7.00	3.00	3.00	11.42	70.05	5.16	5.20	6.27	3.04	7.16	3.16	51.65	46.23	76.58	96.30	369.81	694.00
213	35.00	13.00	8.00	4.00	3.00	9.16	74.68	4.00	5.60	6.34	1.75	6.84	3.19	42.20	37.30	74.22	102.60	288.65	765.00
214	36.00	6.00	9.00	4.00	2.00	9.17	76.29	4.50	4.00	5.87	1.89	6.70	4.04	39.92	38.95	81.27	108.20	267.46	889.00
215	29.00	12.00	6.00	3.00	2.00	10.68	71.98	3.75	6.00	4.68	1.46	7.21	4.12	41.86	39.40	76.34	101.70	301.81	712.00
216	36.00	8.00	7.00	5.00	2.00	11.29	76.40	4.29	7.00	4.29	2.27	6.83	3.46	32.96	32.13	75.89	127.50	225.12	811.00
217	35.00	11.00	4.00	3.00	3.00	10.47	75.03	4.00	6.00	3.95	2.67	6.91	3.69	31.07	30.20	82.46	93.70	214.69	780.00
218	34.00	9.00	6.00	3.00	3.00	7.69	73.01	4.50	6.20	4.37	4.05	6.71	2.27	52.86	38.73	79.42	99.60	354.69	736.00
219	27.00	10.00	5.00	4.00	3.00	8.16	76.98	4.50	6.30	4.44	2.69	5.17	2.59	41.86	39.40	81.24	106.10	216.42	889.00
220	26.00	6.00	7.00	3.00	4.00	8.45	66.85	3.50	4.00	3.43	2.17	6.07	2.67	44.51	38.62	80.16	85.90	270.18	612.00
221	34.00	11.00	8.00	5.00	2.00	6.86	75.99	3.00	5.00	3.92	2.49	6.28	2.86	41.90	36.14	77.25	83.60	263.13	856.00
222	32.00	10.00	6.00	4.00	3.00	6.49	68.14	5.16	5.80	4.17	3.07	5.74	2.27	39.60	36.14	80.17	94.00	227.30	644.00
223	30.00	9.00	7.00	4.00	3.00	7.29	52.13	4.27	5.90	4.22	2.89	5.47	2.76	41.24	39.47	75.81	89.50	225.58	568.00
224	35.00	6.00	8.00	5.00	2.00	8.19	53.19	4.50	5.60	4.12	2.47	7.06	2.59	33.04	36.32	76.29	105.60	233.26	579.00
225	29.00	6.00	9.00	4.00	2.00	10.38	66.49	3.50	7.00	3.97	2.79	7.23	2.46	27.64	30.93	79.48	96.30	199.84	652.00
226	29.00	10.00	6.00	3.00	2.00	11.06	72.86	3.00	5.30	3.79	3.14	6.28	3.16	34.69	31.80	81.12	95.20	217.85	716.00
227	31.00	5.00	7.00	4.00	3.00	10.09	75.19	4.00	7.10	3.95	3.07	5.05	3.08	36.55	34.76	84.27	108.50	184.58	863.00
228	32.00	2.00	6.00	4.00	3.00	12.47	67.09	5.16	9.10	4.35	2.89	4.33	2.14	43.06	36.99	82.14	112.70	186.45	638.00
229	27.00	10.00	8.00	5.00	4.00	10.36	66.95	5.00	8.30	4.28	2.74	4.47	2.06	38.11	33.15	79.64	109.80	170.35	617.00
230	34.00	7.00	10.00	6.00	4.00	10.48	73.96	4.50	7.20	4.39	2.69	3.75	2.27	39.64	37.31	76.28	96.70	148.65	776.00
231	30.00	5.00	6.00	2.00	3.00	9.64	74.59	3.50	6.00	4.25	3.17	3.69	2.64	37.40	34.92	74.29	89.50	138.01	816.00
232	33.00	10.00	7.00	3.00	2.00	9.47	66.09	3.50	5.00	3.76	2.61	4.67	3.09	48.76	47.69	81.12	107.40	227.71	637.00
233	35.00	4.00	9.00	7.00	4.00	8.61	91.89	4.16	5.00	3.92	2.57	3.67	2.68	39.94	35.16	80.26	121.50	146.58	964.00

234	34.00	6.00	8.00	5.00	3.00	8.93	66.09	3.00	6.20	4.28	2.47	3.28	2.26	31.68	30.67	75.19	118.60	103.91	637.00
235	30.00	10.00	5.00	3.00	3.00	8.49	72.60	3.50	5.50	4.27	3.19	4.53	2.47	29.92	28.29	76.23	109.50	135.54	728.00
236	35.00	12.00	7.00	4.00	3.00	9.46	90.49	4.87	6.40	4.13	2.74	3.84	2.62	42.59	39.11	74.19	96.00	163.55	916.00
237	34.00	11.00	9.00	5.00	2.00	9.57	57.19	4.50	7.00	4.16	2.94	3.74	2.26	44.72	39.91	80.27	89.30	167.25	596.00
238	30.00	14.00	6.00	3.00	3.00	10.06	90.83	3.26	6.00	4.43	2.18	3.46	2.49	46.24	37.37	71.26	120.60	159.99	1026.00
239	30.00	6.00	5.00	3.00	2.00	7.58	73.96	3.50	5.00	4.29	3.07	4.42	2.60	47.97	46.44	77.16	111.00	212.03	776.00
240	28.00	7.00	4.00	2.00	4.00	8.46	75.99	5.16	5.40	3.96	1.97	4.15	2.27	48.56	41.93	82.46	127.50	201.52	839.00
241	32.00	8.00	11.00	7.00	3.00	8.93	69.85	5.00	8.19	3.78	2.74	3.71	2.46	40.62	41.72	74.29	130.50	150.70	695.00
242	34.00	7.00	10.00	5.00	3.00	9.07	75.19	4.50	9.00	4.62	2.07	3.49	2.57	39.15	37.07	78.24	125.00	136.63	839.00
243	30.00	12.00	8.00	2.00	2.00	10.69	74.99	3.50	4.80	3.92	2.88	3.48	2.69	40.39	41.56	77.15	96.80	140.56	812.00
244	28.00	6.00	6.00	4.00	4.00	10.56	73.04	4.00	6.20	3.65	2.17	4.57	3.02	39.15	37.07	76.68	95.50	178.92	738.00
245	27.00	6.00	9.00	5.00	4.00	8.39	72.99	3.00	7.14	4.31	2.46	3.87	3.29	36.57	34.19	81.45	94.60	141.53	721.00
246	29.00	9.00	6.00	2.00	3.00	10.27	66.59	3.50	5.00	4.19	3.18	4.29	3.17	41.27	39.66	80.74	89.70	177.05	669.00
247	28.00	5.00	9.00	3.00	2.00	9.46	73.93	4.50	5.10	3.95	3.09	4.61	3.29	52.20	56.29	81.63	106.80	240.64	775.00
248	31.00	11.00	8.00	3.00	3.00	9.68	67.02	4.50	6.00	4.14	4.07	3.65	2.25	36.47	32.22	84.29	95.20	133.12	619.00
249	28.00	7.00	5.00	4.00	4.00	10.38	69.01	5.50	6.20	3.97	2.34	3.65	2.70	39.41	35.61	74.61	86.40	143.85	684.00
250	30.00	15.00	10.00	5.00	3.00	9.26	76.29	5.00	6.00	4.06	2.97	3.28	2.30	44.50	38.47	79.28	108.60	145.96	856.00

X1-Days to first flowering, X2- Number of clusters per plant, X3- Number of flowers per cluster, X4- Number of fruits per cluster, X5- Primary branches per plant, X6- Secondary branches per plant, X7- Average fruit weight (g), X8- Number of locules per fruit, X9- Total soluble solids(Brix), X10- pH, X11-Lycopene content(mg/100g), X12- Ascorbic acid content (mg/100g), X13- Pericarp thickness (mm), X14 - fruit width (mm), X15- fruit length (mm), X16 - Pulp content (%), X17- Plant height (cm), X18- number of fruit per plant, X19- fruit yield per plant (g).

Mean performance of checks

IIHR2358	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19
1	30.00	9.00	5.00	3.00	2.00	6.58	78.40	4.50	3.30	5.70	0.40	10.41	4.91	34.71	35.38	76.28	55.50	27.00	1158.00
2	34.00	10.00	6.00	4.00	3.00	6.27	80.70	5.00	3.00	5.10	0.51	10.87	4.78	38.00	34.21	74.29	59.30	40.00	1189.00
3	32.00	12.00	5.00	2.00	2.00	6.00	81.39	3.50	3.62	5.74	0.60	10.93	4.88	30.07	35.26	78.21	57.67	24.00	1029.00
4	33.00	6.00	7.00	5.00	2.00	5.73	79.10	4.50	3.17	5.08	0.82	10.59	4.99	37.03	35.45	72.57	57.19	30.00	1059.00
5	30.00	11.00	5.00	3.00	3.00	5.48	78.06	3.00	3.50	5.40	0.92	10.87	4.95	33.42	35.41	75.19	56.80	33.00	1009.00
Mean	31.80	9.60	5.60	3.40	2.40	6.01	79.53	4.10	3.32	5.40	0.65	10.73	4.90	34.61	35.17	75.30	57.30	32.64	1088.80

Australian Red	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19
1	24.00	11.00	13.00	11.00	3.00	9.07	10.40	2.50	4.50	4.37	2.37	5.41	1.28	5.35	6.44	81.45	105.30	121.00	600.00
2	25.00	13.00	12.00	10.00	4.00	10.38	9.70	2.00	4.69	4.64	2.56	5.10	1.06	5.15	7.55	80.74	96.20	150.00	774.00
3	27.00	15.00	14.00	9.00	3.00	10.56	8.60	3.50	4.27	5.12	2.41	4.78	1.04	5.70	8.75	81.63	89.00	155.06	624.00
4	23.00	19.00	18.00	15.00	2.00	9.39	8.50	3.00	4.89	4.59	2.47	4.95	0.97	4.21	5.90	84.29	97.00	154.00	720.00
5	26.00	14.00	12.00	8.00	3.00	11.02	11.30	1.50	4.07	4.17	2.39	5.09	1.09	5.35	6.96	82.17	112.40	112.00	619.00
Mean	25.00	14.40	13.80	10.60	3.00	10.08	9.70	2.50	4.48	4.57	2.44	5.06	1.08	5.15	7.12	72.05	105.00	152.64	667.40

X1- Days to first flowering, X2- Number of clusters per plant, X3- Number of flowers per cluster, X4- Number of fruits per cluster, X5- Primary branches per plant, X6- Secondary branches per plant, X7- Average fruit weight (g), X8- Number of locules per fruit, X9- Total soluble solids(Brix), X10- pH, X11- Lycopene content(mg/100g), X12- Ascorbic acid content (mg/100g), X13- Pericarp thickness (mm), X14 - fruit width (mm), X15- fruit length (mm), X16 - Pulp content (%), X17- Plant height (cm), X18- number of fruit per plant, X19- fruit yield per plant (g).