Genetic studies of litchi (*Litchi chinensis* Sonn.) germplasm

THESIS

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In partial fulfilment of the requirements for the Degree of

Doctor of Philosophy

In

HORTICULTURE
(FRUIT SCIENCE)

By

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This is to certify that the thesis entitled **"Genetic studies of litchi (*Litchi chinensis* Sonn.) germplasm"** *submitted in partial fulfilment of the requirement for the degree of "**DOCTOR OF PHILOSOPHY** in **HORTICULTURE** (**FRUIT SCIENCE**) of the Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur is a record of the bonafide research work carried out by* **Mr. Narayan Lal** *under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instruction.*

All the assistance and help received during the course of investigation has been dulyacknowledged by him.

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Publication of Research Paper from Ph.D. thesis work

This is to certify that Mr. Narayan Lal, Ph.D. scholar of the Department of Horticulture - Fruit science submitted the thesis entitled**″ Genetic studies of litchi (*Litchi chinensis* Sonn.) germplasm"** on 16.06.2018 has published the following two research papers(at least one published and one accepted with proof of acceptance) from theresearch work conducted for Ph.D. thesis.

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Symbol Abbreviation	Stand for
A	: Absorbance
$AlCl_3$	: Aluminium chloride
^0B	: Brix
BC	: Before Christ
cv.	: Cultivar
cvs.	: Cultivars
CV	: Coefficient of Variance
Coll.	: Collector Number
CD	: Critical difference
cm	: Centimetre
CE	: Catechin equivalent
CC	: Cubic Centimetre
DNS	: Dinitro-salicylic acid
DMSO	: Dimethyl Sulphoxide
FW	: Fresh weight
g	: Gram
g^{-1}	: Per gram
GAE	: Gallic acid equivalent
ha	: Hectare
H_2SO_4	: Sulfuric acid
HCl	: Hydrochloric acid
IPGRI	: International Plant Genetic Resources Institute

IC	: Indigenous Collection
kg	: Kilogram
FW	: Fresh Weight
DW	: Dry Weight
mg	: Milligram
ml	: Milliliter
/	: Per
%	: Per cent
NaOH	: Sodium hydroxide
No.	: Number
i.e.	: That is
TSS	: Total soluble solids
LFP	: Litchi Fruit Pericarp
dm^{-2}	: Square per decimeter
SD	: Standard Deviation
N	: North
nm	: Nano meter
Na_2CO_3	: Sodium Carbonate
E	: East
N	: Normality
M	: Molarity
Vit-C	: Vitamin -C
UPGMA	: Unweighted Pair Group Method with Arithmetic Mean
viz.	: Namely

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CHAPTER I
INTRODUCTION

INTRODUCTION

The first reference to litchi fruit in literature was found in 1766 B.C. (Hayes 1953). Litchi (*Litchi chinensis* Sonn.) is one of the most popular subtropical fruit of the family Sapindaceae. Litchi falls under sub-family Nepheleae which has about 150 genera and more than 2000 species (Lal 2017). The litchi originated in southern China, possibly northern Vietnam and seems to have been domesticated since 1500 B.C., by the Malayan descent where it has been cultivated for more than 2,300 years (Li 2008). Then, it spread to other parts of the tropical and subtropical world (Goto 1960; Liang 1981). It reached Burma by the end of 17th century and was introduced in India about 100 years later. In India, litchi was first introduced in Bengal and then spread to Bihar and sub-mountaineous districts of Uttar Pradesh in 19th century (Pandey and Sharma 1989). The major litchi producing states in India are Bihar, Uttarakhand, West Bengal, Punjab, Uttar Pradesh, Jharkhand and Tripura (East and Central). Interestingly the possibilities of production of litchi during December–January in non traditional area of the southern India has been recently explored which can make its fruit available during off season. The foothills of the Himalayas, *i.e.* Tarai belt, free from frost, offer good scope for plantation of litchi. India is the second largest producer of litchi next to China with annual production of 583.4 thousand tons from 92.1 thousand hectares area. However, its productivity is 6.3 metric tons/ha (Anon 2017) which is much lower than the average national productivity.

The litchi is one of the most environmentally sensitive fruit tree. It is adapted to the tropics and warm sub-tropics between 13° to 32° N and 6° to 29° S. It grows best in regions having short, dry and cool but frost free winter with temperature around 15 °C or lower for successful flowering. It cannot withstand long, hot and dry summer, probably due to this reason its cultivation is restricted to few countries

in the world. Litchi occupies special position due to its high nutritive value. The average sugar content of the fruit is 11.85 per cent, out of which more than 80 per cent is reducing sugar and 18 per cent is sucrose, 0.8 to 0.9 per cent protein, 0.42 per cent pectin, 0.03 per cent fat and a bountiful of minerals, specially calcium, phosphorus and iron with a total acidity of 0.3 to 0.6 per cent and high vitamin C (mg/100 g) content ranging from 40.2 to 90.0 (Misra 2011).The physico-chemical composition which changes during the maturation determines the quality of the fruit. Under Indian condition, the range of sugar content in the fruits varies from 6.74 to 18.0 per cent (Singh and Singh1954).

Recently, there has been increased interest on phenolic compound and flavonoids in litchi because of their significant bioactivities, such as scavenging free radiclals, chelating metals, regulating enzyme activity and modulating cell proliferation. Litchi contains high amount of phenolic compounds in all parts of the plant including fruits. Health benefits of phenolic compounds including anti carcinogenic, antithrombotic and vasodilatory activities have been reported (Wang *et al.,* 2006; Cook and Samman1996). Litchi fruit is a rich source of natural phenolic compounds (Brat *et al*., 2006). The pericarp (Li and Jiang 2007; Sarni-Manchado *et al.,* 2000; Zhao *et al.,* 2007), pulp (Zhang *et al.,* 2013), seed (Prasad *et al*., 2009; Xu *et al*., 2010) and flower (Chang *et al*., 2013) of litchi contain significant amounts of phenolic compounds. Litchi pericarp is a good source of anthocyanin which impart red colour in litchi. In spite of various litchi cultivars grown in different regions of the world, only few reports on the bioactive content and anthocyanin characteristics of litchi cultivars are available in the literature (Hasegawa *et al.,* 2010; Pande and Akoh 2010; Polat *et al.*, 2010; Xu and Chen 2011) and information regarding differences among cultivars under Indian condition is limited. Thus, more information is needed to quantify phenolic compounds of this fruit that may provide important information to the consumer in terms of recognizing a more nutritious fruit. Such data

will also assist in the cultivar selection for commercial production to meet market demand.

Selection of superior litchi seedlings began more than 1000 years ago. Thirty two litchi cultivars were already described in a compendium of litchi published in 1059 in Fujian, China (Groff 1921). In India and abroad, litchi cultivar nomenclature is confusing with presence of homonyms and synonyms. The confusion emanates due to derivation by translation from Cantonese and Mandarin to English. This has been identified as one of the main bottlenecks for germplasm exchange and its management among different producing countries (Viruel and Hormaza 2004; Madhou *et al.,* 2013).Till date, there is widespread confusion over the identities of litchi cultivars (Batten 1984; Cavaletto 1980; Galan-Sauco and Menini 1989; Goren *et al.,* 2001; Menzel and Simpson 1990; Zee *et al.,* 1998). This confusion is very common in India. In different localities of India, the same cultivars may have different name and different cultivars may have the same name (Anon 1990; Zhang *et al.,* 1997). A part of confusion is the result of simple misidentification.

Considering the importance of litchi, Government of India has established ICAR-National Research Centre on Litchi at Muzaffarpur, Bihar to provide technological support and promote litchi production in the country and to solve the arising problems in litchi identification, germplasm resource management, cultivation practices and improved marketing including export. Information regarding the morphological, physico-chemical and bio chemical characterization of litchi cultivars grown under different regions of the India are scanty. So, characterization is an important aspect for documenting the performance of the germplasm which subsequently will help in the introduction, selection and improvement of the existing litchi cultivars. Such study will generate useful information for the scientist and growers in selecting the right cultivars to be grown. Germplasm characterization is an important component of litchi improvement and breeding programme. It lays the foundation for further scientific

progress in developing new cultivars and in reducing the genetic redundancies. Therefore, it is imperative to analyse and compare morphological, physico-chemical and bio-chemical characteristics of litchi germplasm. Keeping in view the above factors under consideration, the proposed study entitled “Genetic studies of litchi germplasm” was focused on the characterization of different litchi germplasm with the following objectives:

1. To characterize the litchi genotypes
2. To determine the extent of variation in litchi genotypes
3. To estimate the correlation coefficient between yield and its component

CHAPTER II
REVIEW OF LITERATURE

REVIEW OF LITERATURE

Litchi (*Litchi chinensis* Sonn.) is an important subtropical evergreen fruit crop with tremendous export potential and plays a significant role in our national economy. The demand of litchi is increasing in domestic as well as international market. But its cultivation is restricted in some pockets in India because of its specific climatic requirement. Irregular flowering and shy bearing in some cultivars, poor fruit set, heavy fruit drop, poor fruit retention, sun burning, fruit cracking, small fruit size and highly perishable nature are some of the major problems hampering commercial litchi production. Germplasm available in India are mainly of seedling origin. Varietal characterization is an important component in improving and developing new cultivars of litchi. Although litchi is the most important fruit crop of Bihar but morphological, physico-chemical and bio-chemical characterization of litchi has not been up to the mark. The review of relevant research work pertaining to the study carried out on vegetative characters, flowering, fruiting, physicochemical and biochemical compound in litchi has been documented in this chapter under the following heads/sub-heads:

2.1 Tree Character

2. 2 Leaf Character

2.3 Flowering Character

2.4 Fruit Character

2.5 Seed Character

2.6 Physiological and Biochemical Character

2.1 Tree Character

Various observations on tree characters *viz.*, height, trunk girth, tree volume, crown diameter, crown shape, trunk surface, tree

growth habit, branching pattern, branching density and young shoot pubescence were recorded and analyzed by several workers.

The various studies have indicated significant differences in height among litchi cultivars (Miao *et al.,* 1998; Rai *et al*., 2001). Khurshid *et al.* (2004) recorded maximum canopy spread in Bedana cultivar (9.85 m) and minimum tree width in Bombay cultivar (6.40 m) followed by Calcuttia (6.86 m) and Gola cultivar (6.71 m). Bombay and Bedana cultivars had round, dense and symmetrical canopy while Gola had round, less dense, less symmetrical canopy and Calcuttia had round, less dense and non-symmetrical canopy. Rai *et al.* (2001) have also reported genetic variation in 13 litchi cultivars for various traits including tree spread and volume. According to Nakasone and Paull (1998), litchi trees may be broad with low hanging branches or have upright branches and a compact, rounded head, depending upon cultivars.

Chavaradar (2016) studied morpho-physiological characterization of litchi (*Litchi chinensis* Sonn.) on different collection maintained at Wayanad and found the height of the trees ranged from 3.00 m to 19.00 m and displayed 57.87 per cent of CV. The Co-efficient of variation of 74.1 per cent was observed in tree trunk girth and it ranged from 28.00 cm to 54.00 cm. The height as well as girth of the tree is positively influenced by the age of the plant. According to Singh *et al.* (2012) well-managed orchard will be commercially productive for a period of 50 years. Different crown shapes *viz.,* pyramidal, broadly pyramidal, spherical, oblong, semi-circular, elliptical and irregular shapes were noticed among the collections. However, most prominent among these includes semi-circular (34.37 %) followed by oblong (31.25 %), spherical (25.12 %), irregular (3.12 %) and broadly pyramidal shape (3.12 %). The crown structure of a tree solely depends on branching pattern and crotch angles. Different branching patterns *viz.,* erect, opposite, verticillate, horizontal, and irregular were noticed among the collections with maximum tree possessing verticillate branching (65.62%) followed by

horizontal type (15.62 %), irregular type (15.62 %) and erect type (3. 12 %).

Hossain *et al.* (2017) observed the performance of seven litchi cultivars and found that Rajshahi Local/BARI Lichu-1 had the maximum tree height (12.12 m) and trunk circumference (278 cm) while BARI Lichu-4 had the minimum tree height (5.50 m) and BARI Lichu-3 had the minimum trunk circumference (82 cm). Crown diameter and tree volume were also maximum (16.56 m and 979.25 m^3) in Rajshahi Local/BARI Lichu-1 and minimum (7.30 m and 99.70 m^3) in BARI Lichu-3.Trunk surface was rough in all the genotypes except BARI Lichu-2, which possesses smooth trunk surface. Rajshahi Local/BARI Lichu-1 had irregular crown shape as against semi-circular crown shape in other genotypes. Tree growth habit was semi-erect in all genotypes excepting Mongalbari and Bedana that was erect. Branching was dense in four genotypes and medium dense in the remaining three genotypes while it was irregular in all the genotypes.

2.2 Leaf Character

Various observations on leaf characters *viz.*, young and mature leaf colour, arrangement of leaflet, leaflet shape, leaflet blade apex and base shape, leaflet upper and lower surface pubescence, leaflet midrib and venation appearance, leaflet curvature, protuberance, number of leaflet, rachis and petiole length, leaflet blade length and width were recorded and analysed. The foliage colour and leaf shape is genetic traits which are also being used for identification of cultivars (Singh *et al.,* 1999).

Khurshid *et al.* (2004) found that Gola and Bedana cultivars had light-green to green foliage colour, while Calcuttia had light green and Bombay had dark green foliage. The maximum leaf length has been recorded in Bombay cultivar (15.80 cm), followed by Calcuttia cultivar (14.90 cm) while minimum leaf length was observed in Bedana (11.80 cm) and Gola (12.20 cm). However, the maximum leaf

width was reported in Bombay cultivar (5.10 cm) and minimum in Bedana cultivar (3.00 cm). They found that all the cultivars had oval shaped leaves. However, the leaves of Gola cultivar were moderately shiny and slightly wavy while Bombay cultivar had shiny and wavy with leaves curving upward whereas Bedana cultivar had dull and wavy curved upward leaves. The leaves of Calcuttia cultivar were very shiny and wavy curved downward. Gola cultivar had alternate-opposite leaves orientation, while Bombay, Calcuttia and Bedana had alternate leaves orientation. Leaflet ranging from 4-8 with wide variation in colour of emerging flushes were also reported. According to Nakasone and Paull (1998), litchi leaves have 4 - 10 (two to five pairs) leaflets, depending upon the cultivars.

Nakasone and Paull (1998) reported that litchi leaves are arranged alternately, pinnately compound with 2-5 pairs of leaflets arranged in opposite positions or slightly obliquely along the rachis. According to Singh *et al.* (1999), the litchi cultivars can be distinguished on the basis of colour of flush and season of flushing. They further reported that Shahi produced very light coloured flush, while China had pink flush. The colour of Bedana flush was very dark pink.

Chavaradar (2016) reported that the leaf length of the litchi collections ranged from 12 cm to 16.8 cm with low CV (8.67%) as compared to leaf width (14.27%). The leaf size and shape are important varietal characters and is also used for cultivar identification (Singh *et al.,* 1999). The mature leaf shape had a predominance of elliptic shape (96.87 %) while single collection recorded lanceolate shape (3.12 %). The leaf colour of the young flush varies from pinkish green, greenish yellow and light green whereas matured leaf colour was green, light green and dark green. The frequency of mature leaf colour was 65.62 per cent green, 31.25 per cent dark green and 3.12 per cent light green whereas in young leaf 78.12 per cent pinkish green, 12.5 per cent yellowish green and 9.37 per cent light green.

Hossain *et al.* (2017) found that number of leaflets per leaf ranged from 4.33 in BARI Lichu-3 to 7.00 in Mongalbari and Bedana. Leaflets were arranged in opposite, alternate or both opposite and alternate modes. Rachis length was maximum (13.93 cm) in Rajshahi Local and minimum (6.47 cm) in BARI Lichu-3. BARI Lichu-2 had maximum (0.93 cm) while Bedana observed with minimum (0.43 cm) petiole length. Leaf blade length varied from 9.73 cm in BARI Lichu-4 to 15.13 cm in Rajshahi Local while leaf blade width varied from 2.63 cm in BARI Lichu-4 to 5.33 cm in BARI Lichu-2. BARI Lichu-4 showed oblong leaflet blade shape whereas other genotypes had elliptic. Leaflet apex shape was acute or acuminate while leaflet base shape was cuneate or attenuate. Protuberance on petiole was present in four genotypes (Kadmi, Mongalbari, Rajshahi Local and BARI Lichu-4) and absent in the remaining three genotypes.

2.3 Flowering character

A marked variation was reported on various flowering characters *viz.*, panicle initiation, date of opening of male and female flowers, flower disc colour, position of inflorescence, abundance of flower, duration of flowering, length and width of inflorescence and percentage of female flower were recorded and analysed. Litchi inflorescence is determinate and composed of several multiple branched panicles. The length of panicle varies between 10 and 40 cm depending on the cultivars. Panicle produces hundreds of small greenish or yellowish flowers which emit pleasant fragrance when the tree is with full flowering. Width of litchi flowers varies 3 to 6 mm in when fully opens (Sauco1989).

Robbertse *et al.* (1995) reported that the apical bud of a modular branch can only produce one inflorescence, but one or more of the lateral buds, directly below the apical bud may also be transformed into inflorescence. The development of different floral parts takes place in acropetal succession. The individual flowers of litchi are borne in profusion on the axis of the 3rd order, rarely on the 4thand occasionally on the main axis of the inflorescence (Pandey and

Sharma 1998). Khurshid *et al.* (2004) found maximum length of panicle in Gola cultivar, while minimum was recorded in Bedana. Gola had light yellow flower colour, while Bombay, Calcuttia and Bedana cultivars had yellowish colour. Nath *et al.* (2015) reported when difference of temperature was less than 4 °C and humidity difference of about 6.5% during June-August in South India triggered flowering in litchi.

Sarkar and Bandyopadhyay (1989) studied the flowering behaviour of some important litchi cultivars in Gangetic plains of west India and reported earliest panicle emergence in Bedana, while late in Ellaichi. Duration of flowering varied from 24 days in Kasba to 14-15 days in Ellaichi. They also noticed first panicle emergence in Bedana while Ellaichi and Nafarpal showed late panicle emergence. Percentage flower production (in terms of panicles produced) ranged from 51.1 per cent in Muzaffarpur to 27.6 per cent in Ellaichi. The ratio of male to hermaphrodite female flowers was highest in Ellaichi (4.71:1) followed by Bedana (4.35:1) and lowest in Kasba (1.79:1).

Singh *et al.* (2010) reported that the opening of flower in different litchi varieties started from second week of March and continued for a month. Deshi was the first to flower followed by Shahi and Rose Scented. The time of floral initiation varies with genotype and environmental conditions. In the northern hemisphere the flower bud differentiation in litchi starts in December and is completed by the end of January (Shukla and Bajpai 1974). Subsequently the emergence of flower panicle starts during January and is continued up to February, while in southern hemisphere it usually occurs between June and September.

Ray *et al.* (2002) reported that anthesis started in second week of March and continued up to first week of April in different litchi cultivars. Madhou *et al.* (2010) conducted phenological studies over four consecutive fruiting cycles (2003/2004 to 2006/2007) of litchi cultivar Mauritius**,** revealed that accessions could be grouped into early and late-flowering cultivars. Qiu *et al.* (2014) studied the

flowering pattern and fruit set of litchi variety Feizixiao. They found difference in time of the first stage of female flowers occurred 15 to 25 days earlier than the second and third stage of female flowers respectively, whereas fruit maturity differed by 7 to 10 days among them. The fruit from the early flowers were bigger and ripened earlier than those from late flowers. They reported that quality of fruit from early flowering was better than fruit from late flowering. Hossain *et al.* (2017) reported that Panicle emerged during mid to late January in four genotypes but in Bedana, BARI Lichu-2 and BARI Lichu-4 it emerged in early February. Panicle emergence continued up to mid or late February, and in some cases (BARI Lichu-2, 3, 4) up to early March in Pakistan.

Brijwal *et al.* (2016) found that flowering duration in different cultivars of litchi varied from 12 to 21 March during both the years. The earliest initiation of flowering was recorded in cultivar Rose Scented (12 March 2013 and 15 March 2014) followed by Early Seedless (16 March 2013 and18 March, 2014), while it was late in cultivars Late Seedless (19 March 2013 and 21 March 2014) and Calcuttia (21 March 2013 and 20March 2014). The maximum duration of flowering was noticed in cultivar Rose Scented (21.87 days), while the minimum duration of flowering was noticed in Late Seedless *i.e.* 20.00 days. They also reported that Calcuttia produced the biggest panicle having 34.89 cm length followed by Rose Scented (23.51 cm) and Early Seedless (21.33 cm), while the minimum panicle length was found in Late Seedless (8.70 cm). The maximum panicle width was recorded in Rose Scented (26.65 cm) followed by Calcuttia (20.68 cm), while the minimum panicle width was recorded in Late Seedless (15.70 cm).

Chadha and Rajpoot (1969) reported that three types (a) male (b) hermaphrodite functionally female and (c) hermaphrodite functionally male flowers are present in the same inflorescence. A litchi inflorescence bears three different flower types that open in succession on the same panicle (Kift 2002). Each panicle produces

tens to hundreds of small flowers: two functional male types (M1 and M2), and one functional female (F) type (Joubert 1985; Costes 1988). The M1 flower has a rudimentary pistil, which appears as a conspicuous pink, pubescent protuberance. The ovary contains two partially formed ovules with no embryo sac. The pistil is surrounded by six to eight stamens with hairy filaments about 6 mm long. The nectar disc is small. The female flower has a fully developed pistil, which has two-lobed superior ovary containing two anatropous ovules, a short style, and a bifurcated stigma. The surface of the ovary is pubescent, with protuberances that persist and give the fruit its rough surface. Usually, only one of the lobes of the ovary develops into a fruit and other abort. Occasionally, however, the two lobes may develop in twin fruit. Six to eight stamens, which have very, short filaments less than 1.5 mm long, surround the pistil. The anthers contain little viable pollen and do not dehisce, so the flower is functionally female. The nectar disc is large. The M2 flower has a small pistil with a short style that ends in a two-lobed stigma. However, the pistil is non-functional, as the lobes of the stigma do not open. It is surrounded by six to eight stamens, which are similar in appearance and function to those in M1 flowers. The nectar disc is smaller than that of the F flower, but much larger than that of the M1 flower (Mustard *et al.,* 1953; Mustard 1960; Scholefield 1982; Moncur 1988).

Pandey and Sharma (1989) also reported three types of flowers in all the genotypes *viz.,* male, functional male and functional female. Male or staminate flowers can easily be distinguished by the absence of pistil. The filaments in this type of flower varied in length. The functional female flowers strongly resembled the hermaphrodite flowers with 5-8 contabescent stamens and one bicarpeliate pistil. In functional male flower both pistil and stamens were present but the pistil was non-functional as the lobes of the stigma did not open to permit the entrance of the pollen. These three types of flowers were observed in all the seven genotypes studied (Hossain *et al.,* 2017).

According to Menzel (1984) and Menzel and Simpson (1992), the flowers are in order of appearance, functionally male, functionally female and functionally male. Menzel (1983) reported that panicles were normally produced terminally in clusters, but in some trees a high percentage of axillary panicles may also be produced. Robbertse *et al.* (1995) observed that the apical bud of a modular branch produced one inflorescence. One or more of the lateral buds directly below the apical bud were also produced resulting in more than one inflorescence at the tip of a module.

Stern and Gazit (2003) found that there is little overlap of the different flower types on the same inflorescence. Litchi flowers differ in their degree of development and they are classified in Types I, II and III, according to their sex expression. Flowers Types I and III function as males, whereas Type II act like females. Type I flowers were more abundant in the South (85%) than in the North (54%), and it was the only type observed during the first 8 days of bloom. Type II flowers initiated anthesis 12 days after the beginning of flowering. Type III flowers started anthesis 20 days after the beginning of bloom, mostly in the north sections (19%), as compared to southern ones (4%).

Osuna-Enciso *et al.* (2008) reported in 'Brewster' litchi that the distribution of flower Types I, II and III was of 70, 19 and 11%, respectively, with Type I as the earliest and III as the latest. Type I flowers have rudimentary ovule and Type II showed complete ovules without irregularities, whereas Type III ovaries were also complete, although smaller than in Type II, however their nucellus and integuments have deformities. Styles are dichotomous and only Type II have stigma.

Mustard *et al*. (1953) reported that dehiscence begin a day after anthesis and continue up to three days but all the anthers do not dehisce simultaneously. In dry condition, pollen grains are barrel-shaped and tend to be triangular when mounted on a slide in water or lactic acid. Wang *et al.* (2014) found the stigma colour of female

flowers was white and stigma was in the optimal pollination period. Light brown stigma was receptive, but totally brown stigma was unreceptive. The stigma receptivity lasted for at least 3 days. The pollen germinated on stigma two hours after pollination, the pollen tube gradually elongated into the style six hours after pollination, reaching the middle of style twelve hours after pollination, and the upper ovary twenty four hours after pollination.

Sharma and Roy (1987) studied the flowering period which ranged from 27 days in cv. Shahi to 38 days on cv. Bedana, flower emergence beginning in the second week of March and continuing up to the third week of April. Shahi was the first to produce flower panicles followed by Rose Scented, Purbi, China and Bedana and the sequence of flowering also followed the same pattern. The duration of flowering (anthesis to pollination) usually ranges from26-35 days (Chadha and Rajput 1969).

Dabral and Misra (2007) reported that maximum number of male flowers per panicle was noted in cultivar ‘Dehradoon’ followed by ‘Rose Scented’ while minimum number of male flowers per panicle was recorded in ‘Late Seedless’.‘Calcuttia’ produced the maximum number of female flowers per panicle and minimum was found in ‘Early Seedless’ followed by ‘Longia’ and ‘McLean’. Chadha and Rajpoot (1969) stated that highest percentage (48.7) of functionally female flower was found in Calcuttia Late followed by Seedless No. 2 (38.2 per cent), Muzarffarpur and Seedless No. 1. Dehradoon carried the least number of such flowers.

Mishra and Chand (2014) evaluated different litchi germplasm collected from different places and reported that maximum male flowers was observed in Purbi (74.44%). The panicles were found to produce form 700-1100 flowers depending upon the variety. Seedless No. 1 produced the highest number of flowers per panicle followed by Dehradoon, Seedless No. 2 and Calcuttia Late. The minimum numbers of flowers were carried by the panicles of Muzaffarpur variety while Chandola and Mishra (2015) recorded higher number of

flowers in Calcuttia followed by Kasba and Rose Scented while minimum number of total flowers was recorded in Mandraji and Longia.

Biswas *et al.* (1994) investigated seven genotypes of litchi (*Litchi chinensis* Sonn.) including a local cultivar. Among these genotypes, Mandraji was the earliest and maximum flowering whereas, Bombai and Dinajpuri (local cultivar) were the late flowering and China-3 was the minimum flowering genotype. Gupta and Koul (2000) studies floral biology of the three promising cultivars of litchi namely; Dehradoon, Seedless and Calcuttia and found that Dehradoon was the first to flower and had longer flowering period compared to the other two cultivars. The number of flowers per panicle was also highest (838) in Dehradoon.

Sigdel (2005) reported that the maximum flowers were recorded in Rose Scented (770.1/panicle) and minimum in Calcuttia Late (409.5/panicle). Somnuk and Suavansri (2005) studied the floral biology of litchi (*Litchi chinensis* Sonn.) cv. Khom and reported that the number of flowers per panicle was 1786.75±368.61 of which 1162.88±317.50 were male and 367.50±114.76 were female. Das and Roychaudhury (1958) reported number of flowers per panicles in different cultivars of litchi, *viz.,* in Kasba-1870; in Deshi- 2673; in China- 1819; in Ellaichi-1548 and in Bombai- 1878.

Sahay *et al.* (2007) reported that Bedana had significantly the maximum sex ratio followed by Late Bedana and Lal Bombai while, the minimum was obtained in Ajhauli. Sarkar and Bandyopadhyay (1989) studied the sex ratio of three litchi cultivars and found that ratio of male to hermaphrodite flowers was highest in ‘Ellaichi’ (4.71:1) followed by ‘Bedana’ (4.35:1) and lowest in ‘Kasba’ (1.79:1). The sex ratio (male: female flowers) was found maximum in ‘Dehradoon’ and minimum sex ratio was noted with ‘Calcuttia’ (Dabral and Misra 2007). Similar observations made by Chandola and Mishra (2015) as they recorded higher sex ratio in Dehradoon, McLean and Shahi while, minimum was noted in Calcuttia followed by Kasba. Chadha and

Rajpoot (1969) also found male to functionally female flower ratio was the highest in Dehradoon (4:1) followed by Seedless No.1 (2.66:1), Muzaffarpur (24:1), Seedless No. 2 (1.6:1) and Calcuttia Late (1.05:1). Datt (1998) reported that functional female flowers varied greatly between cultivars. The highest percentage of functionally female flowers ratio was observed in Dehradoon followed by Seedless No. 1 and Muzaffarpur. Singh *et al.* (2010) reported that the percentage of functionally female flower and female: male flower ratio was highest in Rose Scented.

Rani *et al.* (2007) found that the total number of flowers per panicle was maximum in Culcuttia (1108.00) followed by Rose Scented (1101.33), while, minimum number of total flowers was produced in cv. Late Seedless (709.99). Maximum number of male flowers per panicle was observed in cultivar Rose Scented (828.66) and minimum was observed in Late Seedless (442.33). Maximum number of female flowers per panicle was observed in Late Large Green (291.33) and minimum female flowers in cv. Muzaffarpur (186.66). Sex ratio was found highest in cv. Maharaj Singh Pasand (3.54) and minimum in cv. Late Seedless (1.65). Ray *et al.* (2002) found that number of staminate flowers and the percentage of female flowers were highest in Rose Scented.

Brijwal *et al.* (2016) showed the maximum number of male flowers per panicle in Calcuttia (277.87) followed by Rose Scented (270.75) and Late Seedless (261.25), while the minimum number of male flowers per panicle was observed in Early Seedless (241.50).The highest values of imperfect hermaphrodite female flowers per panicle were in cultivar Rose Scented (299.50) followed by Calcuttia (292.12), whereas the minimum number of imperfect hermaphrodite female flowers pe rpanicle was estimated in Late Bedana (252.62).The maximum number of imperfect hermaphrodite male flowers per panicle recorded in Rose Scented (294.62) followed by Early Seedless (289.87), while minimum number of male flowers per panicle in Late Seedless (268.62).The pooled analysis showed

the maximum number of flowers per panicle in Rose Scented (864.87), while, the minimum number of flowers per panicle was estimated in Late Seedless (782.50).

Hossain *et al.* (2017) observed synchronization in anthesis of functional male and functional female flowers resulting successful pollination for fruit setting. Inflorescences were basically terminal in all the genotypes but simultaneously axillary inflorescences were also found. Inflorescence stalk colour was green or light green. Flower disk colour was light yellow in Kadmi and BARI Lichu-2, light cream in Mongalbari, Bedana and BARI Lichu-3. While that of Rajshahi Local and BARI Lichu-4 had yellow. Length of inflorescence ranged from 20.00 cm in BARI Lichu-2 to 37.00 cm in Mongalbari and widest inflorescence (27.00 cm) was observed in Kadmi and the narrowest (14.00 cm) in BARI Lichu-3.

2.4 Fruit Character

Various observations on fruit characters *viz.*, date of fruit set, fruit maturity group, bearing and clustering habit, bearing intensity, fruit ripening, shape, shoulder and tip of fruit, segmentation on fruit skin, cracking, mature fruit colour, distribution of colour on fruit surface, shape of tubercles and its density, presence of suture, fruit quality parameters, days taken to maturity, number of fruit per cluster, length and diameter of fruit, and fruit weight were recorded and analyzed.

Das and Roychoudhyury (1958) reported that highest percentage of fruit set was in Kasba and Bombai and lowest was in China and Deshi. Chadha and Rajpoot (1969) showed correlation between fruit set and sex ratio. ‘Calcuttia Late’, had the highest proportion of female flowers (48.7%), had the highest fruit set (23.2%), while, ‘Dehradoon’ had the lowest fraction of female flowers (19.8 %) and had lowest fruit set (8.0%). Rani *et al.* (2007) reported that fruit set per panicle was highest in cv. Rose Scented (35.08) while minimum was observed in cv. Muzaffarpur (23.41). Highest

fruit retention per cent was recorded in cv. Shahi (47.29%) while it was minimum in cv. Longia (35.32%).

Menzel (1984) reported that premature fruit drop commenced soon after fruit set and continued to fruit maturity, with most fruits abscission in the first 2-4 weeks. The initial fruit set in litchi is very high in all the cultivars but a very little portion of it reaches to maturity. Sharma and Roy (1987) found that retention of fruits varied significantly in different verities and ranged from 3% to 39.62 % upto harvest *viz.* Shahi (4%), Rose Scented (5.54%), Purbi (3%), China (39.62%) and Bedana (23.57%). Singh and Dhillon (1983) reported that per cent fruit retention was 16.45, 3.88, 6.45, 4.00, 2.46, 15.77, 7.45, 2.27 and 2.51 in Dehradun, Muzaffarpur, Calcuttia, Rose Scented, Seedless Late, Seedless No. 1, Seedless No. 2, Hongkong, respectively. Hossain *et al.* (2017) reported that fruit set was completed within March in all the genotypes. Kadmi took minimum time (60-65 days) from fruit set to maturity closely preceded by Mongalbari (60-70 days). Maximum time (75 days) was taken by Bedana and BARI Lichu-2. Harvesting duration was also very short for all the genotypes.

Pujari and Syamal (1977) reported that litchi trees suffered from a heavy fruit drop and only a small proportion of it from 2 to 18 per cent was reached to maturity in different cultivars. Kanwar and Kahlon (1985) also studied the extent of fruit drop in 52-year-old trees of Litchi and found the extent was 89.08% in cv. Calcuttia, 86.07% in Muzaffarpur and 81.60% in Seedless Late. The critical period for fruit drop was three weeks after fruit set in Muzaffarpur and Calcuttia but up to 6 weeks after fruit set in Seedless Late. Kumar *et al.* (1998) monitored fruit drop and retention in 10 promising Litchi trees at Ranchi, India in 1990-91. Fruit retention ranged from 23.00 to 40.36% while fruit drop ranged from 59.64 to 77.00%. Chandola and Mishra (2015) observed fruit drop in the range of 83.31% in Rose Scented to 90.57% in Dehradoon and retention in the range of 9.50% in Dehradoon to16.20% in Rose

Scented amongst various genotypes. Chadha and Rajpoot (1969) indicated that initial fruit set in 5 Indian cultivars was very high (71-181 fruits/panicle) but very few fruits were retained at maturity (2-8 fruits/panicle). Sukhvibul *et al.* (2014) reported greatest number of fruits per panicle was in ‘Kom’ (41.6) and lowest in ‘Kra-ok BaiKhing' (17.6). The massive abscission of fruitlets of ‘Hong Huay’ occurred during the first 1-3 weeks after full bloom, which was similar to ‘Kaimana’,‘Mauritius’ and ‘Floridian’ litchi (Stern and Gazit 1999).

Sharma and Roy (1987) evaluated five cultivars in northern Bihar and found highest yield/tree was in China (104.6 kg) and lowest in Bedana (71.4 kg) while Badiyala and Awasthi (1991) recorded a maximum yield of 38 kg per tree for ‘Dehradoon’ cultivar and a minimum yield of 9.6 kg per tree from ‘Seedless late’ varied in Himachal Pradesh. The performance of 15 litchi cultivars were evaluated by Ullah *et al.* (2001) and reported that highest yield was recorded by Bombai (46.62 kg/plant) while China-3 recorded the lowest yield (1.80 kg/plant). Fruit weight varied from 12.00 g (Sonapur) to 23.00 g (V3, BARI). The percentage of edible portion varied from 57.14 (Bombai) to 78.26 (V3, BARI) under Bangladesh conditions.

Chaubey *et al.* (2001) carried out a correlation studies among plant and fruit characters in litchi (*Litchi chinensis* Sonn.) using twelve genotypes. High genetic correlations were observed between fruit weight and fruit volume, fruit weight and aril weight, fruit volume and aril weight, panicle length and panicle breadth, sex ratio and rind weight, plant height and leaf length, plant height and leaf breadth, plant height and leaf volume, chlorophyll *a* and *b*, and chlorophyll *a* and seed weight. Siddiqui (2002) categorized Rajshahi Local/BARI Lichu-1 as early, BARI Lichu-2 as late and BARI Lichu-3 as mid-season variety. He also reported 19.5 g, 15.2 g and 18.4 g fruit weight, and 18.4 to 20.5%, 16.1 to 20.5% and 18.9 % total soluble solids content for BARI Lichu-1, BARI Lichu-2 and BARI Lichu-3, respectively.

Rani *et al.* (2007) recorded maximum fruit yield per tree in cv. Rose Scented (40.00 kg), followed by Shahi (39.16 kg), Maharaj Singh Pasand (39.00 kg), Dehrarose (38.00 kg) and Muzaffarpur (37.00 kg) while minimum fruit yield was obtained from the tree of Longia (29.00 kg) while fruit weight was maximum in cv. Late Seedless (24.50 g) followed by Rose Scented (20.45 g) and minimum in cv. Longia (16.20g). Maximum peel weight was observed in cv. Calcuttia (3.20 g) followed by cv. Late Seedless (3.10 g) and minimum peel weight was observed in Longia (2.16 g). On the basis of time of harvesting Rose Scented, Dehrarose, Shahi, Maharaj Singh Pasand, Muzaffarpur and Mclean were found to be early season cultivars (harvested during 1st week of June), Calcuttia, Longia and Late Large Green were found mid-season (harvested during 3rd week of June) while Late Seedless was harvested during 1st week of July and characterized under late season variety of litchi.

Sahay and Kumar (2007) conducted an experiment to study the fruiting behaviour of different litchi cultivars. Maximum fruit length was recorded in Kasba (3.96 cm) followed by Purbi (3.86 cm) and minimum in Bedana (2.05 cm) while fruit breadth was found maximum in Lal Bombai (3.75 cm) whereas minimum in Bedana (2.2 cm). China exhibited highest TSS/acid ratio (72.92) followed by Purbi (63.90) whereas Green (25.44) possessed significantly least TSS/acid ratio under Bihar conditions.

Dabral and Misra (2007) found highest fruit yield per tree in Rose Scented followed by Dehradoon and Calcuttia while minimum yield was recorded with Longia followed by Kasba. Singh *et al.* (2010) evaluated litchi varieties grown in Bihar for fruit quality and yield. The highest fruit weight of 21 g was recorded in variety Shahi. The minimum skin percentage was recorded in Mandraji and maximum in Kasba. Late Bedana fruits had markedly higher aril percentage while those of Kasba had the least percentage. Total soluble solid content of juice was maximum in Shahi and minimum in

Kasba. Shahi fruits had minimum acid content while both Shahi and China showed higher TSS/acid ratio.

Lal and Mishra (2011) recorded higher yield per tree in Rose Scented followed by PLS-1, Calcuttia and Late Bedana while minimum yield was observed in McLean and Shahi. Maximum fruit yield (73.65 kg/tree) was reported in Rose Scented while minimum in Bombai (38.80 kg/tree) amongst the different germplasm evaluated (Mishra and Chand 2014). Chandola and Mishra (2015) also evaluated germplasm of litchi *viz*., Rose Scented, Calcuttia, Late Seedless, Early Seedless, Longia, Kasba, Mandraji, McLean, Dehradoon and Shahi for fruit yield per tree and found highest in Rose Scented followed by Calcuttia and Dehradoon while minimum yield was noted in Kasba followed by Longia.

Hossain *et al*. (2017) found that Rajshahi Local had maximum fruits per cluster (17.6) and BARI Lichu-3 had the minimum (3.5). Fruit shape was oval in Kadmi; oblong in Mongalbari and Rajshahi Local; cordate in Bedana and BARI Lichu-3 and round in BARI Lichu-2 and BARI Lichu-4. Kadmi and BARI Lichu-3 had even fruit shoulder while the shoulder of the remaining genotypes was protruding. Shape of fruit tip was obtuse only in BARI Lichu-3, which distinguished it from other genotypes having round fruit tip. Fruit segment was smooth in Kadmi and BARI Lichu-4, whereas, other genotypes had swelling type. Length of fruit ranged from 3.10 cm in BARI Lichu-3 to 3.67 cm in Mongalbari. BARI Lichu-4 produced the widest fruit (3.77cm) and Rajshahi Local produced the narrowest (3.10 cm). Mongalbari, Bedana and BARI Lichu-4 were not prone to fruit cracking while in other genotypes fruit cracking was observed at various levels. Colour of mature fruit was partially reddish yellow in Kadmi, BARI Lichu-2 and BARI Lichu-3; uniformly rosy red in Mongalbari; partially pinkish red in Rajshahi Local, and uniformly dark red in Bedana and BARI Lichu-4. The genotypes differed from each other in respect of shape and density of tubercles. Fruit suture

was prominent in Kadmi, BARI Lichu-2 and BARI Lichu-4 while other genotypes had weak suture.

Chadha and Rajpoot (1969) observed the extent of cracking percentage in different cultivars like Dehradoon (27.4%), Muzaffarpur (16.8%), Seedless No.1 (16.7%), Calcuttia Late (3.4 %) and Seedless No.2 (0.3 %) under Gurdaspur (Punjab) conditions. The extent of fruit cracking in Early Large Red (28%), Calcuttia (26.31%), Deshi (20.75%), Rose Scented (17.90 %), Late Seedless (15.31%), Piyazi (14.77%), Early Seedless (11 %) and Saharanpur selection (2 %) have been recorded by Lal and Nirwan (1980) in U.P. conditions. Badiyala and Awasthi (1991) observed fruit cracking percentage in nine different cultivars of litchi varied from 12.89 to 50.60 under Kangra valley of (Himachal Pradesh) conditions. The fruit cracking per cent in Purbi was recorded as 7.13 per cent by Brahmachari and Kumar (1997) at Sabour (Bihar) conditions. While Sinha*et al.* (1999) reported 19.33 per cent fruit cracking in Purbi cultivar of litchi at Ranchi conditions. Haq and Rab (2012) found the highest fruit cracking in cultivars Gola (43.50%) followed by Surahi (31.19 %) and China (23.15% %). and lowest fruit cracking was observed in cultivar Bedana. The fruit cracking percentage was maximum 40.1% in Dehradoon while Calcuttia had the minimum (14.2%) under the subtropical climate of Himachal Pradesh (Kumar *et al.,* 2015).

Biswas and Roy (1983) found that fruit weight increased upto 110 days (25.70 g) after that it decreased. Yen (1984) concluded that the weight of seeded fruit was heavier than seedless fruit, but the aril weight between seeded and seedless fruit was not significantly different. Sharma and Roy (1987) also reported significant variation in fruit and found highest weight of the fruit in Shahi (19.20 g). The length of fruit was maximum in Bombai (4 cm) while it was 3.8 and 3.7 cm in Ellaichi and Purbi, respectively compared to Early Large Red and maximum fruit width was found in Bedana (3.5 cm) followed by 3.2 cm in Muzaffarpur Early and 3.1 cm

in Purbi and Early Large Red. The smallest width of fruit (2.8 cm) was noted in cultivars Bombai and McLean (Ghosh *et al.,* 1988). The average fruit weight ranged between 14.15 to 21.00 g in cultivar Muzaffarpur and Rose Scented produced significantly large fruits (21.3 g) as compared to all other cultivars except Dehradoon, McLean and Large Red (Badiyala and Awasthi 1991).

Dwivedi and Jha (2000) studied fruit traits in litchi cultivars in Nadia. Globose fruit shape was found in Bedana and Naffarpal while oval or oblong shape was found in Deshi, Early Large Red, Early Muzaffarpur, Mclean, Muzaffarpur and Rose Scented but Bombai fruits were heart shaped. Peel colour was mostly red or brown. Fruits of Bedana and Ellaichi were very sweet, while Kasba, Mclean and Rose Scented were less sweet.

Mahajan and Dhillon (2000) evaluated litchi cultivars Dehradoon, Calcuttia, Seedless Late, Rose Scented and Hong Kong for physico-chemical and noticed maximum fruit length (3.28 cm) and diameter (3.10 cm) in Calcuttia followed by Dehradoon. Hong Kong recorded the minimum length (2.69 cm) and diameter (2.48 cm). There was significant variation in fruit weight of different cultivars, being highest with Calcuttia (19.0 g). Dehradoon and Seedless Late ranked second and third, respectively. The peel percentage was significantly highest in Hong Kong (19.02%) followed by Rose Scented, while, lowest in Seedless Late (12.10%). The seed percentage was highest in Hong Kong (23.84%) and lowest in Seedless Late (9.12%).

Neog and Saikia (2001) reported that Muzaffarpur showed superiority over Calcuttia and Bhattacharjee *et al.* (2001) studied on physiology of fruit growth in litchi cultivars and they noted that the growth of peel progressively increased until the aril growth started at around 45 days after fruit set and the rate of increase in peel weight was faster during 15-30 days after fruit set. Mahajan (2002) revealed that the pulp to seed ratio increased during the fruit growth of

‘Calcuttia’ from 0.95 when aril growth was first noticed (30 days after fruit set) to 3.13 on 60 days after fruit set.

Ranjan *et al.* (2002) evaluated Kasba and Bedana and showed highest fruit weight (23.89 g) and volume (22.10 cc), stone weight (5.0 g) and volume (5.5) and pulp weight (15.45 g) in Kasba whereas Early Bedana recorded the highest pulp: stone ratio (9.48) and highest juice content (69.04 %), juice peel rag (8.31%). Kumari *et al.* (2004) studied physical characters of litchi cultivars *viz.,* Deshi, Purbi, China and Kasba, and China and Kasba showed the highest fruit weight, fruit volume, fruit breadth, aril (%), aril:stone and juice (%), while Purbi showed the highest fruit length. Kasba had the highest stone and rag (%). A study was conducted during 2000 and 2001, in Nadia, West Bengal on fruit growth and development of litchi cultivars revealed that the optimum harvesting time after fruit set varied from 54-58 days for Nafarpal, 58-62 days for Piazi and Rose Scented, 62-66 days for Purbi, and 66-70 days Seedless Late. All cultivars showed a sigmoid pattern of growth (Pereiera and Mitra 2006).

Dabral and Misra (2007) reported that fruit length was found significantly high in Calcuttia followed by Rose Scented, Mandraji and Dehradoon, while minimum fruit length was noticed in Longia. The maximum fruit breadth was recorded in Rose Scented (3.17 cm) and Early Seedless (3.17 cm) and minimum was found with Longia (2.70 cm). Rose Scented (20.93 g) gave the maximum fruit weight followed by Dehradoon (20.9 g), Mandraji (20.00 g), Kasba (19.93 g) and McLean (19.33 g). The minimum weight of fruit was found in Longia (13.24 g). Dehradoon (46.13) showed maximum fruit volume while, minimum was observed in Longia (38.93). The maximum fresh weight of aril was observed in Late Seedless (14.60 g) followed by Early Seedless (13.16 g) and minimum was recorded in Mandraji (8.83 g). Singh *et al.* (2010) recorded maximum fruit length and diameter in cultivar Kasba (3.78 and 3.37 cm) while the minimum was recorded for cv. Dehradoon (2.82 and 2.41 cm). The

fruit weight was recorded highest for cultivar Kasba (28.19 g) while the lowest was for cv. Longia (13.96 g).

Haq and Rab (2012) found highest pulp weight in cultivar Gola which was 34.14% than cultivar Bedana but 10.35% and 4.59% higher than cultivars Surahi and China, respectively. Mishra and Chand (2014) found maximum fruit weight (25.50 g), pulp weight (20.15 g) in Rose Scented and Late Seedless, respectively, while minimum fruit weight (19.40 g) was reported in Bombai. Aguas *et al.* (2014) noticed maximum fruits length (35.1 mm), fruit weight (21.2 g) and pulp weight (16.8 g) in Mauritius.

Hossain *et al.* (2017) reported that BARI Lichu-4 had the maximum fruit (26.6 g) and aril (20.6 g) weight, and edible portion (77.44 %), while minimum fruit weight (18.0 g), aril weight (12.30 g) and edible portion (68.33 %) was found in BARI Lichu-2. Total soluble solids varied from 19.78 % in Kadmi to 22.00 % in BARI Lichu-4. Aril flavour was strong in Rajshahi Local and BARI Lichu-4, whereas intermediate in the other genotypes. Aril quality was very sweet for BARI Lichu-4, sour sweet for Kadmi and sweet for the remaining genotypes. Juicy aril was found in Kadmi, Rajshahi Local and BARI Lichu-2 while the aril of other genotypes was very juicy. Overall taste of Bedana and BARI Lichu-4 was excellent and other genotypes were good to very good. Khalid *et al.* (2017) found maximum fruit weight in Calcuttia in year 1 (21.59 g) followed by Gola and Bedana.

Chadha and Rajpoot (1969) reported highest TSS in Seedless No. 1 (18.4 ^{0}B) followed by Calcuttia Late (18.2 ^{0}B), Muzaffarpur (18.0 ^{0}B) and Dehradoon (17.8 ^{0}B), while lowest TSS was observed in Seedless No. 2 (17.2 ^{0}B). Gaur and Bajpai (1978) reported that maximum TSS was found at 57 days after fruit set in cultivar Calcuttia. Badiyala and Awasthi (1991) recorded highest TSS (22.30 ^{0}B) in Rose Scented cultivar followed by Dehradoon and Seedless Early while lowest TSS was found in Saharanpur.

Tripathi *et al.* (1987) also reported highest TSS in Rose Scented (19.0 ^{0}B) and lowest in Calcuttia (17 ^{0}B) followed by Deshi (18.0 ^{0}B). Ghosh *et al.* (1988) found highest TSS in Bedana (18.0 ^{0}B) and lowest in Kasba (13.4 ^{0}B) while other cultivars *i.e.* Deshi, Early Large Red, Ellaichi, McLean, Muzaffarpur, Nafarpal, Purbi, Rose Scented had 17.1, 17.0, 17.5, 16.8, 17.7, 17.6, 17.3, 16.9 TSS ^{0}B, respectively.

Evaluation of litchi cultivars in Pakistan was carried out by Haq and Rab (2001) reported that maximum fruit weight (23.08 g), pulp weight (16.58 g), TSS (22.13 ^{0}B) and total sugars (21.57 per cent) was reported in Gola but also had the maximum fruit cracking (43.50 per cent). It also recorded highest reducing sugars (17.98 %) but the least non-reducing sugars (3.59 %), while Bedana exhibited least reducing sugar (5.67 %).

Studies on physico-chemical characters of litchi by Ranjan *et al.* (2002), under Bihar plateau condition recorded highest fruit weight (23.89 g), volume (22.10 C.C.), stone weight (5 g) and pulp weight (15.45 g) in Kasba, whereas Early Bedana recorded the highest pulp:stone ratio (9.48). The highest juice content (69.04 %) and total soluble solids TSS/acidity ratio (38.72) was recorded in Early Bedana, whereas highest acidity was recorded in Deshi (0.71 %).

Rani *et al.* (2007) reported highest TSS in cultivar Rose Scented (19.66 ^{0}B) followed by Late Seedless (19.33 ^{0}B) while lowest in Longia (16.13 ^{0}B). Maximum total sugars percentage was found in Late Large Green (15.39 %) and minimum in Dehrarose (11.30 %). Acidity was minimum in Rose Scented (0.30%) which is a desirable feature and also indicative of proper conversion of acids into sugars at harvest stage while maximum acidity was found in Longia (0.66 %). The highest ascorbic acid was found in Dehrarose (23.66 mg/100 g pulp) and minimum in Longia (16.33 mg/100 g pulp).

Kumar (1992) reported 11.02 per cent total sugar in litchi fruits at the time of harvesting while Song (1995) reported 16.37±1.45 per cent in the same cultivar. Ghaffoor *et al.* (1999) reported that reducing, non-reducing and total sugars varied from 4.47 to 6.92 %, 4.10 %, to 5.30 and 8.60 % to 11.60 %, respectively in five litchi cultivar *viz.,* Purbi, Bedana, Serai, Bombai and Gola. Singh *et al.* (1987) reported that total acidity was significantly higher in Culcuttia (0.54 %) whereas lowest in Muzaffarpur (0.51 %) and Early Large Red (0.51 %). Tripathi *et al*. (1987) reported that Rose Scented had maximum reducing sugar (9.24 %) while the minimum (8.21 %) was recorded in Calcuttia. Total sugar was found maximum (12.59 %) in Rose Scented and minimum (10.82 %) in Calcuttia. Ram *et al.* (2005) analysed physico-chemical parameters of ripe fruits. They found highest fruit weight was in Shahi (18.61 g) and lowest in GTL-48 (15.55 g). The greatest fruit diameter was recorded for GTL-48 (3.35 cm). Shahi fruits had the greatest peel content (17.21 %), acidity (0.526 %), and reducing sugar (9.2 %) and non-reducing sugar (6.01 %) contents. Rose Scented had the greatest pulp content (71.11 %), ascorbic acid content (34.7 mg/100 g) and total sugar content (13.28 %) and lowest acidity (0.526 %). The TSS content was highest in GTL-48 (17.76%) and lowest in Rose Scented (16.23 %). GTL-48 had the lowest total sugar (11.48%) and non-reducing sugar (4.21 %) contents.

Sharma and Roy (1987) reported that the titratable acidity was minimum in Shahi (8.35 %) and maximum in Bedana (0.59 %). Total acidity was significantly high in Calcuttia (0.54%), whereas lowest in Muzaffarpur (0.51%) and Early Large Red (0.51%) (Singh *et al.,* 1987). Ghosh *et al.* (1988) recorded high acidity in McLean (1.24%) while it was minimum in Bedana (0.39%). Badiyala and Awasthi (1991) found maximum acidity in Calcuttia whereas Dehradoon had the minimum acidity (0.42%). Chang and Lin (2004) reported major organic acids in the fruit were succinic acid (the most abundant), malic acid and citric acid and titratable acid and organic

acids reduced rapidly from the 8th week to the 10th week after full bloom.

Chadha and Rajpoot (1969) recorded highest ascorbic acid content in variety Calcuttia Late (44 mg/100 g) closely followed by Seedless No. 2 (43.6 mg/100 g) while the lowest was in Muzaffarpur (20.9 mg/100 g). Tripathi *et al.* (1987) reported that 'Deshi' contains 30 mg/100 g of ascorbic acid while Rose Scented contains 24 mg/100 g. Ascorbic acid (mg/100 g) in Early Large Red, Calcuttia, Muzaffarpur and Bedana were 38.43, 35.76, 44.36 and 37.88, respectively (Singh *et al.,* 1987). Ghosh *et al.* (1988) found maximum ascorbic acid content in Bedana (26.9 mg/100 g) and McLean (24.3 mg/100 g), while the minimum was found in Bombai (17.2 mg/100 g). Ghaffoor *et al.* (1999) reported ascorbic acid content ranged from 45.72 to 60.02 mg/100 g pulp of five litchi cultivars.

Mahajan and Dhillon (2000) evaluated Litchi cultivars Dehradoon, Calcuttia, Seedless Late, Rose Scented and Hong Kong for physico-chemical attributes in Punjab. The maximum total soluble solids (18.2 ^{0}B) and total sugars (12.8%) were observed in Seedless Late followed by Calcuttia and Dehradoon. Hong Kong recorded the minimum level of total soluble solids and total sugars. Maximum acidity (0.52%) was also recorded in Hong Kong followed by Rose Scented while Calcuttia was recorded with the minimum acidity of 0.40%. The maximum ascorbic acid (30.0 mg/100 g) was noticed in Rose Scented and minimum in Seedless Late (26 mg/100 g). Dehradoon, Seedless Late and Rose Scented were harvested on 15 June, whereas, Calcuttia on 21 June. Hong Kong was marked as the late cultivar which ripened on 5 July.

Rani (2006) reported maximum TSS in Rose Scented (19.66 ^{0}B) followed by Late Seedless (19.33) and minimum TSS was observed in Longia (16.13 ^{0}B) followed by McLean (16.23 ^{0}B). Maximum acidity was recorded in Longia (0.66 %) followed by McLean (0.64 %), Calcuttia (0.63 %), Shahi (0.62 %) and Late Large

Green (0.61 %). The minimum acidity was observed in Rose Scented (0.30 %). Singh *et al.* (2010) found highest TSS in Deshi (22.82 ^{0}B) followed by Trikolia (22.43 ^{0}B) while the lowest in Late Bedana (18.17 ^{0}B). Acidity was recorded maximum in cultivar Dehradoon (0.41 %) followed by Kasba (0.40 %) and minimum was recorded in cultivar Late Bedana (0.27%). The TSS of Gola (22.13 ^{0}B) was higher than cultivars Bedana, Surahi and China (26.48, 11.93 and 7.86 ^{0}B, respectively (Haq and Rab 2012). Mishra and Chand (2014) recorded maximum TSS (22.1 ^{0}Brix) and minimum acidity (0.39 %) in Late Seedless while maximum acidity was recorded in Shahi (0.60 %) and maximum ascorbic acid was obtained in Calcuttia (28.2 mg/100g).

Singh and Nath (2015) identified important clones for higher fruit weight clones *viz.,* A2 (622.29 g), A11 (21.75 g) and A15 (21.21 g), for high TSS clones *viz.,* T9 (20.88 ^{0}B), A23 (20.16 ^{0}B) and T5 (19.88 ^{0}B), for small seeds (A26 (1.18), A25 (1.37) and A27 (1.95) and for high pulp percentage A26 (72.96%), T15 (69.83%) and T14 (68.63%). Khalid *et al.* (2017) observed maximum peel weight (g) in Calcuttia in (4.333 g), while, average peel content (%) and average peel thickness (mm) were recorded in Gola in year 1 (20.637 %) and (1.756 mm), followed by Calcuttia and Bedana. The maximum total soluble solid was found in Bedana (18.3 ^{0}B), acidity in Gola (1.4 %) and reducing sugars in Gola (14.843 %).

2.5 Seed Characteristics

Various observations on seed characters *viz.*, seed shape, seed coat colour, seed weight, length and width of seed were recorded and analysed.

Pandey and Sharma (1989) found that seeds of China were glaucous, dark chocolate in colour, oblong to concave or convex in shape, medium in size (2.9 cm length and 1.5 cm diameter) and seed weight (3.49 g). The ratio of rind:pulp:seed was 16.42 : 69.22 : 14.36.

Dabral and Misra (2007) reported maximum fresh weight in Calcuttia (3.83 g) and Kasba (3.83 g), however, minimum was found in Early Seedless (0.88 g) followed by Late Seedless (1.11 g). The seed length varied among the litchi cultivars and maximum was measured in Calcuttia. However, minimum length of seed was found in Early Seedless followed by Late Seedless. Rani *et al.* (2007) also found maximum seed weight (3.33g) in Calcuttia, where minimum in Late Seedless (1.38 g). Mishra and Chand (2014) found maximum seed weight (4.61 g) in Bombai selection while minimum peel weight was recorded in Early Bedana (4.58 g) and maximum seed:peel:pulp was registered in Bombai.

Hossain *et al.* (2017) noticed variation for shape, size and colour of seed and found Mongalbari produced the longest (2.49 cm) and widest (1.57 cm) seed, while BARI Lichu-3 had the shortest (1.82 cm) and BARI lichu-2 had the narrowest (1.30 cm) seed. The minimum seed weight was reported in BARI Lichu-3 (2.30 g) followed by BARI Lichu-2 (2.70 g) and BARI Lichu-4 (2.78 g) while maximum seed weight (4.00 g) was recorded in Mongalbari. Oval shaped seed was found only in BARI Lichu-3, while seed shape of other genotypes was oblong. Seed coat colour was dark brown in Kadmi and Mongalbari, dull brown in BARI Lichu-4 and brown in the remaining genotypes. Khalid *et al.* (2017) showed maximum seed weight in Gola (2.856 g) followed by Calcuttia and Bedana.

2.6 Physiological and bio-chemical character

Various observations on physiological and bio chemical characteristics *viz.*, chlorophyll content in leave, total phenol, flavonoids and total anthocyanin were recorded and analyzed. Biochemical compound is secondary plant metabolites eliciting pharmacological or toxicological effects. Many types of secondary metabolites are produced within the plants and metabolic routes for compounds associated with plant growth and development. Litchi pericarp is rich source of anthocyanin. During maturity the colour of the pericarp changes from green to reddish pink with decreasing

chlorophyll content and increasing anthocyanin synthesis (Underhill and Crichtley 1992).

Hieke *et al.* (2002) studied on changes in leaf color and chlorophyll concentration of cultivars Bengal litchi. They evaluated at different stages *viz.,* Stage 1, soft red, Day 18; Stage 2, red brown, Day 27; Stage 3, green brown, Day 32; Stage 4, light green, Day 39; Stage 5,green soft, Day 44; and Stage 6, dark green, Day 49. Chlorophyll concentrations increased from 0.7 ± 0.2 mg/g in young red leaves to 10.3 ± 0.7 mg/g in dark green leaves. Hieke *et al.* (2002a) also found an 8.5-fold increase in total chlorophyll concentration during development from young red leaves to mature dark green leaves in litchi. Sukhvibul *et al.* (2014) showed that chlorophyll content varied on litchi cultivars and reported chlorophyll A, chlorophyll B and chlorophyll AB were 1.6-2.1 mg dm^{-2}, 0.46-0.62 mg dm^{-2} and 2.0-2.8 mg dm^{-2}, respectively.

Bernhoft (2010) reported that most of the plant species are capable of producing biochemical compounds. Phenolic compounds are well-known phytochemicals and commonly found in all plants. Spectrophotometric and chromatographic techniques are widely used to identify and quantify individual phenolic compounds (Ali *et al.,* 2013).

Hu *et al.* (2010) evaluated phenolic contents and antioxidant activities in fruit pericarp of eight litchi (*Litchi chinensis* Sonn.) cultivars ('Nuomici', 'Feizixao', 'Guiwei', 'Edanli','Yuhebao', 'Dingxiang', 'Wuye' and 'Lanzhu'). Among these cultivars, phenolic acids in dry pericarp ranged from 1.0 to 2.4 g 100 g^{-1} DW and total flavonoids from 1.5 to 3.8 g 100 g^{-1} DW. These compounds are the highest in 'Nuomici', 'Feizixiao' and 'Edanli', moderate in 'Yuhebao' and 'Wuye', and lowest in 'Guiwei', 'Dingxiang' and 'Lanzhu'.

Wang *et al.* (2011) reported that total phenolic concentrations in dried litchi pericarp of ten cultivars ranged from 51 to 102 g kg^{-1}. Cultivars ‘Nuomici’ exhibited significantly higher concentrations of

proanthocyanidins, flavonoids, phenolic acids and therefore total soluble phenolics than the other cultivars, while ‘Lanzhu’ and ‘Guiwei’ had minor values in phenolics.

Li *et al.* (2012) reported that Litchi Fruit Pericarp (LFP) contains significant amounts of phenolics which have been found to exhibit diverse biological activities. The total phenolic and flavonoid contents ranged from 9.39 to 30.16 mg gallic acid equivalents/g fresh weight (FW) and from 7.12 to 23.46 mg catechin equivalents/g FW, respectively. The total anthocyanin contents ranged from 1.77 to 20.94 mg cyanidin-3 glucoside equivalents/100 g FW.

Zhang *et al.* (2013) studied phenolic profiles and antioxidant activity of litchi pulp of 13 varieties. The free, bound and total phenolic contents were 66.17–226.03, 11.18–40.54, and 101.51–259.18 mg of gallic acid equivalents/100 g, respectively. The free, bound and total flavonoid contents were 16.68–110.33, 10.48–22.75, and 39.43–129.86 mg of catechin equivalents/100 g, respectively. Free phenolics and flavonoids contributed averagely 80.1% and 75% to their total contents, respectively. They found that phenolics and flavonoids exist mainly in the free form in litchi pulp.

Quiang *et al.* (2013) evaluated phenolic composition of litchi (*Litchi chinensis* Sonn.) pulp from three cultivars. Hemaoli, a wild litchi cultivar, showed the highest content of total phenolics, flavonoids and procyanidins in pulp. In Hemaoli, (-) - epicatechin was the predominant compound, whereas flavone glycosides accounted for the majority of the phenolic compounds identified in Feizixiao and Lanzhu cultivars, with quercetinrhammosyl- rutinoside being predominant.

CHAPTER III
MATERIALS AND METHODS

MATERIALS AND METHODS

Investigation entitled “Genetic studies of litchi germplasm” was carried out at ICAR-NRC on Litchi, Muzaffarpur, Bihar during the year 2016-17 and 2017-18. The present experiment was carried out with the objective of evaluating the morphological, physico-chemical and major bioactive traits in various germplasm of litchi present at National Active Germplasm Site, ICAR-NRC on Litchi, Muzaffarpur. The details of the experimental methodology are presented as below:

3.1 Location of the Experiment Site

The ICAR-National Research Centre on Litchi is located at Muzaffarpur, Bihar between 26^{o}5’64”N latitude and 85^{o}26’64”E longitude and an altitude of 210 meters above the mean sea level. The research farm of the centre is spread over an area of 35 ha.The soil type of the site is alluvial with sandy loam texture having calcareous in nature with pH ranging from 7.5 - 8.0.

3.2 Climate and Weather

The region is characterized by humid subtropical climate with temperature varying from 30°C to 43°C in summer and 5°C to 10°C in winter. The region is characterized by dry and hot summer and cold winter with heavy rainfall during rainy season. The onset of monsoon usually occurs in the second or third week of June and continues in appreciable amount up to mid of September. The meteorological data of the experimental site during the period of investigation are given in Appendix I.

3.3 Material Source

Thirty litchi germplasm of thirteen years age with uniform vigour and size were selected for the investigation. These trees were given uniform cultural practices. Three tree of each germplasm were considered for recording the observations. The experiment was conducted in Randomized Block Design.

3.4 Treatments details

S.N.	Notation	Genotypes	Accession Number
1	T_1	Kasba	IC-0615585
2	T_2	Late Large Red	IC-0615586
3	T_3	Bedana	IC-0615587
4	T_4	Bedana Selection	IC-0615588
5	T_5	Lal Bombay	IC-0615589
6	T_6	Mandaraji	IC-0615590
7	T_7	Purbi	IC-0615591
8	T_8	Calcuttia	IC-0615592
9	T_9	Bedana Selection Pant	IC-0615593
10	T_{10}	Rose Scented	IC-0615594
11	T_{11}	Swarna Roopa	IC-0615595
12	T_{12}	Late Bedana	IC-0615596
13	T_{13}	Trikolia	IC-0615597
14	T_{14}	Yogda Selection (P_2)	Coll. 39
15	T_{15}	Longia	IC-0615599
16	T_{16}	Dehrarose	IC-0615600
17	T_{17}	Ajhauli	IC-0615601
18	T_{18}	Green	IC-0615602
19	T_{19}	Calcuttia Late	IC-0615603
20	T_{20}	Seedless Late	IC-0615604
21	T_{21}	Seedless No.2	IC-0615605
22	T_{22}	Dehradoon	IC-0615606
23	T_{23}	Ellaichi	IC-0615608
24	T_{24}	Shahi	IC-0615610
25	T_{25}	China	IC-0615611
26	T_{26}	Early Bedana	IC-0615613
27	T_{27}	Deshi	Coll. 35
28	T_{28}	Surguja Selection-1	Coll. 36
29	T_{29}	CHES-II	Coll. 37
30	T_{30}	Bombai-I	Coll. 38

3.5 Observations recorded:

3.5.1 Tree Characters

3.5.1.1 Qualitative characters

3.5.1.1.1 Trunk surface

The trunk surface was visually assessed and rated as follows:

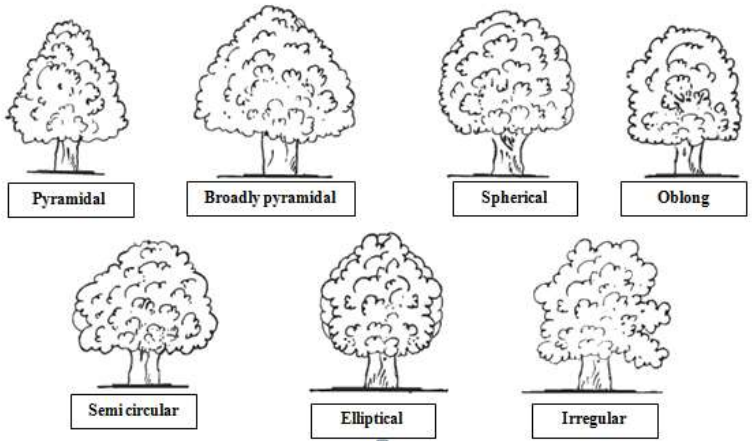
1= Smooth, 2=Rough, 3 = Very rough

3.5.1.1.2 Crown shape

Crown shape was assessed as visual mean of appearance (IPGRI) by considering the following ratings:

1=Pyramidal, 2=Broadly pyramidal, 3= Spherical, 4= Oblong,

5= Semicircular, 6= Dome shaped, 7= Irregular



3.5.1.1.3 Tree growth habit

The tree growth habit was visually observed and rated as follow:

1= Erect/upright, 2= Semi-erect, 3= Spreading, 4= Drooping

3.5.1.1.4 Branching density

The branching density of tree was visually recorded and rated as follows:

3= Sparse, 4= Medium, 7= Dense

3.5.1.1.5 Branching pattern

The branching pattern of tree was observed and rated as follows:

1= Erect, 2= Opposite, 3= Verticillate, 4= Horizontal, 5= Irregular

3.5.1.1.6 Young shoot pubescence

The young shoot pubescence was observed by considering the following ratings: 1= Glabrous, 2= Pubescent

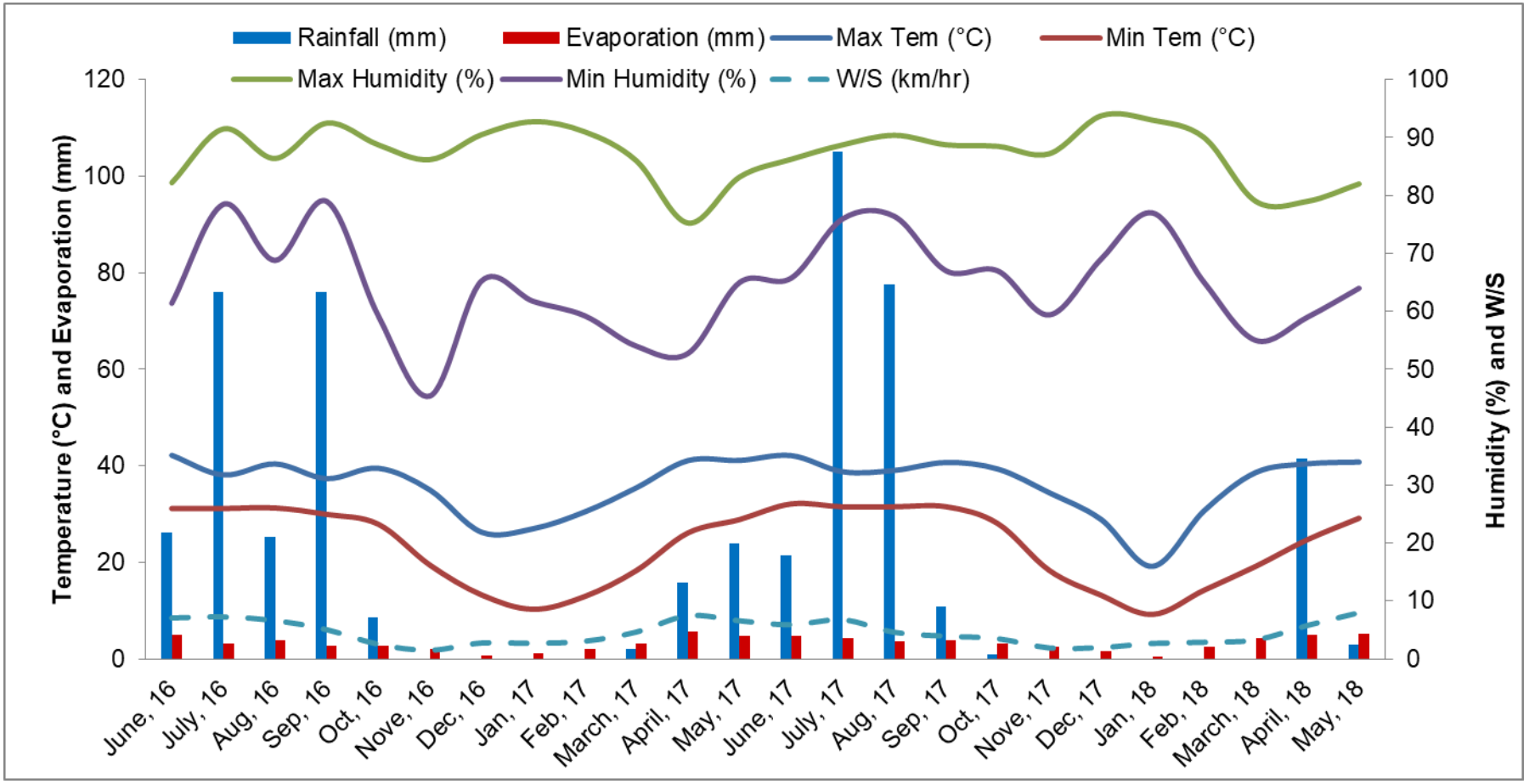
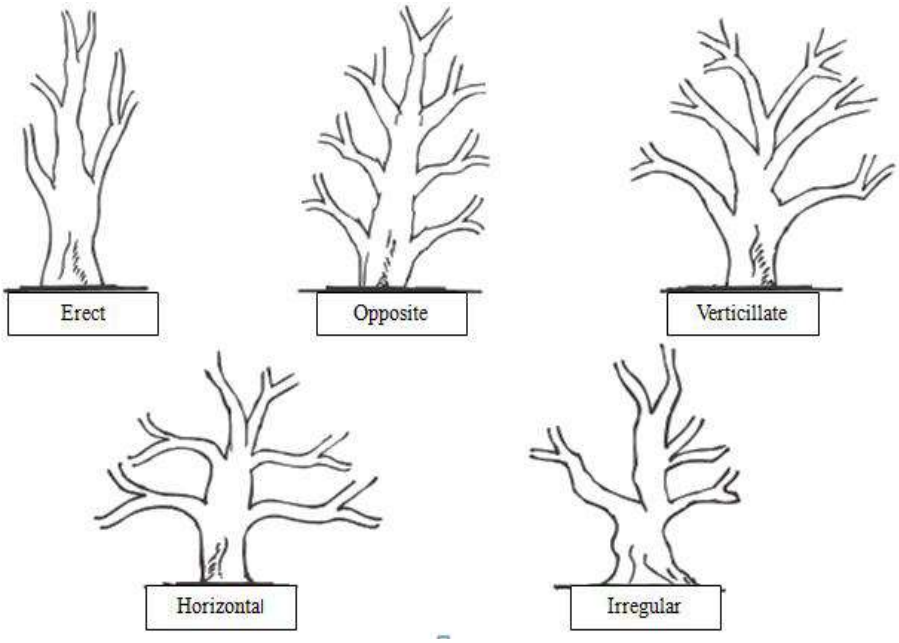


Figure 2.1: Mean monthly weather conditions at Muzaffarpur during investigation (2016-2018)



3.5.1.2 Quantitative characters

3.5.1.2.1 Tree height (m)

Observations on height of the trees were measured from the ground surface to the upper most part of canopy with the help of measuring tape and the data expressed in meter.

3.5.1.2.2. Trunk girth (cm)

The trunk girth was measured with the help of measuring tape at 30 cm above ground level and mentioned in centimetre.

3.5.1.2.3 Crown diameter (m)

The diametric length of the ground space occupied by the tree was measured in two directions and the crown diameter as North-South and East-West directions and mean value is expressed as crown diameter.

3.5.1.2.4 Tree volume (m^3)

The volume of the tree was calculated following the formula suggested by Westwood *et al.* (1963):

$$\frac{4}{3}a^2b$$

Where, a = half of spread, b = half of height.

3.5.2 Leaf characters

An average of 20 fully expanded representative leaves was collected from different trees of each cultivar to study the various leaf characters.

3.5.2.1 Qualitative characters

3.5.2.1.1 Young leaf colour

The colour of newly emerged leaf was evaluated as per the following rating:

1=Light green, 2=Yellowish green, 3=Green, 4=Light purple, 5=Purple,

6=Pinkish green, 7=Reddish brown, 8=Pink, 9=Bright Pink, 10 = Deep Pink

3.5.2.1.2 Mature leaf colour

The colour of mature leaf was evaluated at the adaxial side at fully mature stage and recorded as per the following rating:

1=Light green, 2=Green, 3= Dark green,4= Pinkish green

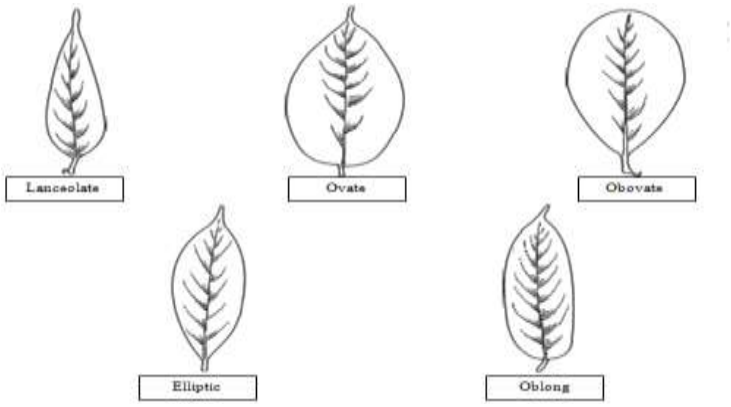
3.5.2.1.3 Arrangement of leaflet

The arrangement of leaflets either alternate (1) or opposite (2) or both (3) were studied for each genotype.

3.5.2.1.4 Leaflet blade shape

Shape of the leaflet blade was studied and recorded as per the following rating:

1=Lanceolate, 2= Ovate,3=Obovate, 4= Elliptical, 5= Oblong



3.5.2.1.5 Leaflet apex shape

Shape of the leaflet apex was examined under the following options:

1= Acute, 2= Acuminate

3.5.2.1.6 Leaflet base shape

Shape of leaflet base was visually observed as per the following rating:

1=Attenuate, 2= Oblique, 3=Cuneate, 4=Obtuse

3.5.2.1.7 Leaflet upper surface pubescence

The pubescence of leaflet on upper surface was observed and rated as follow:

0=Absent, 1=Present

3.5.2.1.8 Leaflet lower surface pubescence

The pubescence of Leaflet on lower surface was observed and rated as follow: 0= Absent, 1=Present

3.5.2.1.9 Leaflet midrib appearance

The appearance of midrib of leaflet was recorded as per the following rating:

1=Not prominent, 2=Slightly prominent, 3= Prominent

3.5.2.1.10 Leaflet venation appearance

The appearance of venation was observed by considering the following ratings:

1= Not prominent, 2= slightly prominent, 3= Prominent

3.5.2.1.11 Leaflet curvature

The curve of leaflet was observed as per the following rating:

1=Curve upward from the midrib, 2=Curve downward along the margin,

3= Flat, no curve, 4=Curve down slightly at the top

3.5.2.1.12 Protuberance

The presence (1) or absence (0) of Protuberances on petioles was assessed and rated as follow: 0= Absent, 1= Present

3.5.2.2 Quantitative characters

3.5.2.2.1 Number of leaflet

Average number of leaflets from 10 leaves was recorded.

3.5.2.2.2 Rachis length (cm)

The rachis length was measured in centimetre from the base of shoot to the tip from where the uppermost leaflet stalk emerges in the leaf.

3.5.2.2.3 Length of petiole (cm)

The length of the petiole was measured from rachis to the base of the leaflet blade.

3.5.2.2.4 Leaflet blade length (cm)

Length of the leaflet blade was measured in centimetre from the base to the tip of the leaflet blade.

3.5.2.2.5 Leaflet blade width (cm)

Width of the leaflet blade was measured in centimetre at the widest portion.

3.5.3 Flowering characters:

3.5.3.1 Qualitative characters

3.5.3.1.1 Date of first and last panicle initiation

The trees under the study were regularly visited at alternate days during the months of January to March in two successive years (2017 and 2018) to record the time of emergence of panicle on each genotype.

3.5.3.1.2 Date of opening of first and last male flower

Date of opening of male flower was recorded by visual observations of each tree through regular visits during flowering time.

3.5.3.1.3 Date of opening of first and last hermaphrodite functional male

Date of opening of hermaphrodite functional male was recorded by visual observations of each tree through regular visits during flowering time.

3.5.3.1.4 Date of opening of first and last hermaphrodite functional female

Date of opening of hermaphrodite functional female was recorded by visual observations of each tree by regular visits during flowering time.

3.5.3.1.5 Flower disc colour

The flower disc colour was observed and was rated as follow:

1=Light cream, 2=Light yellow,3= Dark yellow, 4=Pinkish

3.5.3.1.6 Position of inflorescence

The position of inflorescence was observed and was rated as follow: 1=Terminal, 2=Axillary, 3=Both

3.5.3.1.7 Abundance of flower

The flower abundance was visually assessed and rated as follow:

1=Profuse, 2=Moderate, 3=Sparse

3.5.3.2 Quantitative characters

3.5.3.2.1 Duration of flowering (Days)

Duration of flowering was calculated by recording of initiation of opening of first flower and ending of opening of flower in the same panicle.

3.5.3.2.2 Length of inflorescence (cm)

Five panicles were tagged on four sides of plant *i.e.,* east, west, north and south for measuring the length of the inflorescence from the base to the tip and expressed in centimetre.

3.5.3.2.3 Width of inflorescence (cm)

On the five tagged panicles width of the inflorescence was measured at the widest portion of the inflorescence at full bloom stage and expressed in centimetre.

3.5.3.2.4 Per cent of functional female flower

Number of hermaphrodite female flowers (F) was counted and per cent hermaphrodite female flowers (F) were calculated over the total number of flowers.

3.5.4 Fruit characters

3.5.4.1 Qualitative characters

3.5.4.1.1 Date of initiation and end of fruit set

Date of fruit set was recorded when tagged panicles of each germplasm starts and end set fruits.

3.5.4.1.2 Fruit maturity group

Maturity group of fruit was assessed as per the following rating:

1= Early, 2=Medium, 3= Late

3.5.4.1.3 Fruit ripening

Ripening of fruit on single plant was observed as per following rating:

1=Synchronous ripening, 2=Non-synchronous ripening

3.5.4.1.4 Fruit bearing habit

Fruit bearing habit was assessed as per the following rating:

1=Regular, 2=Alternate years, 3=Irregular, 4= Partially Regular Bearer

3.5.4.1.5 Fruit bearing intensity

Fruit bearing intensity was assessed as per the following rating:

1=Poor, 2=Medium, 3=Heavy

3.5.4.1.6 Fruit clustering habit

Fruit clustering habit was evaluated under

1=Solitary, 2=Clusters

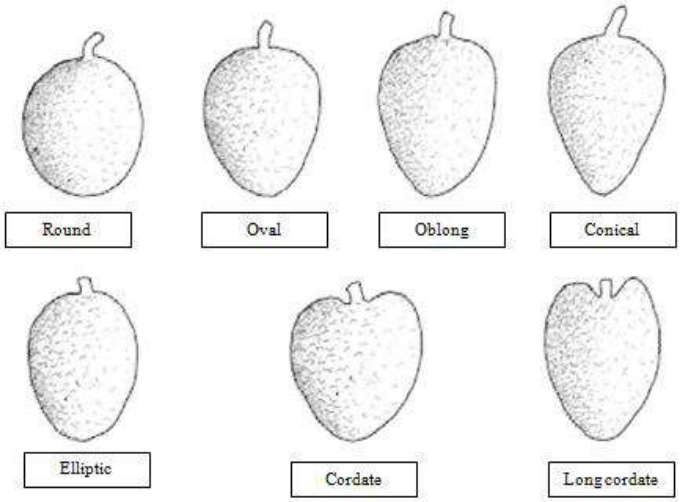
3.5.4.1.7 Tendency of fruiting

The tendency of fruiting was observed as:

1=Low, 2=Medium, 3= High

3.5.4.1.8 Fruit shape

Shape of the fruit was scored as1=Round, 2=Oval, 3=Oblong, 4=Conical, 5=Elliptic, 6=Cordate, 7=Long cordate



3.5.4.1.9 Fruit shoulder

The nature of fruit shoulders were observed and scored as:

1=Smooth or uneven,2= Protruding

3.5.4.1.10 Fruit tip

Shape of the fruit apex was observed and rated as follow:

1=Round, 2= Obtuse, 3= Acute

3.5.4.1.11 Segmentation on fruit skin

The nature of fruit segment was observed as per the following rating:

1=Sharp pointed, 2=Nipple shaped, 3=Swelling type, 4=Smooth

3.5.4.1.12 Cracking of fruit skin

The nature of fruit cracking (per bunch) was observed and rated as follow: 1=Not prone to cracking, 2=Prone to cracking, 3=Highly prone to cracking

3.5.4.1.13 Mature fruit colour

The colour of the fruits of each cultivar was visually observed at full mature stage and rated as follow:

1=Green, 2=Greenish yellow, 3=Greenish red, 4=Pinkish red,

5=Crimson, 6=Red, 7=Reddish yellow, 8=Dark red, 9=Purple red, 10=Rosy red, 11=Deep orange, 12=Deep pink, 13= Scarlet

3.5.4.1.14 Distribution of colour on fruit surface

The pattern of colour distribution on fruit surface was assessed and rated as follow:

1=Uniform, 2=Partial

3.5.4.1.15 Shape of tubercles

The shape of the tubercles was visually assessed by considering the following rating:

1=Slightly pointed, 2= Sharp pointed, 3= Extremely sharp pointed,

4=Wedge, 5=Obtuse, 6=Smooth, 7=Cuneate

3.5.4.1.16 Tubercles density

The density of the tubercles was recorded at fruit maturity and rated as follows:

3=Sparse, 5=Medium, 7=Dense

3.5.4.1.17 Presence of suture

The nature of suture was assessed as per following rating:

0=Absent, 3=Weak (visible, if noticed carefully), 7=Prominent (easily visible).

3.5.4.1.18 Fruit attractiveness

A combined assessment of fruit shape, size, colour and overall appearance was made for all the genotypes and fruits of each genotype were classified into 4 categories:

1=Poor, 2=Intermediate, 3=Good, 4=Excellent

3.5.4.1.19 Aril texture

The texture of aril was recorded on observation of fully ripe fruit and recorded as: 1=Soft, 2=Firm, 3=Coarse, 4=Fibrous, 5=Melting, 6=Leathery, 7= Crisp, 8=Extremely crisp

3.5.4.1.20 Aril quality

The quality of fruit was assessed by taste and recorded as per following rating:

1=Insipid, 2=Acidic, 3=Bitter, 4=Sweet

3.5.4.1.21 Aril flavour

Flavour of the aril was tasted by taking it into the mouth and recorded as per following rating:

1=Weak, 2=Intermediate, 3=Strong

3.5.4.1.22 Aril juiciness

The juiciness of aril was scored as: 0= Not juicy, 1=Juicy, 2=Very juicy

3.5.4.1.23 Aril colour

The aril colour was recorded of fully ripe fruit and rated as follows:

1=White, 2=Dull white, 3=Creamy white, 4=Creamy yellow, 5=Yellow, 6=Pearl white, 7=Waxy white, 8=Waxy yellow

3.5.4.2 Quantitative characters

3.5.4.2.1 Number of days from fruit set to maturity

The number of days was calculated from fruit set to harvesting by counting the number of days.

3.5.4.2.2 Number of fruit per cluster

The number of fruit was counted from the tagged panicle at harvesting.

3.5.4.2.3 Fruit length (mm)

Fruit length of a randomly collected sample having ten fruits per replication was measured at the longest positions by digital vernier's calliper and average fruit length was expressed in millimetre.

3.5.4.2.4 Fruit diameter (mm)

Fruit diameter of a randomly collected sample having ten fruits per replication was measured at the widest positionsby digital vernier callipers and average fruit width was expressed in millimetre.

3.5.4.2.5 Fruit weight (g)

Ten fruits per replication from each tree were randomly taken and weight (g) was recorded on a digital balance. The mean weight (g) was computed by dividing the total weight of the fruits with the number of fruits.

3.5.4.2.6 Aril weight (g)

The weight of peel and stone were subtracted from fruit weight to obtain the aril weight.

3.5.4.2.7 Aril thickness (mm)

The full mature fruit was cut into half and thickness of aril was measured at thickest point (shoulder part)with a digital vernier calliper and recorded in millimetre.

3.5.4.2.8 Total Soluble Solid (^{0}Brix)

Total soluble solids in the fruits were recorded at room temperature using digital refractometer and were expressed in terms of ^{0}Brix (Rangana 1997). Five fruits per replication were taken from each treatment for taking the average value.

3.5.4.2.9 Ascorbic acid (mg/100g)

Ascorbic acid content was estimated by the visual titration as described by Freed (1966). Twenty two mg of Sodium bicarbonate and 25 mg of 2,6 dichloro phenol indophenols were added to 100 ml distilled water and mix thoroughly. This reagent was kept in a amber colour bottle and stored in freeze and used within a week of its preparation.

$$\text{Ascorbic acid (mg/100 g)} = \frac{Volume\ made\ up\ x\ Dye\ factor\ x\ Titre\ value}{Aliquot\ of\ extract\ taken\ for\ est.\ x\ volume\ of\ sample\ taken} \times 100$$

3.5.4.2.10 Total sugar (%)

Total sugar content of litchi pulp was determined calorimetrically by the anthrone method (Jayaraman 1981).

Reagents: The following reagents were used for determination of total sugar:

(a) Anthrone reagent: the reagent was prepared by dissolving 2 g of anthrone in one litre of concentrated H_2SO_4,

(b) Standard glucose solution: a standard solution of glucose was prepared by dissolving 10 mg of glucose in 100 ml of distilled water.

Extraction of sugar from litchi pulp: Four gram of litchi flesh was cut into small pieces and immediately plunged into boiling ethyl alcohol and was allowed to boil for 5 to 10 minutes (5 to 10 ml of alcohol was used per gram of pulp).

The extract was cooled and crushed thoroughly in a mortar with pestle. Then the extract was filtered through two layers of muslin cloths and the ground tissue was re extracted for three minutes in hot 80% alcohol, using 2 to 3 ml of alcohol per gram of tissue. The second extraction ensured complete removal of alcohol soluble substances. The extract was cooled and passed through two layers of muslin cloth. Both of the extracts were filtered through Whatmann no.

41 filter paper. The volume of the extract was evaporated to about 25% (1/4) of the volume over a steam bath and cooled. This reduced volume of extract was transferred to a 100 ml volumetric flask and it was made up to the mark with distilled water.

Procedure: Aliquot of 1 ml of pulp extract was pipette into test tubes and 4 ml of the anthrone reagent was added to each of this solution and mixed well. Glass marbles were placed on top of each test tube to prevent loss of water through evaporation. Then the tubes were placed in a boiling water bath for 10 minutes and then cooled. A reagent blank was prepared by taking 1 ml of water and 4 ml of anthrone reagent in a tube and treated similarly. The absorbance of blue green solution was measured at 680 nm in a colorimeter. A standard curve of glucose was prepared and the amount of total sugar present in the extract was calculated from the standard curve of glucose. Finally, the percentage of total sugar was determined by using the following formula:

$$\text{Total sugar (g/100 g)} = \frac{Quantity\ of\ sugar\ obtained}{Weight\ of\ Sample} \times 100$$

3.5.4.2.11 Acidity (%)

Ten ml of juice was taken and volume made up 100 ml with distilled water. Then 10 ml of this solution was taken for the purpose of titration with 0.1 N NaOH as per method described by Ranganna (1997) using phenolphthalein as indicator. Titratable acidity of litchi fruits was calculated by using the following:

$$\text{Titratable acidity (\%)} = \frac{Titre\ value\ x\ Normality\ of\ alkali\ x\ equiv.wt.of\ acid}{Volume\ of\ sample\ taken\ x\ volume\ of\ sample} \times 100$$

3.5.4.2.12 Reducing sugar:

The reducing sugar of litchi pulp was determined by Dinitrosalicylic acid method (Miller 1972).

Reagents: The following reagents were used for determination of total sugar:

Dinitrosalicylic acid: Dissolved by stirring one gram of DNS, 200 mg crystalline phenol and 50 mg sodium sulphate in 100 ml of 1% NaOH.

40 % Rochelle salt Solution

Procedure: Hundred mg of sample was weighed and extracted sugar with 80 % Ethanol twice (5 ml each time). Supernatant was collected and evaporated by keeping it on water bath at 80 ^{0}C. Sugar was dissolved by adding 10 ml of distilled water. The 0.3 ml of extract was taken in test tube and volume made up to 3 ml with distilled water and added 3 ml of DNS reagent. The content was heated in a water bath for five minutes and added 1 ml of Rochelle salt. Read the absorbance at 510 nm when solution was cool. The standard glucose was made to prepare graph and calculated the amount of reducing sugar.

3.5.4.2.13 TSS/acidity ratio

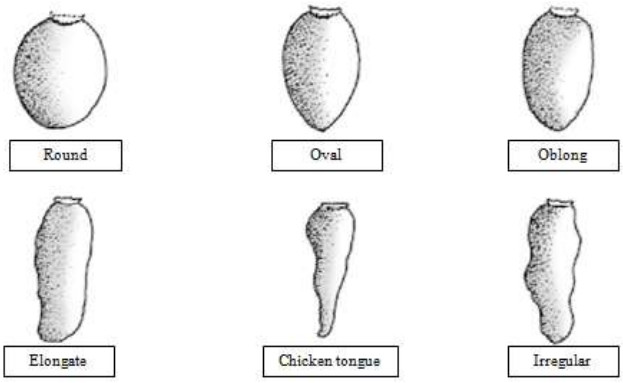
It was calculated by dividing the total soluble solids with titratable acidity.

3.5.5 Seed characters

3.5.5.1 Qualitative characters

3.5.5.1.1 Seed shape: The shape of the seed was visually assessed and recorded as per the following rating:

1=Round, 2=Oval, 3=Oblong, 4=Elongate, 5=Chicken tongue, 6=Irregular



3.5.5.1.2 Seed coat colour: The colour of seed coat was visually assessed and rated as follows:

1=Off-white, 2=Creamish, 3=Dull brown, 4=Brown, 5=Dark brown

3.5.5.2 Quantitative characters

3.5.5.2.1 Seed length (mm)

Seed length of a randomly collected sample having five fruits was measured by digital vernier's calliper and average seed length was expressed in terms of millimetre.

3.5.5.2.2 Seed width (mm)

Seed width of a randomly collected sample having five fruits was measured by digital vernier's calliper and average seed width was expressed in terms of centimetre millimetre.

3.5.5.2.3 Weight of seed (g)

It was calculated by taking the weight of each seed on electronic weighing balance after extracting it from the fruit. Seed weight was expressed in grams.

3.5.6 Physiological and Bio-chemical character

3.5.6.1 Chlorophyll (mg/100 g)

The chlorophyll contents (chlorophyll a, b and total chlorophyll) of the leaves were analyzed following the method suggested by Arnon (1949). Fully mature open leaf was chosen as the experimental sample for chlorophyll estimation. Accurately, 0.5 g of clean leaf sample was immersed in 10 ml of dimethyl sulphoxide (DMSO) AR grade. The sample was incubated at 80 ^{0}C for four hours in hot air oven. After incubation, it was taken out and 1 ml of the solution was

diluted to 5 ml with DMSO and the sample was then read on a Spectrophotometer at 645 and 663 nm using pure DMSO as blank. Chlorophyll a, chlorophyll b and total chlorophyll were calculated according to the following formula:

Chlorophyll a (mg/100 g) = 12.7 (A_{663}) - 2.69 (A_{645})

Chlorophyll b (mg/100 g) = 22.9 (A_{645}) - 4.68 (A_{663})

Total chlorophyll (mg/100 g) = 20.2 (A_{645}) + 8.02 (A_{663})

3.5.6.2 Total phenol (mg GAE/g):

The total phenolic content was determined by the method given by Sethi *et al.* (2013). Weighed exactly 200 mg of the sample and ground it with pestle and mortar in 10 ml of 80 % ethanol. Centrifuged to homogenate at 10,000 rpm for 10 minutes and extract the supernatant. Pipetted out 20 microlitre in attest tube and make up the volume to 3 ml with distilled water and then added 0.5 ml of 1N of FCR (Folin Ciocalteau reagent). After three minutes, added 2 ml of 20% of Na_2CO_3 solution to each tube. The sample was mixed thoroughly and the absorbance was taken at 750 nm. Standard curve was established using various concentrations of gallic acid and results were expressed as gallic acid equivalent (GAE). Total Phenolic content was calculated as gallic acid equivalent (mg/100g).

3.5.6.3 Total flavonoids (mg CE/g)

The total flavonoids content was determined by the method given by Sethi *et al.* (2013). A known volume (1ml) of the sample extract in 80% ethanol was added to make up the volume to 5 ml with distilled water and 0.3 ml of 5% sodium nitrite was added. After 5 minutes, 0.3 ml of 10% $AlCl_3$ was added and after 6 minutes, 2 ml of 1M NaOH was added to mixture. This was followed by adding distilled water to make a final volume to 10 ml and mix to appear pink to yellow colour. Absorbance was read at 510 nm against the blank (water) and flavonoids content was expressed as catechin/g.

3.5.6.4 Total anthocyanin (mg/100 g)

Ten gram peel sample of each genotype was grinded in 10 ml of Ethanolic:HCL (85:15) was transferred to 50 ml conical flask. The solution was stored overnight at 4 ^{0}C and then filtered. Washed the bottle and residue on filter paper repeatedly with Ethanolic:HCL. Finally, make up the final volume of the solution up to 100 ml and store in the dark for 2 hrs. The absorbance of the sample was taken at 535 nm and total anthocyanin concentration was calculated by the following formula (Rangana 1997):

Total Anthocyanin (mg/100 g) = $\frac{OD\ x\ Dilution\ x\ total\ volume\ made\ up}{Weight\ of\ sample\ x\ e} \times 100$

Where, e = 98.2 (Absorbance of a solution containing 0.1mg/ml anthocyanin)

3.6 Statistical analysis

The observation recorded under Randomized Block Design (RBD) was subjected to statistical analysis by using Analysis of variance (Burton 1952), Correlation coefficient (Miller *et al.,* 1958) and Path coefficient analysis (Dewey and Lu 1959) were computed. Cluster analysis was performed based on Euclidean distance using unweighted pair-group method of arithmetic averages (UPGMA) by cluster function in R software v3.1.3. The results were presented by way of tables and graphs.

CHAPTER IV
RESULTS

RESULTS

The results of the field experiment entitled "Genetic studies of litchi (*Litchi chinensis* Sonn.) germplasm" was conducted during year 2016-17 and 2017-18 at National Active Germplasm Site, ICAR-NRC on Litchi, Muzaffarpur (Bihar) are presented in this chapter. Thirty germplasms were characterized and the results are presented under different heads and sub-heads. All phenotypic characters were recorded based on IPGRI descriptor.

4.1. Tree Characters

The observations on qualitative tree characters among the litchi germplasm under study are presenred below:

4.1.1. Qualitative characters

The data regarding the qualitative characters of tree are presented in table 4.1.1.

4.1.1.1 Trunk surface

The different trunk surfaces like smooth, rough and very rough were noticed among germplasm (Plate 1). Maximum germplasm possessed rough surface. Smooth surface were noticed in seven germplasm *viz*., IC-0615591, IC-0615593, IC-0615595, IC-0615603, IC-0615604, IC-0615605 and IC-0615613 while only two genotypes *viz*., Coll. 36 and Coll. 38 had very rough surface.

4.1.1.2 Crown shape

All the germplasm showed a broadly pyramid shaped canopy except IC-0615585, IC-0615586, IC-0615587, IC-0615592, IC-0615594, IC-0615595 and IC-0615597 which had spherical shaped canopy.

Smooth

Rough

Very Rough

Plate 1: Variations in trunk surface

Semi-erect

Spreading

Drooping

Plate 2: Variations in tree growth habit

Table 4.1.1: Qualitative tree characteristics of 30 litchi germplasm

Germplasm	Trunk Surface			Crown shape							Tree growth habit				Branching density			Branching pattern					Young Shoot pubescence	
	1	2	3	1	2	3	4	5	6	7	1	2	3	4	3	4	7	1	2	3	4	5	1	2
	Smooth	Rough	Very rough	Pyramidal	Broadly Pyramidal	Spherical	Oblong	Semicircular	Dome	Irregular	Erect	Semi-erect	Spreading	Drooping	Sparse	Medium	Dense	Erect	Opposite	Verticillate	Horizontal	Irregular	Glabrous	Pubescent
IC-0615585		2				3							3			4				3				1
IC-0615586		2				3							2			4				3				1
IC-0615587		2				2							3			4				5				2
IC-0615588		2				3							3			4				5				1
IC-0615589		2				2							2			4				5				1
IC-0615590		2				2							2			4				5				1
IC-0615591		1				2							2			4				5				1
IC-0615592		2				3							2			4				5				1
IC-0615593		1				2							4			7				3				2
IC-0615594		2				3							2			7				5				1
IC-0615595		1				3							3			7				3				1
IC-0615596		2				2							4			7				3				2

IC-0615597	2	3	2	4	5	1
Coll. 39	2	2	3	4	3	1
IC-0615599	2	2	2	3	5	1
IC-0615600	2	2	2	3	5	1
IC-0615601	2	2	2	4	5	1
IC-0615602	2	2	2	3	3	1
IC-0615603	1	2	2	4	3	1
IC-0615604	1	2	4	7	5	1
IC-0615605	1	2	2	4	5	1
IC-0615606	2	2	2	4	5	1
IC-0615608	2	2	2	4	3	1
IC-0615610	2	2	2	3	5	1
IC-0615611	3	2	2	4	5	1
IC-0615613	1	2	3	4	5	1
Coll. 35	2	2	2	3	5	1
Coll. 36	3	2	2	4	5	1
Coll. 37	2	2	2	4	5	1
Coll. 38	3	2	2	4	3	1

4.1.1.3 Tree growth habit

The growth habits of germplasm were recorded as semi-erect, spreading and drooping in our study (Plate 2). The drooping growth habit was noticed in three genotypes *viz.,* IC-0615593, IC-0615596 and IC-0615604 while spreading growth habit was noticed in IC-0615585, IC-0615587, IC-0615588, IC-0615595, Coll. 39, IC-0615613 and rest germplasm had semi-erect growth habit.

4.1.1.4 Branching density

Low branching density was noticed in three genotypes *viz*., IC-0615599, IC-0615600 and IC-0615602 while high branching density was noticed in four genotypes *viz*., IC-0615593, IC-0615594, IC-0615595 and IC-0615603, and medium branching density were recorded in rest germplasm.

4.1.1.5 Branching pattern

Verticillate branching pattern was found more common in ten genotypes *viz*., IC-0615586, IC-0615587, IC-0615593, IC-0615595, IC-0615596, Coll. 39, IC-06155602, IC-0615603, IC-0615608 and Coll. 38 while other germplasm had irregular branching pattern.

4.1.1.6 Young shoot pubescence

Glabrous young shoot pubescence was noticed in all the genotypes except IC-0615587, IC-0615593 and IC-0615596 which had pubescent shoot.

4.1.2. Quantitative characters

4.1.2.1. Tree height (m)

The observations recorded on tree height are presented in table 4.1.2 and graphically depicted in Figure 4.1. The height of plant in litchi genotypes ranged from 2.20 to 4.45 m in 2017 and from 2.80 to 4.75 m in 2018. The analysis of variance indicated that the germplasm differed significantly in both the years and pooled analysis as well. The maximum height was noticed in genotype Coll. 39 (4.45 m) followed by IC-0615585 and IC-0615610 (4.20 m), IC-0615586 (4.10 m), IC-0615597 (4.00 m) whereas, lowest height of tree was

recorded in IC-0615599 (2.20 m) followed by IC-0615608 (3.00 m), IC-0615595 (3.10 m) during first year while during second year, the maximum height was recorded in Coll. 39 (4.75 m) followed by IC-0615610 (4.60 m), IC-0615585 and IC-0615586 (4.40 m), Coll. 35 (4.35 m) whereas, the lowest height was noticed in IC-0615599 (2.8 m) followed by IC-0615608 (3.20 m), IC-0615587 and IC-0615613 (3.40 m).

In pooled analysis, the maximum height was recorded in genotype Coll. 39 (4.60 m) succeeded by IC-0615610 (4.40 m), IC-0615585 (4.30 m), IC-0615586 (4.25 m) whereas, lowest height was noticed in IC-0615599 (2.50 m) followed by IC-0615608 (3.10 m) and IC-0615587 (3.25 m).

4.1.2.2 Trunk girth (cm)

The observations recorded on trunk girth are presented in table 4.1.3 and graphically depicted in Figure 4.2. The trunk girth of litchi genotypes ranged from 33 to 65.50 cm in 2017 and from 38 to 72 cm in 2018. The analysis of variance revealed that the germplasm differed highly significantly in both the years and pooled analysis as well.The maximum girth of trunk was recorded in genotype IC-0615596 (65.50 cm) followed by IC-0615597 (65.00 cm), IC-0615592 and IC-0615602 (63.00 cm) whereas, minimum trunk girth was found in both the genotypes IC-0615587 and IC-0615599 (33.00 cm) followed by IC-0615608 (42.00 cm) and IC-0615588 (44.00 cm) during 2017.

In 2018, the maximum trunk girth was found in IC-0615592 (72.00 cm) followed by IC-0615602 (71.20 cm) and IC-0615597 (71.00 cm) while lowest trunk girth was recorded in IC-0615587 (38.00 cm) followed by IC-0615599 (40.00 cm) and IC-0615608 (44.00 cm).

From the pooled data it was observed that the maximum girth was found in genotype IC-0615597 (68.00 cm) followed by IC-0615592 (67.50 cm) and IC-0615596 (67.33 cm) whereas, lowest

Table 4.1.2: Height of different litchi germplasm

Germplasm	Tree height (m)		
	2017	2018	Pooled
IC-0615585	4.20	4.40	4.30
IC-0615586	4.10	4.40	4.25
IC-0615587	3.10	3.40	3.25
IC-0615588	3.30	3.70	3.50
IC-0615589	3.80	3.95	3.88
IC-0615590	3.90	4.10	4.00
IC-0615591	3.40	3.80	3.60
IC-0615592	3.65	3.90	3.78
IC-0615593	3.97	4.20	4.09
IC-0615594	3.80	4.00	3.90
IC-0615595	3.10	3.45	3.28
IC-0615596	3.50	3.65	3.58
IC-0615597	4.00	4.20	4.10
Coll. 39	4.45	4.75	4.60
IC-0615599	2.20	2.80	2.50
IC-0615600	3.80	3.95	3.88
IC-0615601	3.80	4.20	4.00
IC-0615602	3.75	3.95	3.85
IC-0615603	3.75	3.80	3.78
IC-0615604	3.80	3.85	3.83
IC-0615605	3.70	3.80	3.75
IC-0615606	3.80	4.20	4.00
IC-0615608	3.00	3.20	3.10
IC-0615610	4.20	4.60	4.40
IC-0615611	3.80	4.00	3.90
IC-0615613	3.20	3.40	3.30
Coll. 35	3.75	4.35	4.05
Coll. 36	3.30	3.65	3.48
Coll. 37	3.80	4.25	4.03
Coll. 38	3.50	3.60	3.55
SEm ±	0.06	0.04	0.04
CD at 5%	0.16	0.12	0.10

Table 4.1.3: Trunk girth of different litchi germplasm

Germplasm	Trunk girth (cm)		
	2017	2018	Pooled
IC-0615585	55.50	60.15	57.83
IC-0615586	55.00	63.00	59.00
IC-0615587	33.00	38.00	35.50
IC-0615588	44.00	52.00	48.00
IC-0615589	52.00	58.50	55.25
IC-0615590	60.00	62.00	61.00
IC-0615591	61.00	67.00	64.00
IC-0615592	63.00	72.00	67.50
IC-0615593	57.50	62.50	60.00
IC-0615594	56.00	60.00	58.00
IC-0615595	47.50	53.50	50.50
IC-0615596	65.50	69.15	67.33
IC-0615597	65.00	71.00	68.00
Coll. 39	60.00	68.30	64.15
IC-0615599	33.00	40.00	36.50
IC-0615600	52.00	62.00	57.00
IC-0615601	60.00	64.50	62.25
IC-0615602	63.00	71.20	67.10
IC-0615603	57.50	61.30	59.40
IC-0615604	56.00	63.00	59.50
IC-0615605	50.00	57.00	53.50
IC-0615606	63.00	70.00	66.50
IC-0615608	42.00	44.00	43.00
IC-0615610	61.00	64.00	62.50
IC-0615611	46.00	55.00	50.50
IC-0615613	46.00	54.00	50.00
Coll. 35	50.00	57.00	53.50
Coll. 36	45.20	53.20	49.20
Coll. 37	50.40	59.40	54.90
Coll. 38	46.00	54.80	50.40
SEm ±	1.76	5.66	5.95
CD at 5%	5.00	16.05	16.88

Table 4.1.4: Crown diameter of different litchi germplasm

Germplasm	Crown diameter (m)		
	2017	2018	Pooled
IC-0615585	5.14	5.38	5.26
IC-0615586	5.30	5.51	5.40
IC-0615587	3.60	4.08	3.84
IC-0615588	4.55	4.95	4.75
IC-0615589	4.65	5.71	5.18
IC-0615590	4.95	5.26	5.11
IC-0615591	4.05	4.87	4.46
IC-0615592	4.25	5.30	4.78
IC-0615593	6.15	6.98	6.57
IC-0615594	5.10	5.32	5.21
IC-0615595	4.60	4.91	4.75
IC-0615596	6.05	6.53	6.29
IC-0615597	4.75	5.37	5.06
Coll. 39	5.10	5.47	5.29
IC-0615599	3.30	3.93	3.62
IC-0615600	5.45	6.14	5.80
IC-0615601	5.50	6.12	5.81
IC-0615602	5.95	6.37	6.16
IC-0615603	4.70	5.14	4.92
IC-0615604	5.55	6.13	5.84
IC-0615605	4.70	4.83	4.77
IC-0615606	5.95	6.18	6.07
IC-0615608	3.70	4.25	3.98
IC-0615610	6.00	6.40	6.20
IC-0615611	4.85	5.18	5.02
IC-0615613	5.00	5.22	5.11
Coll. 35	5.35	5.74	5.55
Coll. 36	5.15	5.83	5.49
Coll. 37	5.80	6.30	6.05
Coll. 38	5.60	5.99	5.80
SEm ±	0.04	0.03	0.03
CD at 5%	0.10	0.09	0.09

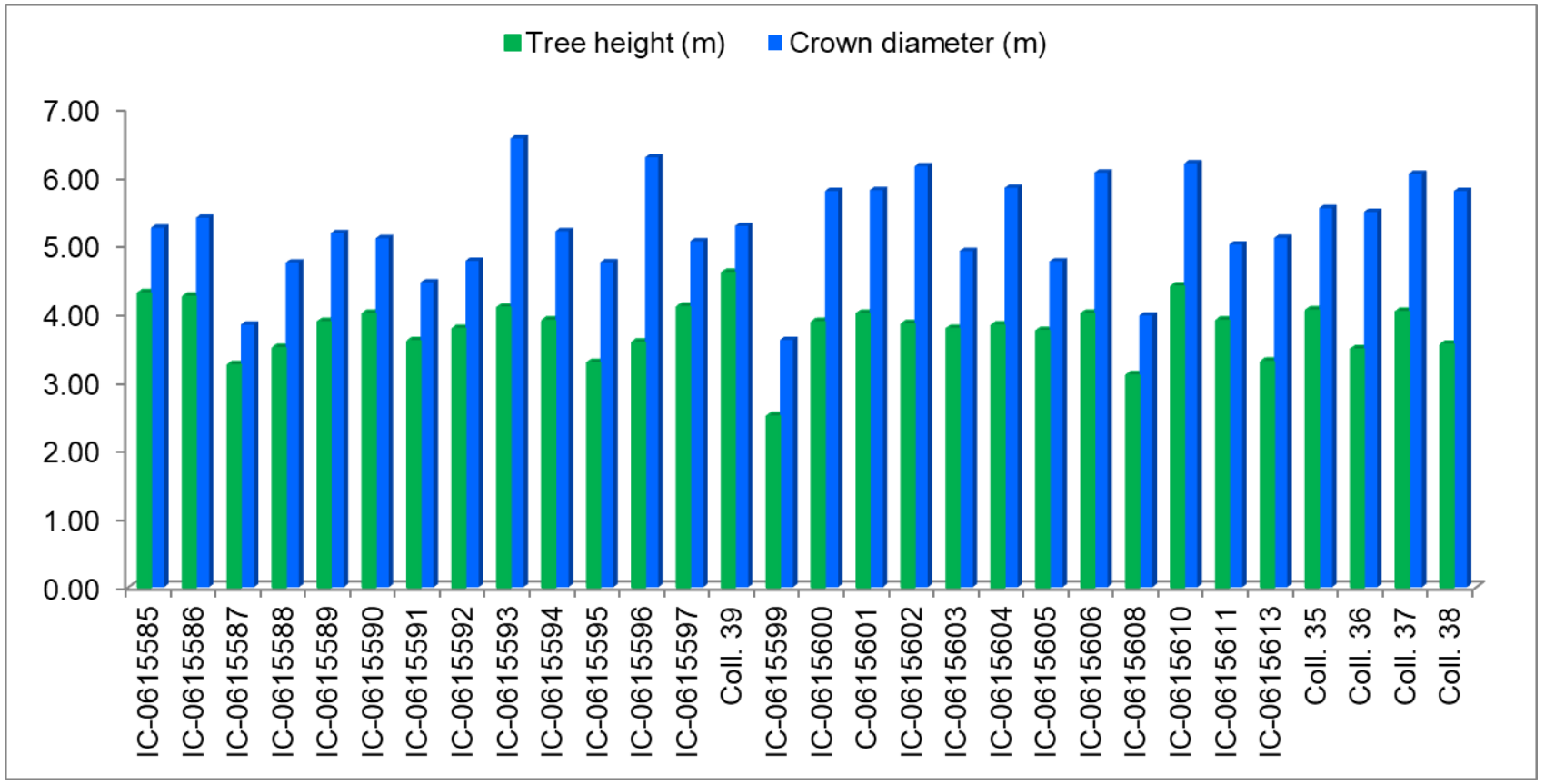


Figure 4.1: Variation in tree height and crown diameter among 30 litchi germplasm

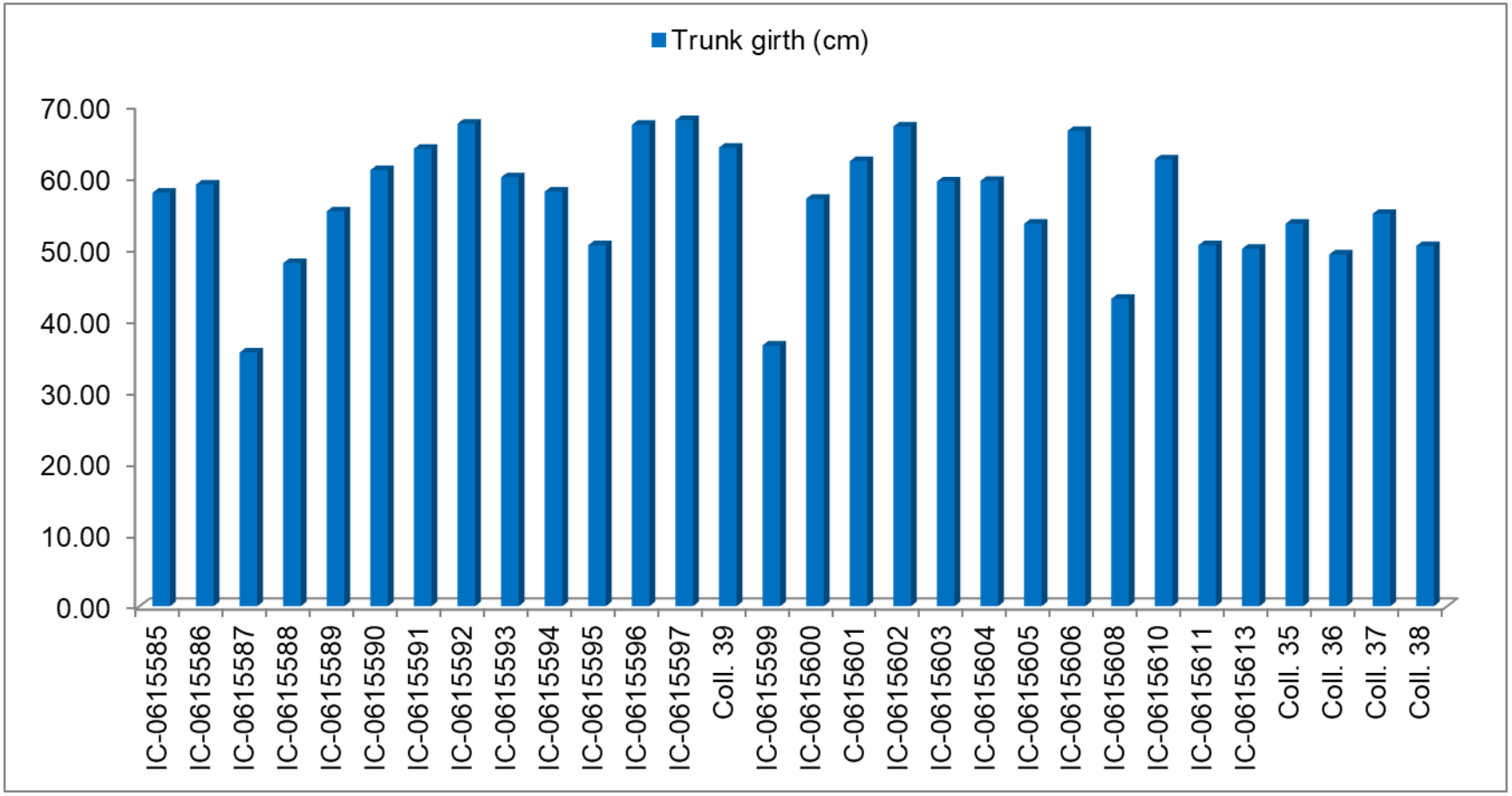


Figure 4.2: Variation in trunk girth among 30 litchi germplasm

girth was recorded in IC-0615587 (35.50 cm) followed by IC-0615599 (36.50 cm) and IC-0615608 (43.00 cm).

4.1.2.3 Crown diameter (m)

The data regarding crown diameter has been presented in table 4.1.4 and graphically depicted in Figure 4.1. The crown diameter in litchi genotypes ranged from 3.30 to 6.15 m in 2017 and from 3.93 to 6.98 m in 2018. The analysis of variance indicated that the germplasm differed highly significantly in both the years and pooled analysis as well. A glance of the data indicated in both the years and pooled analysis as well. A glance of the data indicated that crown diameter was found maximum in genotype IC-0615593 (6.15 m) followed by IC-0615596 (6.05 m) and IC-0615610 (6.00) whereas, lowest was recorded in IC-0615599 (3.30 m) followed by IC-0615587 (3.60 m) and IC-0615608 (3.70 m) during 2017.

In 2018, the maximum crown diameter was recorded in genotype IC-0615593 (6.98 m) followed by IC-0615596 (6.53 m) and IC-0615610 (6.40 m) whereas, lowest crown diameter was found in IC-0615599 (3.93 m) followed by IC-0615587 (4.08 m) and IC-0615608 (4.25 m).

From the pooled data it was observed that the maximum crown diameter was recorded in genotype IC-0615593 (6.56 m) followed by IC-0615596 (6.29 m) and IC-061561 (6.02 m) while lowest was found in IC-0615599 (3.61 m) followed by IC-0615587 (3.84 m) and IC-0615608 (3.97 m).

4.1.2.4 Tree volume (m^3)

Data regarding the tree volume of litchi germplasm are given in table 4.1.5 and graphically depicted in Figure 4.3**.** The tree volume in litchi genotypes ranged from 5.66 to 32.16 m^3 in 2017 and from 7.20 to 34.02 m^3 in 2018. A close persual of the data indicated that tree volume was recorded maximum in genotype IC-0615593 both the year (32.16 m^3 and 34.02 m^3) followed by IC-0615610 (28.6 m^3 and

Table 4.1.5: Tree volume of different litchi germplasm

Germplasm	Tree volume (m^3)		
	2017	2018	Pooled
IC-0615585	20.21	21.17	20.69
IC-0615586	20.68	22.19	21.44
IC-0615587	8.59	9.42	9.01
IC-0615588	13.44	15.07	14.26
IC-0615589	20.60	21.41	21.00
IC-0615590	17.94	18.86	18.40
IC-0615591	13.38	14.95	14.17
IC-0615592	17.05	18.21	17.63
IC-0615593	32.16	34.02	33.09
IC-0615594	17.86	18.80	18.33
IC-0615595	12.40	13.80	13.10
IC-0615596	24.81	25.88	25.34
IC-0615597	19.18	20.14	19.66
Coll. 39	22.14	23.63	22.88
IC-0615599	5.66	7.20	6.43
IC-0615600	23.82	24.76	24.29
IC-0615601	23.66	26.15	24.91
IC-0615602	25.30	26.65	25.97
IC-0615603	16.47	16.69	16.58
IC-0615604	23.76	24.08	23.92
IC-0615605	14.37	14.76	14.56
IC-0615606	24.13	26.67	25.40
IC-0615608	9.01	9.61	9.31
IC-0615610	28.60	31.32	29.96
IC-0615611	16.95	17.84	17.40
IC-0615613	14.50	15.40	14.95
Coll. 35	20.54	23.83	22.18
Coll. 36	18.65	20.62	19.64
Coll. 37	25.07	28.04	26.56
Coll. 38	20.88	21.47	21.18
SEm ±	0.67	0.64	0.66
CD at 5%	1.04	0.94	0.88

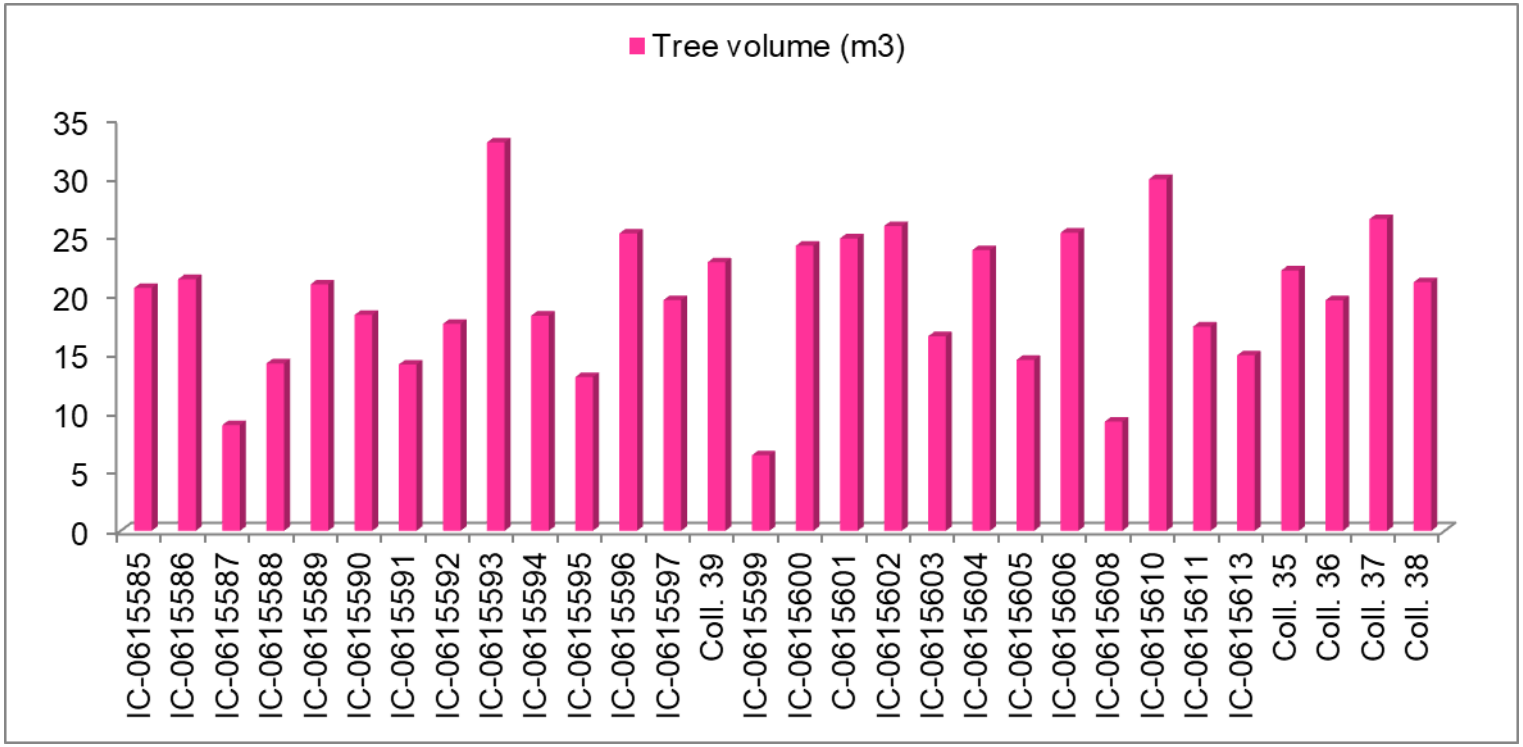


Figure 4.3: Variation in tree volume among 30 litchi germplasm

31.32 m^3) while lowest volume was found in IC-0615599 (5.66 m^3 and 7.2 m^3) followed by IC-0615587 (8.59 m^3 and 9.42 m^3).

From the pooled data it was observed that the maximum volume was found in IC-0615593 (33.09 m^3) followed by IC-0615610 (29.96 m^3), Coll. 37 (26.56 m^3), IC-0615602 (25.97 m^3) and IC-0615606 (25.40 m^3) whereas, lowest volume was recorded in IC-0615599 (6.43 m^3) followed by IC-0615587 (9.01 m^3), IC-0615608 (9.31 m^3), IC-0615595 (13.1 m^3) and IC-0615591 (14.17 m^3).

The maximum increases in tree volume were found in genotypes IC-0615599 (27.21%) and lowest in genotypes IC-0615603 (1.34 %).

4.2 Leaf characters

The observations on qualitative leaf characters among the litchi germplasm under study are presenred below:

4.2.1 Qualitative characters

The data regarding the qualitative character of leaf are presented in table 4.2.1 and 4.2.2.

4.2.1.1 Young leaf colour

The newly emerged young leaves of litchi showed variations in leaf colours (Plate 3 and 7). Deep pink colour was observed in three genotypes *viz*., IC-0615585, IC-0615593, IC-0615604, while bright pink colour was observed in six genotypes *viz*., IC-0615587, IC-0615592, IC-0615596, IC-0615611, IC-0615613 and Coll. 37. The pink colour was noticed in nine genotypes *viz*., IC-0615588, IC-0615590, IC-0615591, IC-0615595, IC-0615599, IC-0615603, IC-0615605, Coll. 36 and Coll. 38 whereas, yellowish green colour was observed in twelve genotypes *viz*.,IC-0615586, IC-0615589, IC-0615594, IC-0615594, IC-0615597, Coll. 39, IC-0615600, IC-0615601, IC-0615602, IC-0615606, IC-0615608, IC-0615610 and Coll. 35.

Yellowish Green | Pink | Bright Pink | Deep Pink

Plate 3: Variations in colour of young leaf

Light Green | Green | Dark Green

Plate 4: Variations in colour of mature leaf

4.2.1.2 Mature leaf colour

Green, Light Green and Dark Green colours were noticed in mature leaves among the germplasm (Plate 4 and 8). Green colour of mature leaves were noticed in eleven genotypes *viz*., IC-0615586, IC-0615589, IC-0615594, IC-0615595, Coll. 39, IC-0615599, IC-0615600, IC-0615608, IC-0615585, Coll. 35 and Coll. 37 while dark green colour was noticed in fourteen genotypes *viz*., IC-0615585, IC-0615587, IC-0615588, IC-0615590, IC-0615591, IC-0615592, IC-0615593, IC-0615596, IC-0615603, IC-0615604, IC-0615611, IC-0615613, Coll. 36 and Coll. 38. Light green colour was observed in five genotypes *viz*., IC-0615597, IC-0615601, IC-0615602, IC-0615605 and IC-0615606.

4.2.1.3 Arrangement of leaf

The arrangement of leaflets were recorded as opposite and both (alternate and opposite) among the all germplasm. Opposite arrangement of leaflets was noticed in all germplasm except IC-0615589, IC-0615594, IC-0615597, IC-0615605, IC-0615606, IC-0615611, Coll. 35, Coll. 36 and Coll. 37 which had both types of arrangement of leaflets.

4.2.1.4 Leaflet blade shape

All the germplasm possessed elliptic leaflet blade shape except IC-0615586 which had lanceolate shape.

4.2.1.5 Leaflet apex shape

Acute leaflet apex shape was noticed in all germplasm.

4.2.1.6 Leaflet base shape

Cuneate leaflet base shape was noticed in twenty two genotypes *viz*., IC-0615585, IC-0615587, IC-0615588, IC-0615589, IC-0615590, IC-0615591, IC-0615592, IC-0615593, IC-0615594, IC-0615595, IC-0615597, IC-0615600, IC-0615601, IC-0615602, IC-0615604,IC-0615608, IC-0615610, IC-0615611, IC-0615613, Coll. 35, Coll. 37 and Coll. 38 while oblique was found in IC-0615586 and IC-0615613, and attenuate leaflet base shape was noticed in six

genotypes *viz*., IC-0615595, Coll. 39, IC-0615599, IC-0615605, IC-0615606 and Coll. 36.

4.2.1.7 Leaflet upper surface pubescence

Leaflet upper surface pubescence was absent in all germplasm.

4.2.1.8 Leaflet lower surface pubescence

Leaflet lower surface pubescence was absent in all germplasm.

4.2.1.9 Leaflet midrib appearance

The leaflet midrib appearance was prominent in all germplasm.

4.2.1.10 Leaflet venation appearance

Leaflet venation appearance was prominent in six genotypes *viz*., IC-0615585, IC-0615586, IC-0615589, IC-0615595, IC-0615597 and IC-06155600. Non-prominent leaflet venation appearance was noticed in only two genotypes *viz*., IC-0615599 and IC-0615603 while slightly prominent was noticed in twenty two genotypes *viz*., IC-0615587, IC-0615588, IC-0615590, IC-0615591, IC-0615592, IC-0615593, IC-0615594, IC-0615595, Coll. 39, IC-0615601, IC-0615602, IC-0615604, IC-0615604, IC-0615606, IC-0615608, IC-0615610, IC-0615611, IC-0615613, Coll. 35, Coll. 36, Coll. 37 and Coll. 38.

4.2.1.11 Leaflet curvature

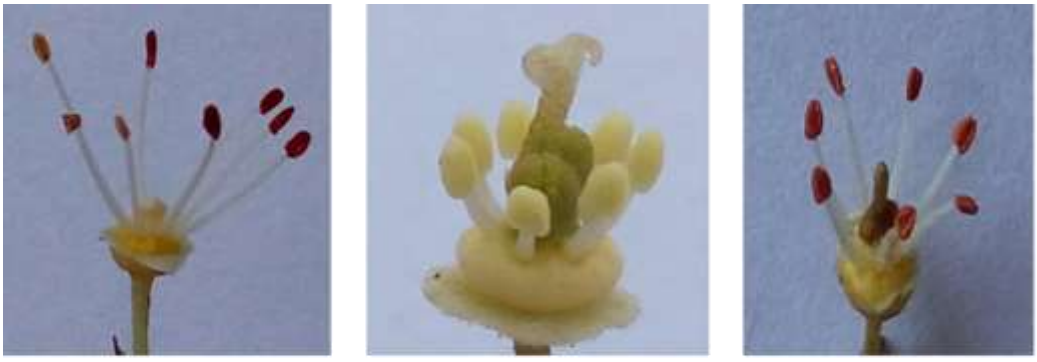
The leaflet curvature was observed (Plate 5) and noticed upward curve from the middle portion of leaflet in twenty one genotypes *viz*., IC-0615585, IC-0615586, IC-0615587, IC-0615588, IC-0615589, IC-0615593, IC-0615594, IC-0615595, IC-0615596, IC-0615597, Coll. 39, IC-0615599, IC-0615600, IC-0615601, IC-0615602, IC-0615606, IC-0615608, IC-0615610, IC-0615613, Coll. 35 and flat in IC-0615605 and only one genotype IC-0615605 has flat leaflet (no curve) while downward curve along the margin was noticed in rest germplasm.

4.2.1.12 Protuberance

Protuberance on petiole was present in all germplasm.

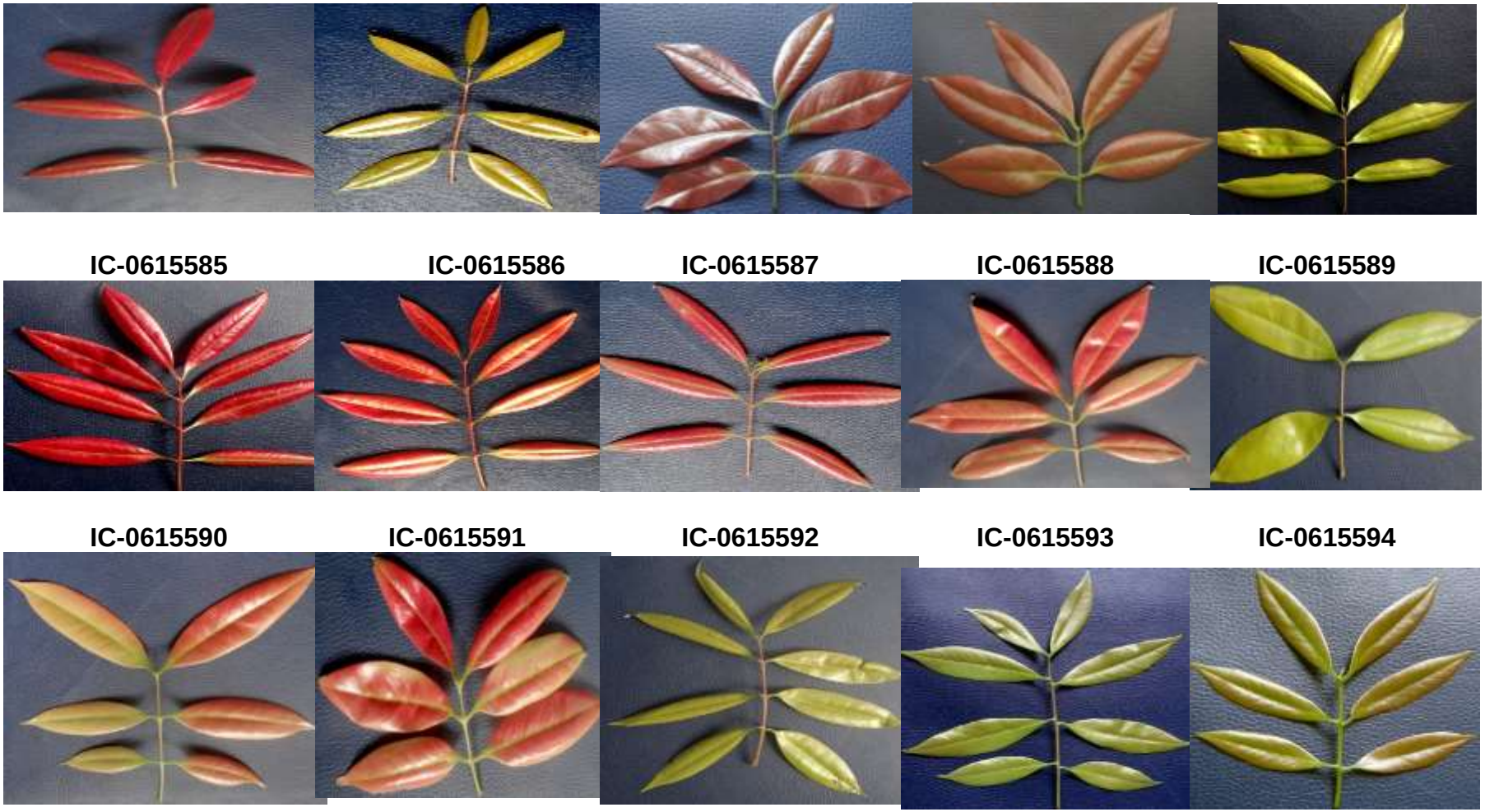
Flat Upward curve Downward

Plate 5: Variations in leaf curvature



M1 male flower Hermaphrodite (F) female flower M2 male flower

Plate 6: Different types of flowers in litchi



IC-0615585 IC-0615586 IC-0615587 IC-0615588 IC-0615589

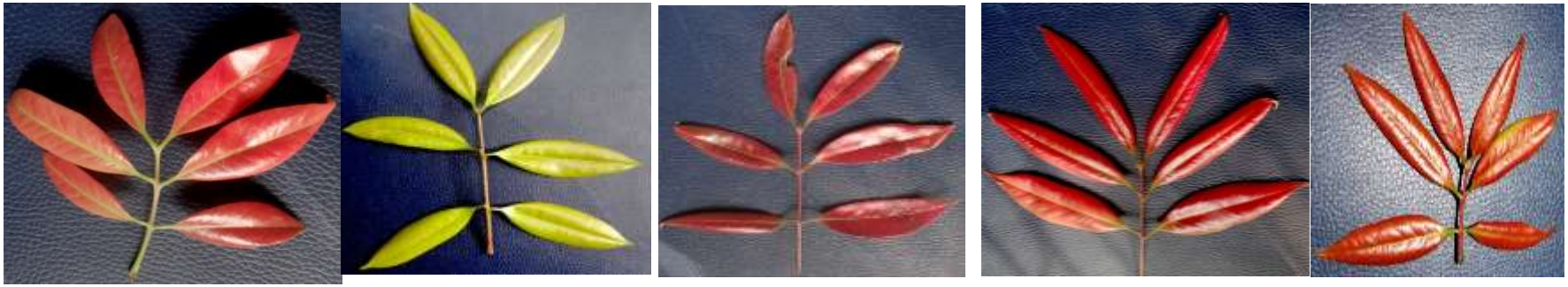
IC-0615590 IC-0615591 IC-0615592 IC-0615593 IC-0615594

IC-0615595 IC-0615596 IC-0615597 Coll. 39 IC-0615599

Plate 7: Variations in young leaf among 30 litchi germplasm

IC-0615600 IC-0615601 IC-0615602 IC-0615603 IC-0615604

IC-0615605 IC-0615606 IC-0615608 IC-0615610 IC-0615611



IC-0615613 Coll. 35 Coll. 36 Coll. 37 Coll. 38

Plate 7 (Contd): Variations in young leaf among 30 litchi germplasm

IC-0615585

IC-0615586

IC-0615587

IC-0615588

IC-0615589

IC-0615590

IC-0615591

IC-0615592

IC-0615593

IC-0615594

IC-0615595

IC-0615596

IC-0615597

Coll. 39

IC-0615599

Plate 8: Variation in mature leaf among 30 litchi germplasm

IC-0615600

IC-0615601

IC-0615602

IC-0615603

IC-0615604

IC-0615605

IC-0615606

IC-0615608

IC-0615610

IC-0615611

IC-0615613

Coll. 35

Coll. 36

Coll. 37

Coll. 38

Plate 8 (Contd): Variations in mature leaf among 30 litchi germplasm

Table 4.2.1: Qualitative leaf characteristics of 30 litchi germplasm

Germplasm	Young leaf colour										Mature leaf colour				Arrangem-ent of leaflet			Leaflet blade shape				Leaflet apex shape		Leaflet base shape			
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	1	2	3	1	2	3	4	1	2	1	2	3	4
	Light green	Yellowish green	Green	Light purple	Purple	Pinkish green	Reddish brown	Pink	Bright Pink	Deep Pink	Light green	Green	Dark green	Pinkish green	Alternate	Opposite	Both	Lanceolate	Ovate	Elliptic	Oblong	Acute	Acuminate	Attenuate	Oblique	Cuneate	Obtuse
IC-0615585	10										3				2			3				1		3			
IC-0615586	2										2				2			1				1		2			
IC-0615587	9										3				2			3				1		3			
IC-0615588	8										3				2			3				1		3			
IC-0615589	2										2				3			3				1		3			
IC-0615590	8										3				2			3				1		3			
IC-0615591	8										3				2			3				1		3			
IC-0615592	9										3				2			3				1		3			
IC-0615593	10										3				2			3				1		3			
IC-0615594	2										2				3			3				1		3			

IC-0615595	8	2	2	3	1	1
IC-0615596	9	3	2	3	1	3
IC-0615597	2	1	3	3	1	3
Coll. 39	2	2	2	3	1	1
IC-0615599	2	2	2	3	1	1
IC-0615600	2	2	2	3	1	3
IC-0615601	2	1	2	3	1	3
IC-0615602	2	1	2	3	1	3
IC-0615603	8	3	2	3	1	2
IC-0615604	10	3	2	3	1	3
IC-0615605	8	1	3	3	1	1
IC-0615606	2	1	3	3	1	1
IC-0615608	2	2	2	3	1	3
IC-0615610	2	2	2	3	1	3
IC-0615611	9	3	3	3	1	3
IC-0615613	9	3	2	3	1	3
Coll. 35	2	2	3	3	1	3
Coll. 36	8	3	3	3	1	1
Coll. 37	9	2	3	3	1	3
Coll. 38	8	3	2	3	1	3

Table 4.2.2: Qualitative leaf characteristics of 30 litchi germplasm

Germplasm	Leaflet upper surface pubescence		Leaflet lower surface pubescence		Leaflet midrib appearance			Leaf venation appearance			Leaflet curvature				Protuberance	
	0	1	0	1	1	2	3	1	2	3	1	2	3	4	0	1
	Absent	Present	Absent	Present	Not prominent	Slightly prominent	Prominent	Not prominent	Slightly prominent	Prominent	Curve upward from the midrib	Curve downward along the margin	Flat, no curve	Curve down slightly at the top	Absent	Present
IC-0615585	0		0		3			3			1				1	
IC-0615586	0		0		3			3			1				1	
IC-0615587	0		0		3			2			1				1	
IC-0615588	0		0		3			2			1				1	
IC-0615589	0		0		3			3			1				1	
IC-0615590	0		0		3			2			2				1	
IC-0615591	0		0		3			2			2				1	
IC-0615592	0		0		3			2			2				1	
IC-0615593	0		0		3			2			1				1	

IC-0615594	0	0	3	2	1	1
IC-0615595	0	0	3	2	1	1
IC-0615596	0	0	3	3	1	1
IC-0615597	0	0	3	3	1	1
Coll. 39	0	0	3	2	1	1
IC-0615599	0	0	3	1	1	1
IC-0615600	0	0	3	3	1	1
IC-0615601	0	0	3	2	1	1
IC-0615602	0	0	3	2	1	1
IC-0615603	0	0	3	1	2	1
IC-0615604	0	0	3	2	1	1
IC-0615605	0	0	3	2	3	1
IC-0615606	0	0	3	2	1	1
IC-0615608	0	0	3	2	1	1
IC-0615610	0	0	3	2	1	1
IC-0615611	0	0	3	2	2	1
IC-0615613	0	0	3	2	1	1
Coll. 35	0	0	3	2	1	1
Coll. 36	0	0	3	2	2	1
Coll. 37	0	0	3	2	2	1
Coll. 38	0	0	3	2	2	1

4.2.2 Quantitative characters:

4.2.2.1 Number of leaflet

The observations recorded on number of leaflet are presented in table 4.2.3. A perusal of data clearly showed that the genotype Coll. 35 produced maximum number of leaflets (7.48) followed by IC-0615610 (7.45) and IC-0615606 (7.28) whereas, minimum number of leaflet was found in genotype IC-0615587 (5.00) followed by IC-0615595 (5.52) and Coll. 39 (5.52) during 2017 while during 2018, the similar trend with maximum number of leaflets was found in Coll. 35 (7.30) followed by IC-0615610 (5.20) and minimum in IC-0615597 (5.09).

On the basis of pooled data, the maximum number of leaflets was found in genotype Coll. 35 (7.29) followed by IC-0615610 (7.23) and IC-0615590 (6.98) while lowest number of leaflets was recorded in IC-0615587 (5.05) followed by IC-0615595 (5.37) and IC-0615599 (6.04).

4.2.2.2 Rachis length (cm)

The observations recorded on rachis length presented in table 4.2.4 and graphically depicted in Figure 4.4. Statistical analysis of data reflected that highly significant difference was observed among different germplasm in respect of length of rachis. Maximum rachis length was recorded in genotype IC-0615608 for both the years (15.50 cm and 15.30 cm) while minimum length of rachis was found in IC-0615588 for both the years (6.30 cm and 6.53 cm) 2017 and 2018, respectively. However, IC-0615588 was *at par* with IC-0615595 in respect of minimum length of rachis.

Based on pooled data it has been stated that longest rachis length was recorded in IC-0615608 (15.40cm) followed by Coll. 35 (11.37 cm), IC-0615602 (11.25 cm) and IC-0615597 (11.20) whereas, minimum in IC-0615588 (6.45 cm) which was *at par* with IC-0615595 (6.51 cm) and IC-0615587 (6.52 cm).

Table 4.2.3: Number of leaflet of different litchi germplasm

Germplasm	Number of leaflet		
	2017	2018	Pooled
IC-0615585	6.10	6.09	6.10
IC-0615586	7.00	6.94	6.97
IC-0615587	5.00	5.09	5.05
IC-0615588	6.40	6.36	6.38
IC-0615589	6.50	6.62	6.56
IC-0615590	6.96	7.00	6.98
IC-0615591	6.85	6.92	6.89
IC-0615592	6.22	6.20	6.21
IC-0615593	6.70	6.67	6.69
IC-0615594	6.36	6.46	6.41
IC-0615595	5.40	5.64	5.52
IC-0615596	6.00	6.10	6.05
IC-0615597	6.80	6.82	6.81
Coll. 39	6.70	6.73	6.71
IC-0615599	6.00	6.08	6.04
IC-0615600	6.74	6.80	6.77
IC-0615601	6.36	6.31	6.33
IC-0615602	6.57	6.46	6.52
IC-0615603	6.26	6.27	6.27
IC-0615604	6.58	5.82	6.20
IC-0615605	6.56	6.69	6.63
IC-0615606	6.50	6.46	6.48
IC-0615608	6.93	6.95	6.94
IC-0615610	7.25	7.20	7.23
IC-0615611	6.95	6.97	6.96
IC-0615613	6.67	5.46	6.07
Coll. 35	7.28	7.30	7.29
Coll. 36	6.60	6.77	6.68
Coll. 37	6.56	6.69	6.63
Coll. 38	6.83	6.85	6.84
SEm ±	0.05	0.07	0.07
CD at 5%	0.15	0.19	0.21

Table 4.2.4: Rachis length of different litchi germplasm

Germplasm	Rachis length (cm)		
	2017	2018	Pooled
IC-0615585	8.25	8.86	8.56
IC-0615586	10.00	10.18	10.09
IC-0615587	6.50	6.60	6.52
IC-0615588	6.30	6.53	6.45
IC-0615589	9.95	9.81	9.88
IC-0615590	9.20	9.88	9.54
IC-0615591	9.60	9.24	9.42
IC-0615592	10.00	10.06	10.03
IC-0615593	7.48	7.96	7.72
IC-0615594	8.37	8.62	8.50
IC-0615595	6.46	6.56	6.51
IC-0615596	7.45	7.74	7.60
IC-0615597	11.00	11.40	11.20
Coll. 39	9.87	10.32	10.10
IC-0615599	7.75	7.81	7.78
IC-0615600	10.00	9.48	9.74
IC-0615601	9.86	10.10	9.98
IC-0615602	11.00	11.50	11.25
IC-0615603	9.52	9.65	9.59
IC-0615604	7.00	6.99	7.00
IC-0615605	8.45	8.97	8.71
IC-0615606	10.25	10.00	10.13
IC-0615608	15.50	15.30	15.40
IC-0615610	10.75	11.18	10.97
IC-0615611	10.30	10.92	10.61
IC-0615613	7.24	7.71	7.48
Coll. 35	11.50	11.24	11.37
Coll. 36	9.75	10.34	10.05
Coll. 37	11.00	10.74	10.87
Coll. 38	9.25	9.75	9.50
SEm ±	0.28	0.45	0.32
CD at 5%	0.80	1.27	0.92

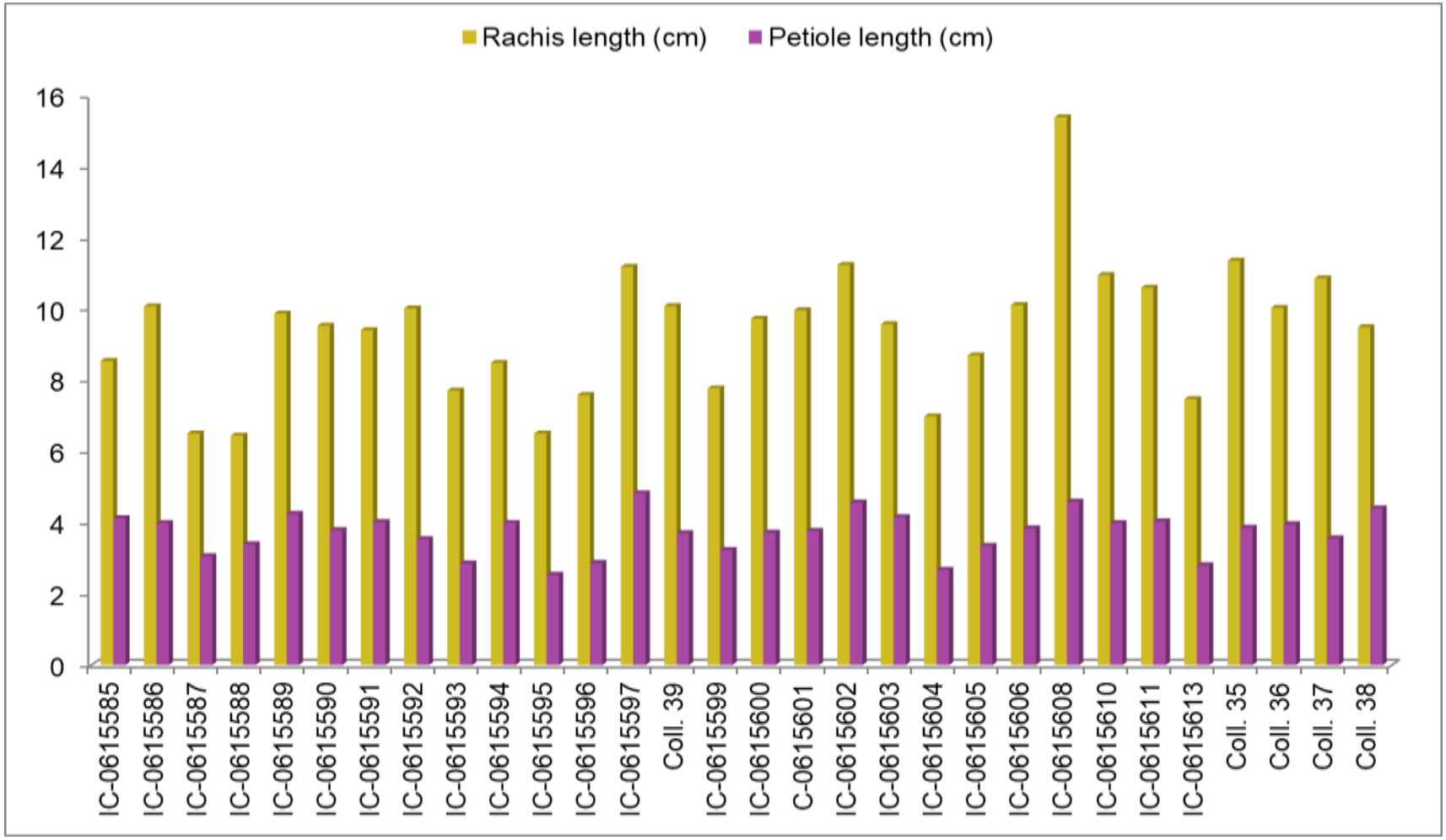


Figure 4.4: Variation in rachis and petiole length among 30 litchi germplasm

4.2.2.3 Length of petiole (cm)

The data with regards to petiole length for both the years and their mean values are shown in table 4.2.5 and graphically depicted in Figure 4.4. The analysis of variance table showed that the differences among germplasm were highly significant in both theyears and pooled analysis as well. A perusal of data clearly showed that the maximum length of petiole was recorded in genotype IC-0615597 in both the years (2017 and 2018) with 4.86 cm and 4.80 cm, respectively followed by IC-0615608 (4.61 cm and 4.58 cm), IC-0615602 (4.59 cm and 4.55 cm) and IC-0615589 (4.25 cm and 4.26 cm) whereas, minimum length was found in genotype IC-0615595 in both the years with 2.53 cm and 2.54 cm, respectively followed by IC-0615604 (2.69 cm and 2.66 cm), IC-0615613 (2.83 cm and 2.79 cm) and IC-0615593 (2.86 cm and 2.85 cm).

In pooled data also, maximum length of petiole was recorded in genotype IC-0615597 (4.83 cm) followed by IC-0615608 (4.60 cm) which was *at par* with IC-0615602 (4.57 cm) whereas, minimum length of petiole was found in IC-0615595 (2.54 cm) followed by IC-0615604 (2.68 cm), IC-0615613 (2.81 cm) and IC-0615593 (2.86 cm).

4.2.2.4 Leaflet blade length (cm)

Data regarding the leaflet length of litchi germplasm are given in table 4.2.6 and graphically depicted in Figure 4.5. It was observed from the analysis of variance that the differences among germplasm were highly significant in both the years and pooled analysis as well.

A perusal of data clearly showed that the maximum length of leaflet blade was recorded IC-0615608 in both the years with 16.00 cm and 15.96 cm, respectively followed by IC-0615594 (14.35 cm and 14.32 cm), IC-0615605 (14.10 cm and 14.00 cm) whereas, minimum length was recorded in IC-0615595 in both the years with 8.20 cm and 8.00 cm, respectively followed by IC-0615587 (8.70 cm and 8.64 cm), IC-0615613 (9.08 cm and 9.00 cm).

Table 4.2.5: Petiole length of different litchi germplasm

Germplasm	Length of petiole (cm)		
	2017	2018	Pooled
IC-0615585	4.14	4.12	4.13
IC-0615586	3.97	4.01	3.99
IC-0615587	3.04	3.08	3.06
IC-0615588	3.39	3.40	3.40
IC-0615589	4.25	4.26	4.26
IC-0615590	3.79	3.80	3.80
IC-0615591	4.03	4.01	4.02
IC-0615592	3.55	3.53	3.54
IC-0615593	2.86	2.85	2.86
IC-0615594	3.99	4.00	4.00
IC-0615595	2.53	2.54	2.54
IC-0615596	2.89	2.86	2.88
IC-0615597	4.86	4.80	4.83
Coll. 39	3.69	3.72	3.71
IC-0615599	3.22	3.25	3.24
IC-0615600	3.74	3.71	3.73
IC-0615601	3.79	3.75	3.77
IC-0615602	4.59	4.55	4.57
IC-0615603	4.17	4.15	4.16
IC-0615604	2.69	2.66	2.68
IC-0615605	3.37	3.34	3.36
IC-0615606	3.87	3.82	3.85
IC-0615608	4.61	4.58	4.60
IC-0615610	3.98	4.00	3.99
IC-0615611	4.09	4.00	4.05
IC-0615613	2.83	2.79	2.81
Coll. 35	3.88	3.84	3.86
Coll. 36	3.93	4.00	3.97
Coll. 37	3.56	3.56	3.56
Coll. 38	4.43	4.38	4.41
SEm ±	0.08	0.07	0.06
CD at 5%	0.22	0.20	0.18

Table 4.2.6: Length of leaflet blade of different litchi germplasm

Germplasm	Leaflet blade length (cm)		
	2017	2018	Pooled
IC-0615585	12.15	12.24	12.20
IC-0615586	13.50	13.34	13.42
IC-0615587	8.70	8.64	8.67
IC-0615588	11.38	11.34	11.36
IC-0615589	13.00	12.84	12.92
IC-0615590	14.05	14.00	14.03
IC-0615591	11.35	11.00	11.18
IC-0615592	12.15	12.00	12.08
IC-0615593	11.47	11.28	11.38
IC-0615594	14.35	14.32	14.34
IC-0615595	8.20	8.00	8.10
IC-0615596	9.60	9.20	9.40
IC-0615597	12.25	12.14	12.20
Coll. 39	10.95	10.85	10.90
IC-0615599	9.70	10.00	9.85
IC-0615600	13.30	13.00	13.15
IC-0615601	14.09	14.00	14.05
IC-0615602	12.40	12.10	12.25
IC-0615603	13.77	13.57	13.67
IC-0615604	13.05	13.00	13.03
IC-0615605	14.10	14.00	14.05
IC-0615606	12.85	12.75	12.80
IC-0615608	16.00	15.96	15.98
IC-0615610	13.25	13.40	13.33
IC-0615611	13.75	13.80	13.78
IC-0615613	9.08	9.00	9.04
Coll. 35	12.35	12.24	12.30
Coll. 36	11.65	11.42	11.54
Coll. 37	13.45	13.24	13.35
Coll. 38	12.85	12.67	12.76
SEm ±	0.27	0.28	0.28
CD at 5%	0.76	0.79	0.81

Table 4.2.7: Width of leaflet blade of different litchi germplasm

Germplasm	Leaflet blade width (cm)		
	2017	2018	Pooled
IC-0615585	4.00	3.82	3.91
IC-0615586	3.50	3.42	3.46
IC-0615587	3.60	3.52	3.56
IC-0615588	4.25	4.18	4.22
IC-0615589	3.50	3.52	3.51
IC-0615590	3.85	3.81	3.83
IC-0615591	3.20	3.15	3.18
IC-0615592	4.05	4.00	4.03
IC-0615593	3.92	4.00	3.96
IC-0615594	3.90	4.00	3.95
IC-0615595	3.70	3.80	3.75
IC-0615596	3.80	3.90	3.85
IC-0615597	3.90	3.85	3.88
Coll. 39	3.60	3.54	3.57
IC-0615599	3.00	2.98	2.99
IC-0615600	4.20	4.12	4.16
IC-0615601	4.10	4.00	4.05
IC-0615602	4.10	4.12	4.11
IC-0615603	5.10	5.00	5.05
IC-0615604	4.15	4.18	4.17
IC-0615605	3.70	3.60	3.65
IC-0615606	3.45	3.47	3.46
IC-0615608	4.20	4.10	4.15
IC-0615610	4.15	4.05	4.10
IC-0615611	4.00	4.00	4.00
IC-0615613	3.41	3.43	3.42
Coll. 35	3.60	3.70	3.65
Coll. 36	3.76	3.71	3.74
Coll. 37	3.85	3.80	3.83
Coll. 38	4.00	3.96	3.98
SEm ±	0.19	0.15	0.15
CD at 5%	0.54	0.42	0.41

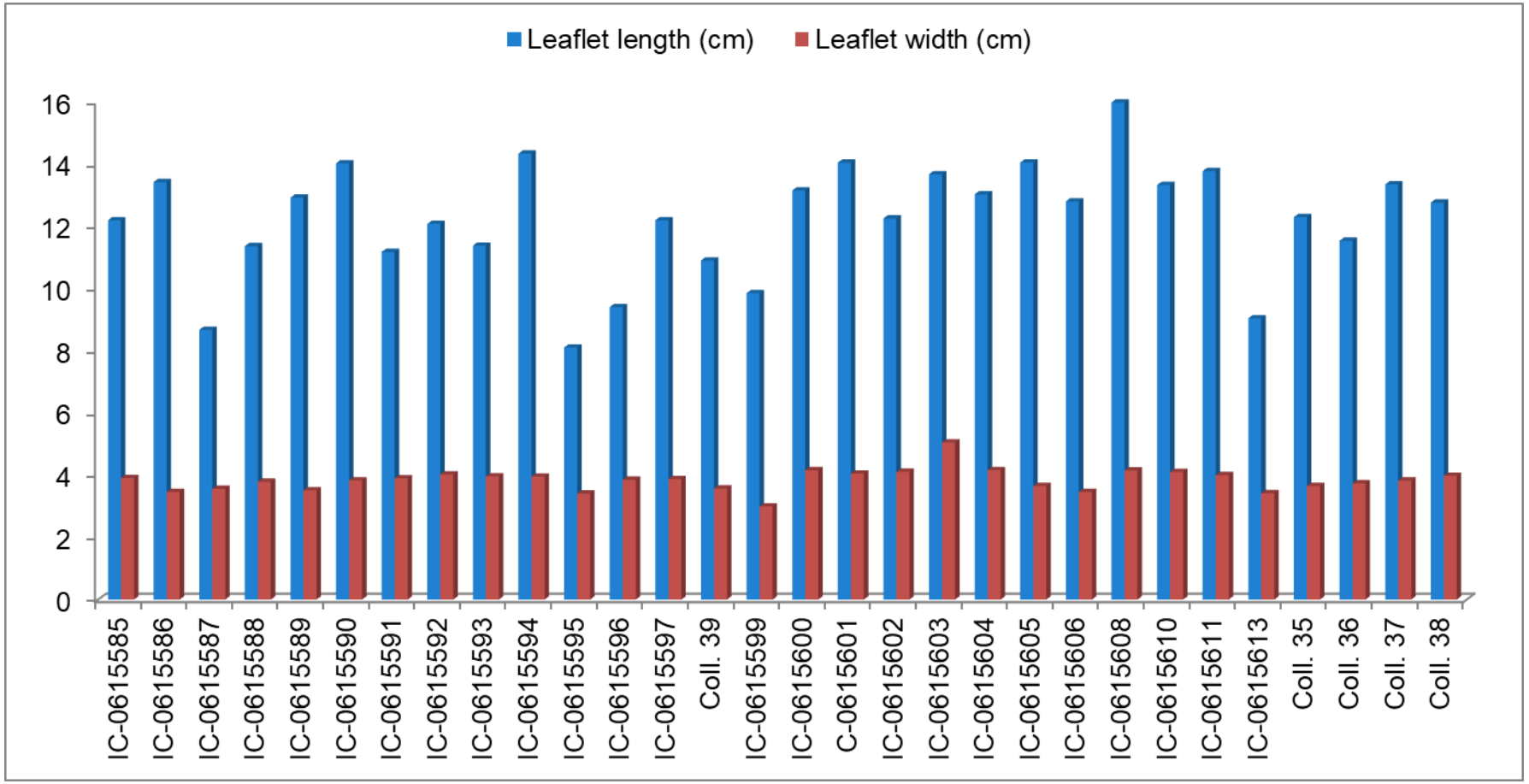


Figure 4.5: Variation in length and width of leaflet among 30 litchi germplasm

An observation of pooled data revealed that the maximum leaflet blade length was recorded in IC-0615608 (15.98 cm) followed by IC-0615594 (14.34 cm) and IC-0615601 (10.05 cm) while lowest length was found in IC-0615595 (8.10 cm) which was *at par* with IC-0615587.

4.2.2.5 Leaflet blade width (cm)

The data on leaflet width have been presented in table 4.2.7 and illustrated in Figure 4.5. The analysis of leaflet blade width for both the years and pooled data revealed that the germplasm differed significantly with respect to leaf width. A perusal of data clearly showed that the maximum width of leaflet blade was recorded with IC-0615603 in both the years (5.10 cm and 5.00 cm, respectively) and minimum in IC-0615599 (3.00 and 2.98 cm) followed by IC-0615595 (3.70 and 3.80 cm).

Pooled analysis revealed similar trend with maximum width was in IC-0615603 (5.05 cm) followed by IC-0615604 (4.17 cm) and IC-0615600 (4.16 cm) whereas, the lowest width was found in IC-0615599 (2.99 cm) followed by IC-0615595 (3.75 cm).

4.3 Flowering characters

The observations on flowering characters among the litchi germplasm under study are presenred below:

4.3.1 Qualitative characters

The data regarding qualitative flowering characters are presented in table 4.3.1, 4.3.2 and 4.3.3.

4.3.1.1 Date of first and last panicle emergence

The data regarding the date of panicle emergence of litchi germplasm are given in Table 4.3.1. A close perusal of data showed that date of initiation of panicle emergence in different germplasm of litchi under study varied from 10th January to 6th February during both the years. Panicle emergence was earliest (10thJanuary, 2017 and

12th January, 2018) in genotype IC-0615602 followed by IC-0615610 (13th January, 2017 and 14th January, 2018), while panicle emergence was late in IC-0615586 (5th February, 2017 and 6th February, 2018). The end of panicle emergence in different germplasm of litchi under study varied from 23rd January to 30th January during both the years. The first ending of panicle emergence was noticed in genotype IC-0615602 (23rd Januray, 2017 and 30th January, 2018) while it was finally ended in IC-0615599 (20th February, 2017) and in genotype IC-0615599 and IC-0615595 (22nd February, 2018).

The duration of panicle emergence was found minimum in Coll. 39 (13 days) and maximum in IC-0615603 (21 days) in the first year while during second year, the mimimum days were recorded in IC-0615586 (14 day) and maximum in IC-0615595 (26 days).

4.3.1.2 Date of opening of first and last male flower

The litchi produces three types of flower shown in plate 6. The data regarding the date of opening of first and last male flower of litchi germplasm are given in table 4.3.1. The opening of male flower started from 2nd March to 22nd March for both the years. The first opening of male flower was recorded in genotype IC-0615602 (2nd March, 2017 and 8th March, 2018) followed by IC-0615610 and IC-0615599 (4th March, 2017) and IC-0615599 and IC-0615587 (9th March, 2018). The last opening of male flower started from 8th March to 28th March for both the years. The opening of male flower was firstly ended in IC-0615602 (8th March, 2017 and 13th March, 2018) followed by IC-0615587 (9th March, 2017) andIC-0615589 (14th March, 2018) and opening of male flower was lastly ended in IC-0615599 (26th March, 2017 and 28th March, 2018).

Table 4.3.1: Qualitative flowering characteristics of 30 litchi germplasm

Germplasm	Date of first and last panicle initiation							Date of opening of first and last male flower			
	2017			2018			Pooled	2017		2018	
	Initiation	End	Days	Initiation	End	Days	Days	Start	End	Start	End
IC-0615585	23.01.17	05.02.17	14	21.01.18	08.02.18	19	16.50	12.03.17	18.03.17	16.03.18	21.03.18
IC-0615586	05.02.17	18.02.17	14	06.02.18	19.02.18	14	14.00	10.03.17	15.03.17	15.03.18	21.03.18
IC-0615587	20.01.17	04.02.17	16	22.01.18	10.02.18	20	18.00	05.03.17	09.03.17	09.03.18	13.03.18
IC-0615588	25.01.17	10.02.17	17	23.01.18	11.02.18	20	18.50	07.03.17	13.03.17	10.03.18	15.03.18
IC-0615589	22.01.17	05.02.17	15	24.01.18	10.02.18	18	16.50	09.03.17	14.03.17	10.03.18	14.03.18
IC-0615590	20.01.17	06.20.17	16	21.01.18	12.02.18	23	19.50	07.03.17	12.03.17	16.03.18	21.03.18
IC-0615591	22.01.17	08.02.17	18	24.01.18	14.02.18	22	20.00	07.03.17	11.03.17	17.03.18	21.03.18
IC-0615592	20.01.17	05.02.17	17	24.01.18	14.02.18	22	19.50	09.03.17	15.03.17	14.03.18	19.03.18
IC-0615593	20.01.17	07.02.17	19	23.01.18	14.02.18	23	21.00	11.03.17	18.03.17	14.03.18	19.03.18
IC-0615594	16.01.17	31.01.17	19	19.01.18	08.02.18	22	20.50	05.03.17	12.03.17	13.03.18	20.03.18
IC-0615595	26.01.17	11.02.17	17	30.01.18	22.02.18	23	20.00	16.03.17	24.03.17	20.03.18	27.03.18
IC-0615596	23.01.17	05.02.17	14	25.01.18	15.02.18	22	18.00	13.03.17	20.03.17	16.03.18	22.03.18
IC-0615597	15.01.17	30.01.17	16	17.01.18	06.02.18	21	18.50	07.03.17	13.03.17	15.03.18	21.03.18
Coll. 39	27.01.17	08.02.17	13	25.01.18	10.02.18	17	15.00	11.03.17	16.03.17	13.03.18	17.03.18
IC-0615599	30.01.17	20.02.17	22	28.01.18	22.02.18	26	24.00	19.03.17	26.03.17	22.03.18	28.03.18
IC-0615600	17.01.17	02.02.17	17	18.01.18	07.02.18	23	20.00	04.03.17	10.03.17	09.03.18	15.03.18
IC-0615601	18.01.17	01.02.17	15	18.01.18	06.02.18	20	17.50	06.03.2017	12.03.17	13.03.18	20.03.18

IC-0615602	10.01.17	23.01.17	14	12.01.18	30.01.18	19	16.50	02.03.17	08.03.17	08.03.18	13.03.18
IC-0615603	20.01.17	09.02.17	21	23.01.18	15.02.18	24	22.50	17.03.17	23.03.17	20.03.18	26.03.18
IC-0615604	18.01.17	02.02.17	16	18.01.18	08.02.18	22	19.00	13.03.17	19.03.17	15.03.18	21.03.18
IC-0615605	25.01.17	09.02.17	16	26.01.18	13.02.18	19	17.50	13.03.17	20.03.17	17.03.18	21.03.18
IC-0615606	16.01.17	31.01.17	19	16.01.18	05.02.18	21	20.00	06.03.17	12.03.17	12.03.18	17.03.18
IC-0615608	17.01.17	02.02.17	17	18.01.18	08.02.18	22	19.50	10.03.17	17.03.17	21.03.18	26.03.18
IC-0615610	13.01.17	30.01.17	18	14.01.18	03.02.18	21	19.50	04.03.17	11.03.17	11.03.18	17.03.18
IC-0615611	22.01.17	07.02.17	17	24.01.18	14.02.18	22	19.50	12.03.17	18.03.17	15.03.18	21.03.18
IC-0615613	14.01.17	29.01.17	16	16.01.18	05.02.18	21	18.50	07.03.17	13.03.17	14.03.18	19.03.18
Coll. 35	14.01.17	28.01.17	15	15.01.18	03.02.18	20	17.50	05.03.17	11.03.17	11.03.18	15.03.18
Coll. 36	18.01.17	05.02.17	19	20.01.18	12.02.18	24	21.50	14.03.17	21.03.17	20.03.18	25.03.18
Coll. 37	16.01.17	31.01.17	19	18.01.18	07.02.18	21	20.00	12.03.17	17.03.17	16.03.18	19.03.18
Coll. 38	20.01.17	09.02.17	19	22.01.18	15.02.18	25	22.00	15.03.17	22.03.17	18.03.18	22.03.18

Table 4.3.2: Qualitative flowering characteristics of 30 litchi germplasm

Germplasm	Date of opening of first and last female flower				Date of opening of first and last -hermaphrodite flower (Functional male)			
	2017		2018		2017		2018	
	Start	End	Start	End	Start	End	Start	End
IC-0615585	17.03.17	22.03.17	20.03.18	23.03.18	23.03.17	29.03.17	24.3.18	30.03.18
IC-0615586	14.03.17	19.03.17	20.03.18	24.03.18	18.03.17	24.03.17	23.03.18	29.03.18
IC-0615587	09.03.17	14.03.17	14.03.18	19.03.18	15.03.17	21.03.17	20.03.18	26.03.18
IC-0615588	13.03.17	18.03.17	15.03.18	19.03.18	19.03.17	28.03.17	20.03.18	29.03.18
IC-0615589	14.03.17	19.03.17	16.03.18	22.03.18	18.03.17	27.03.17	21.03.18	31.03.18
IC-0615590	12.03.17	19.03.17	21.03.18	28.03.18	18.03.17	27.03.17	26.03.18	03.04.18
IC-0615591	11.03.17	18.03.17	21.03.18	28.03.18	17.03.17	28.03.17	27.03.18	09.04.18
IC-0615592	14.03.17	20.03.17	17.03.18	22.03.18	21.30.17	31.03.17	23.03.18	04.04.18
IC-0615593	19.03.17	24.03.17	20.03.18	24.03.18	25.03.17	31.03.17	26.03.18	01.04.18
IC-0615594	12.03.17	18.03.17	20.03.18	25.03.18	17.03.17	26.03.17	24.03.18	01.04.18
IC-0615595	23.03.17	27.03.17	26.03.18	29.03.18	27.03.17	02.04.17	29.03.18	05.04.18
IC-0615596	21.03.17	27.03.17	21.03.18	26.03.18	25.03.17	31.03.17	24.03.18	31.03.18
IC-0615597	13.03.17	18.03.17	21.03.18	25.03.18	17.03.17	24.03.17	24.03.18	29.03.18
Coll. 39	17.03.17	23.03.17	18.03.18	22.03.18	23.03.17	31.03.17	22.03.18	31.03.18
IC-0615599	27.03.17	30.03.17	30.03.18	02.04.18	30.03.17	06.04.17	01.04.18	08.04.18
IC-0615600	11.03.17	17.03.17	16.03.18	20.03.17	18.03.17	27.03.17	20.03.18	29.03.18

IC-0615601	11.03.17	17.03.17	19.03.18	25.03.2018	16.03.17	24.03.17	23.03.18	28.03.18
IC-0615602	09.03.17	15.03.17	15.03.18	21.03.18	14.03.17	22.03.17	20.03.18	27.03.18
IC-0615603	23.03.17	27.03.17	26.03.18	29.03.18	28.03.17	05.04.17	30.03.18	07.04.18
IC-0615604	18.03.17	22.03.17	20.03.18	24.03.18	22.03.17	01.04.17	25.03.18	03.04.18
IC-0615605	21.03.17	25.03.17	22.03.18	26.03.17	25.03.17	31.03.17	26.03.18	31.03.18
IC-0615606	13.03.17	19.03.17	18.03.18	23.03.18	18.03.17	25.03.17	21.03.18	27.03.18
IC-0615608	17.03.17	22.03.17	26.03.18	30.03.18	21.03.17	28.03.17	28.03.18	02.04.18
IC-0615610	11.03.17	18.03.17	17.03.18	25.03.18	16.03.17	28.03.17	24.03.18	02.04.18
IC-0615611	17.03.17	23.03.17	20.03.18	26.03.18	21.03.17	31.03.17	24.03.18	02.04.18
IC-0615613	13.03.17	18.03.17	18.03.18	23.03.18	17.03.17	23.03.17	22.03.18	27.03.18
Coll. 35	12.03.17	17.03.17	19.03.18	23.03.18	16.03.17	25.03.17	22.03.18	31.03.18
Coll. 36	22.03.17	28.03.17	26.03.18	30.03.18	28.03.17	03.04.17	30.03.18	05.04.18
Coll. 37	17.03.17	22.03.17	19.03.18	23.03.18	23.03.17	31.03.17	25.03.18	03.04.18
Coll. 38	23.03.17	27.03.17	24.03.18	26.03.18	27.03.17	03.04.17	27.03.18	06.04.18

4.3.1.3 Date of opening of first and last female flower

The data regarding the date of opening of first and last female flower of litchi germplasm are given in table 4.3.2. The opening of female flower started from 9th March to 30th March for both the years. The first opening of female flower was seen in genotype IC-0615602 (9th March, 2017) and IC-0615587 (9th March, 2017 and 14th March, 2018). The opening of last female flower started from 27th March to 2nd April for both the years. The opening of female flower was firstly ended in genotype IC-0615587 (14th March, 2017) and IC-0615587, IC-0615588 and IC-0615602 (19th March, 2018). The opening of female flower was lastly ended in IC-0615599 (30th March, 2017 and 1st April, 2018) followed by Coll. 36 (28th March, 2017 and 30th March, 2018).

4.3.1.4 Date of opening of first and last hermaphrodite flower (Functional male)

The data regarding the date of opening of first and last hermaphrodite male flower of litchi germplasm are given in table 4.3.2. The opening of Hermaphrodite male flower started from 14th March to 1st April for both the years. The first opening of Hermaphrodite male flower was found in genotype IC-0615602 (14th March, 2017) and IC-0615587, IC-0615588 and IC-0615602 (20th March, 2018) and the opening of Hermaphrodite male flower was eventually recorded in IC-0615599 (30th March, 2017 and 1st April, 2018). The opening of last Hermaphrodite male flower started from 21st March to 8th April for both the years. The opening of Hermaphrodite male flower was firstly ended in genotype IC-0615587 (21st March, 2017 and 26th March, 2018) and the opening of Hermaphrodite male flower was finally ended in genotype IC-0615599 (6th March, 2017 and 8th March, 2018).

4.3.1.5 Flower disc colour

The data regarding flower disc colour of litchi germplasm are given in table 4.3.3 and Plate 9. The Dark yellow flower disc colour was noticed in two genotypes *viz*., IC-0615585 and IC-0615591,

whereas, pink colour of flower disc was found in three genotypes *viz*., IC-0615597, IC-0615602 and IC-0615613 and rest genotypes had light yellow colour of flower disc.

4.3.1.6 Position of inflorescence

The data regarding the positions of inflorescenceof litchi germplasm are given in table 4.3.3. All the litchi germaplasm produces terminal panicle except IC-0615588, IC-0615593, IC-0615595, IC-0615596, IC-0615604 and IC-0615613 which produced both types of panicle (Auxillary and Terminal).

4.3.1.7 Abundance of flower

The data regarding the abundance of flower in litchi germplasm are given in table 4.3.3 and abundance of flowers in panicle can be seen in plate 10. The sparse flower was noticed in two genotypes IC-0615595 and IC-0615599 and while moderate flower was found in four genotypes IC-0615585, IC-0615588, IC-0615613 and IC-0615605 and rest genotypes showed profuse flowers in panicle.

Light Yellow **Dark Yellow** **Pinkish**

Plate 9: Variations in flower disc colour in litchi

Table 4.3.3: Qualitative flowering characteristics of 30 litchi germplasm

Germplasm	Flower disc colour				Position of inflorescence			Abundance of flower		
	1	2	3	4	1	2	3	1	2	3
	Light Cream	Light Yellow	Dark Yellow	Pink	Terminan	Axillary	Both	Profuse	Moderate	Sparse
IC-0615585	3				1			2		
IC-0615586	2				1			1		
IC-0615587	2				1			1		
IC-0615588	2				3			2		
IC-0615589	2				1			1		
IC-0615590	2				1			1		
IC-0615591	3				1			1		
IC-0615592	2				1			1		
IC-0615593	2				3			1		
IC-0615594	2				1			1		
IC-0615595	2				3			3		
IC-0615596	2				3			1		
IC-0615597	4				1			1		
Coll. 39	2				1			1		
IC-0615599	2				1			3		
IC-0615600	2				1			1		
IC-0615601	2				1			1		
IC-0615602	4				1			1		
IC-0615603	2				1			1		
IC-0615604	2				3			1		
IC-0615605	2				1			2		
IC-0615606	2				1			1		
IC-0615608	4				1			2		
IC-0615610	2				1			1		
IC-0615611	2				1			1		
IC-0615613	2				3			1		
Coll. 35	2				1			1		
Coll. 36	2				1			1		
Coll. 37	2				1			1		
Coll. 38	2				1			1		

4.2.1 Quantitative characters

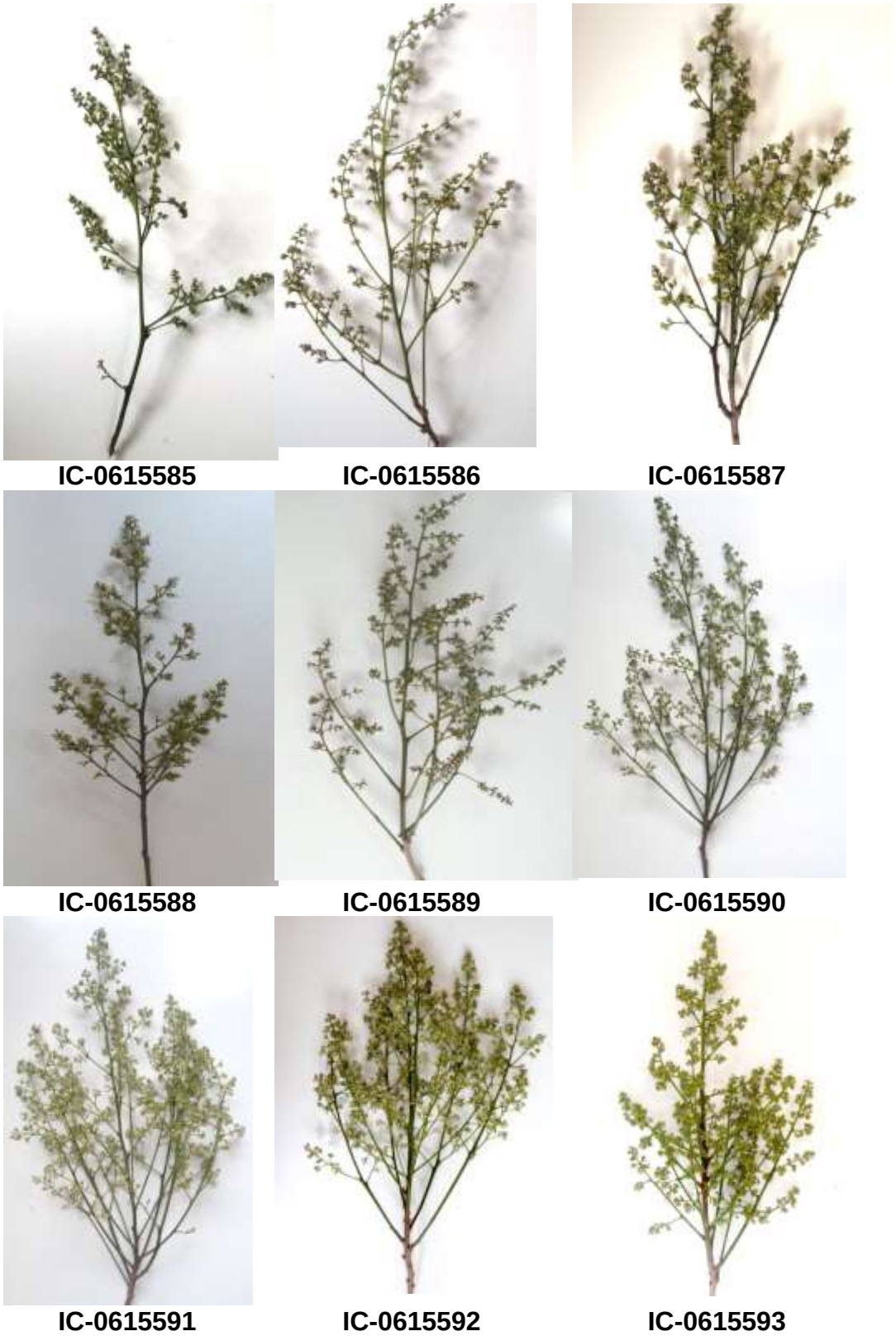
4.2.1.1 Duration of flowering (Days)

Average days taken for completion of flowering (opening of first male to end of last male flower) for both years and their mean are presented in table 4.3.4 and graphically depicted in Figure 4.6. The duration of flowering varied from 14 days to 25 days. The analysis of data indicated that there was highly significant difference in duration of flowering.The analysis data showed that maximum duration of flowering was found in genotype IC-0615610 (25 days) followed by IC-0615600 (24 days) and IC-0615592 (23 days) whereas, minimum days for flowering was recorded in genotype IC-0615586 (15 days) followed by 17 days for both the genotypes IC-0615587 and IC-0615613 during 2017. But in 2018, maximum duration of flowering was found in genotype IC-0615592 (24 days) followed by IC-0615610 (23 days) while minimum days was recorded in IC-0615613 (14 days) followed by 15 days in three genotypes IC-0615587, IC-0615597 and IC-0615605.

On the basis of pooled data, maximum duration of flowering was found in genotype IC-0615610 (24 days) followed by 22.5 days in two genotypes (IC-0615592 and IC-0615600) whereas, minimum days was recorded in genotype IC-0615586 (15 days) followed by IC-0615613 (15.5 days) and IC-0615597 (16.5 days).

4.2.1.2 Length of inflorescence (cm)

A close perusal of data presented in table 4.3.5 and Figure 4.7 exhibited significant variation with regard to length of inflorescence among the litchi germplasm for both the years. The length of panicle in litchi genotypes ranged from 17 to 47 cm in 2017 and from 15.4 to 48 cm in 2018. The maximum length of inflorescence was recorded in genotype IC-0615610 in both the years (47 cm and 48 cm) followed by IC-0615602 (44.30 cm and 45 cm) and IC-0615597 (44 cm and 42.75) whereas, minimum length was found in genotype IC-0615613 in both the years (17 cm and 15.4 cm) followed by IC-0615593 (20 cm and 22 cm) and IC-0615595 (24 cm and 24.50 cm). The pooled data



IC-0615585 IC-0615586 IC-0615587

IC-0615588 IC-0615589 IC-0615590

IC-0615591 IC-0615592 IC-0615593

Plate 10: Variations in panicle among 30 litchi germplasm

IC-0615594

IC-0615595

IC-0615596

IC-0615597

Coll. 39

IC-0615599

IC-0615600

IC-0615601

IC-0615602

IC-0615603

IC-0615604

IC-0615605

Plate 10 (Contd): Variations in panicle among 30 litchi genotypes

IC-0615606

IC-0615608

IC-0615610

IC-0615611

IC-0615613

Coll. 35

Coll. 36

Coll. 37

Coll. 38

Plate 10 (Contd): Variations in panicle among 30 litchi genotypes

Table 4.3.4: Duration of flowering in different litchi germplasm

Germplasm	Duration of flowering (Days)		
	2017	2018	Pooled
IC-0615585	18	16	17
IC-0615586	15	15	15
IC-0615587	17	18	17.5
IC-0615588	22	20	21
IC-0615589	19	22	20.5
IC-0615590	21	19	20
IC-0615591	22	24	23
IC-0615592	23	22	22.5
IC-0615593	21	19	20
IC-0615594	22	20	21
IC-0615595	18	17	17.5
IC-0615596	19	16	17.5
IC-0615597	18	15	16.5
Coll. 39	21	19	20
IC-0615599	19	18	18.5
IC-0615600	24	21	22.5
IC-0615601	19	16	17.5
IC-0615602	21	21	21
IC-0615603	20	19	19.5
IC-0615604	18	20	19
IC-0615605	19	15	17
IC-0615606	20	16	18
IC-0615608	19	18	18.5
IC-0615610	25	23	24
IC-0615611	20	19	19.5
IC-0615613	17	14	15.5
Coll. 35	21	21	21
Coll. 36	21	17	19
Coll. 37	20	19	19.5
Coll. 38	20	20	20
SEm ±	0.10	0.39	0.50
CD at 5%	0.23	1.13	1.42

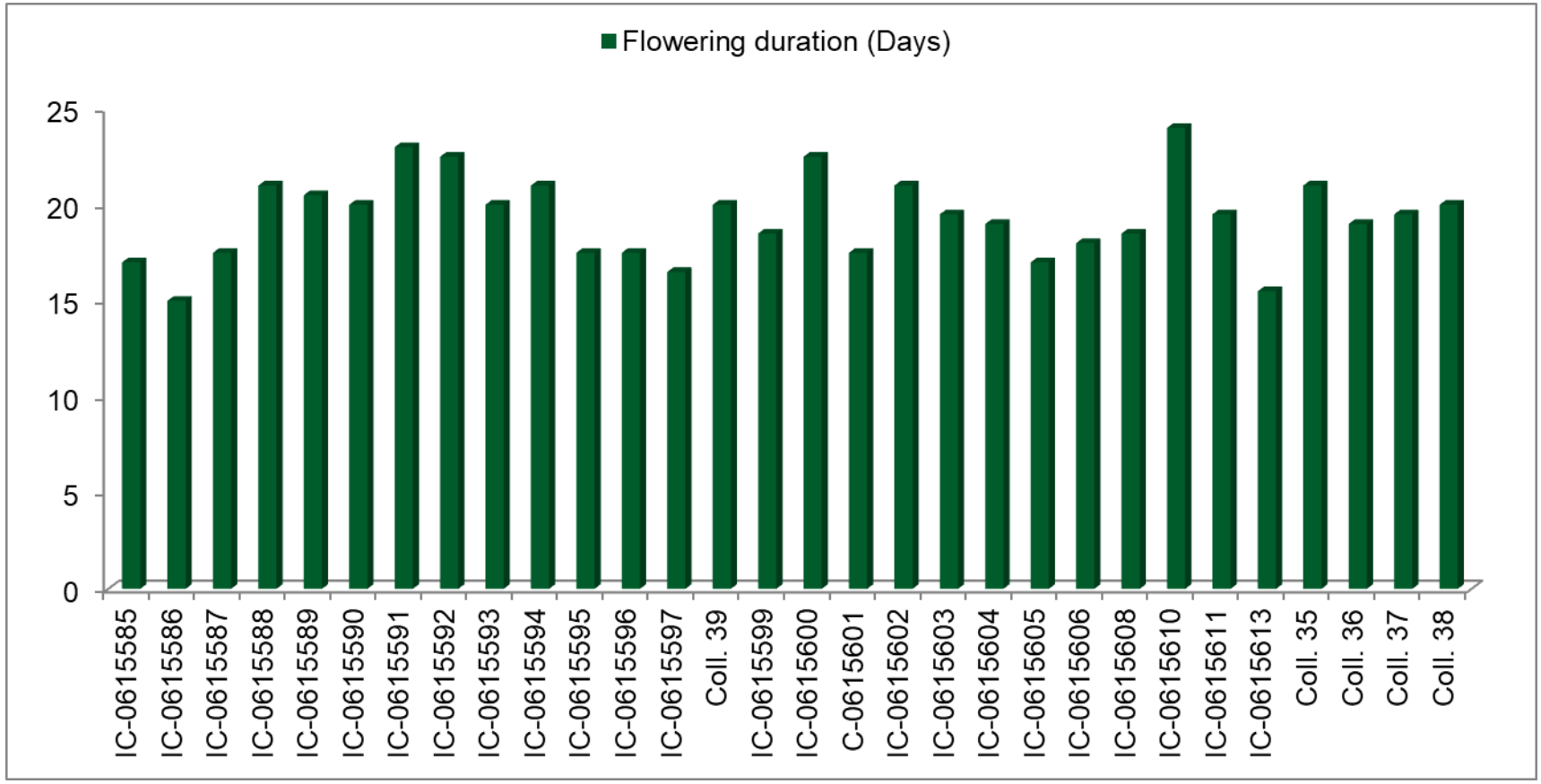


Figure 4.6: Variation in duration of flowering among 30 litchi germplasm

Table 4.3.5: Length of inflorescence in different litchi germplasm

Germplasm	Length of inflorescence (cm)		
	2017	2018	Pooled
IC-0615585	25.70	26.20	25.95
IC-0615586	32.00	30.00	31.00
IC-0615587	25.00	24.00	24.50
IC-0615588	26.00	25.70	25.85
IC-0615589	38.00	35.50	36.75
IC-0615590	37.00	39.40	38.20
IC-0615591	34.00	36.80	35.40
IC-0615592	35.00	38.00	36.50
IC-0615593	20.00	22.00	21.00
IC-0615594	42.25	40.65	41.45
IC-0615595	24.00	24.50	24.25
IC-0615596	25.00	23.60	24.30
IC-0615597	44.00	43.75	43.88
Coll. 39	33.00	32.45	32.73
IC-0615599	26.50	30.00	28.25
IC-0615600	42.50	40.25	41.38
IC-0615601	38.00	40.00	39.00
IC-0615602	44.30	45.00	44.65
IC-0615603	34.00	35.00	34.50
IC-0615604	31.00	34.00	32.50
IC-0615605	24.00	26.00	25.00
IC-0615606	40.00	42.30	41.15
IC-0615608	34.00	36.40	35.20
IC-0615610	47.00	48.00	47.50
IC-0615611	42.25	40.60	41.43
IC-0615613	17.00	15.40	16.20
Coll. 35	32.50	33.00	32.75
Coll. 36	32.00	34.00	33.00
Coll. 37	37.00	38.00	37.50
Coll. 38	30.00	30.60	30.30
SEm ±	0.36	0.493	0.45
CD at 5%	1.03	1.39	1.27

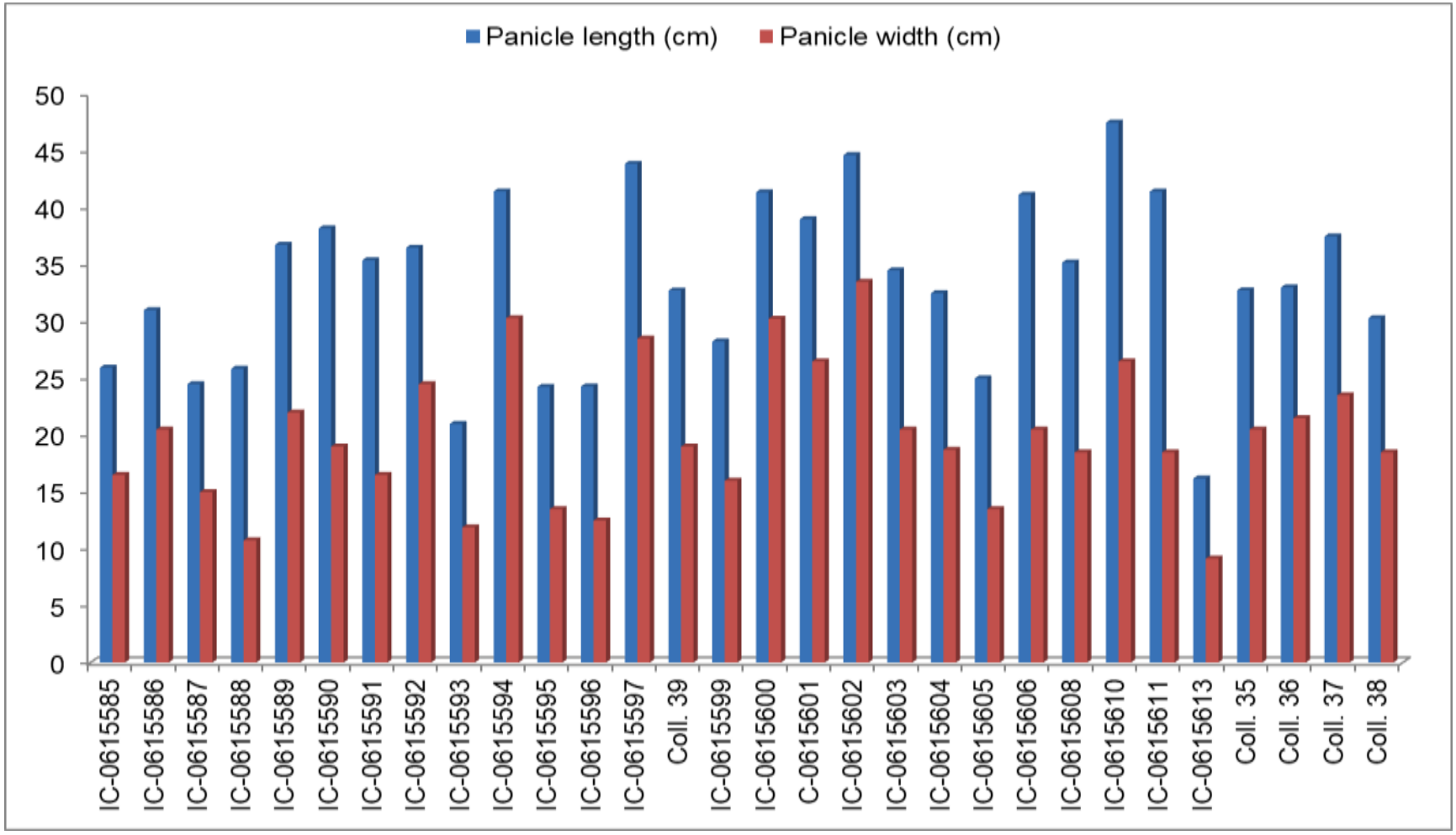


Figure 4.7: Variation in length and width of panicle among 30 litchi germplasm

reflected that maximum length was in genotype IC-0615610 (47.50 cm) followed by IC-0615602 (44.62 cm), IC-0615597 (43.88 cm) whereas, minimum in genotype IC-0615613 (16.20 cm) followed by IC-0615593 (21.00 cm).

4.2.1.3 Width of inflorescence (cm)

The data regarding width of inflorescence are presented in table 4.3.6 and depicted in Figure 4.7. The statistical analysis of the data revealed that the differences among the germplasmin respect of width of inflorescence was found to be highly significant in both the years as well as in pooled analysis.The maximum width of inflorescence was recorded in genotype IC-0615602 in both the years (32 cm and 35 cm) followed by IC-0615594 (30 cm and 30.60 cm) and IC-0615600 (30 cm and 30.50 cm) whereas, minimum width was found in genotype IC-06156013 in both the years (9.30 cm and 8 cm) followed by IC-0615586 (10 cm and 11.50 cm) and IC-0615593 (12 cm and 11.80 cm).

The pooled analysis showed the maximum width of inflorescence was found in genotype IC-0615602 (33.50 cm) followed by IC-0615593 (30.30 cm) and IC-0615600 (30.25 cm) while minimum width in genotype IC-0615613 (9.15 cm) followed by IC-0615596 (11 cm) and IC-0615593 (11.50 cm).

4.2.1.4 Functional female flower (%)

The data pertaining to per cent of female flowers per panicle are shown in table 4.3.7 and graphically depicted in Figure 4.8.The statistical analysis of data indicated that the differences among the germplasm in respect of per cent of female flowers per panicle were found to be highly significant in both the years and pooled analysis as well. The maximum per cent of female flower was recorded in genotype Coll. 38 (48.96 %) followed by Coll. 36 (43.72 %) and Coll. 37 (30.18 %) whereas, minimum was found in genotype IC-0615585 (4.90 %) which was *at par* with IC-0615599 (5.70 %) and IC-0615588

Table 4.3.6: Width of inflorescence in different litchi germplasm

Germplasm	Width of inflorescence (cm)		
	2017	2018	Pooled
IC-0615585	16.00	17.00	16.50
IC-0615586	20.00	21.00	20.50
IC-0615587	14.00	16.00	15.00
IC-0615588	10.00	11.50	10.75
IC-0615589	23.00	21.00	22.00
IC-0615590	18.00	20.00	19.00
IC-0615591	17.00	16.00	16.50
IC-0615592	24.00	25.00	24.50
IC-0615593	12.00	11.80	11.90
IC-0615594	30.00	30.60	30.30
IC-0615595	13.00	14.00	13.50
IC-0615596	13.00	12.00	12.50
IC-0615597	29.00	28.00	29.00
Coll. 39	20.00	18.00	19.00
IC-0615599	15.00	17.00	16.00
IC-0615600	30.00	30.50	30.25
IC-0615601	25.00	28.00	26.50
IC-0615602	32.00	35.00	33.50
IC-0615603	20.00	21.00	20.50
IC-0615604	18.45	19.00	18.73
IC-0615605	14.00	13.00	13.50
IC-0615606	20.00	21.00	20.50
IC-0615608	18.00	19.00	18.50
IC-0615610	28.00	25.00	26.50
IC-0615611	19.00	18.00	18.50
IC-0615613	9.30	9.00	9.15
Coll. 35	20.00	21.00	20.50
Coll. 36	22.00	21.00	21.50
Coll. 37	23.00	24.00	23.50
Coll. 38	18.00	19.00	18.50
SEm ±	0.37	0.29	0.32
CD at 5%	1.05	0.84	0.90

Table 4.3.7: Functional female flower in different litchi germplasm

Germplasm	Functional female flower (%)		
	2017	2018	Pooled
IC-0615585	4.90	3.02	3.96
IC-0615586	13.75	12.84	13.30
IC-0615587	8.73	9.69	9.21
IC-0615588	6.70	5.81	6.25
IC-0615589	12.16	13.44	12.80
IC-0615590	26.83	21.59	24.21
IC-0615591	30.13	44.14	37.13
IC-0615592	15.80	16.76	16.28
IC-0615593	12.66	15.11	13.88
IC-0615594	26.13	21.25	23.69
IC-0615595	17.62	9.16	13.39
IC-0615596	20.15	13.69	16.92
IC-0615597	11.53	14.17	12.85
Coll. 39	11.62	12.88	12.25
IC-0615599	5.70	5.22	5.46
IC-0615600	15.05	11.54	13.29
IC-0615601	27.70	28.02	27.86
IC-0615602	15.17	13.02	14.10
IC-0615603	26.56	34.52	30.54
IC-0615604	17.93	20.08	19.01
IC-0615605	18.81	33.56	26.19
IC-0615606	21.95	18.96	20.46
IC-0615608	26.63	23.68	25.15
IC-0615610	21.18	21.42	21.30
IC-0615611	14.38	13.52	13.95
IC-0615613	11.70	12.15	11.92
Coll. 35	13.78	12.99	13.38
Coll. 36	43.72	42.92	43.32
Coll. 37	30.18	24.01	27.09
Coll. 38	48.96	36.49	42.72
SEm ±	4.21	0.19	0.37
CD at 5%	11.95	0.56	1.04

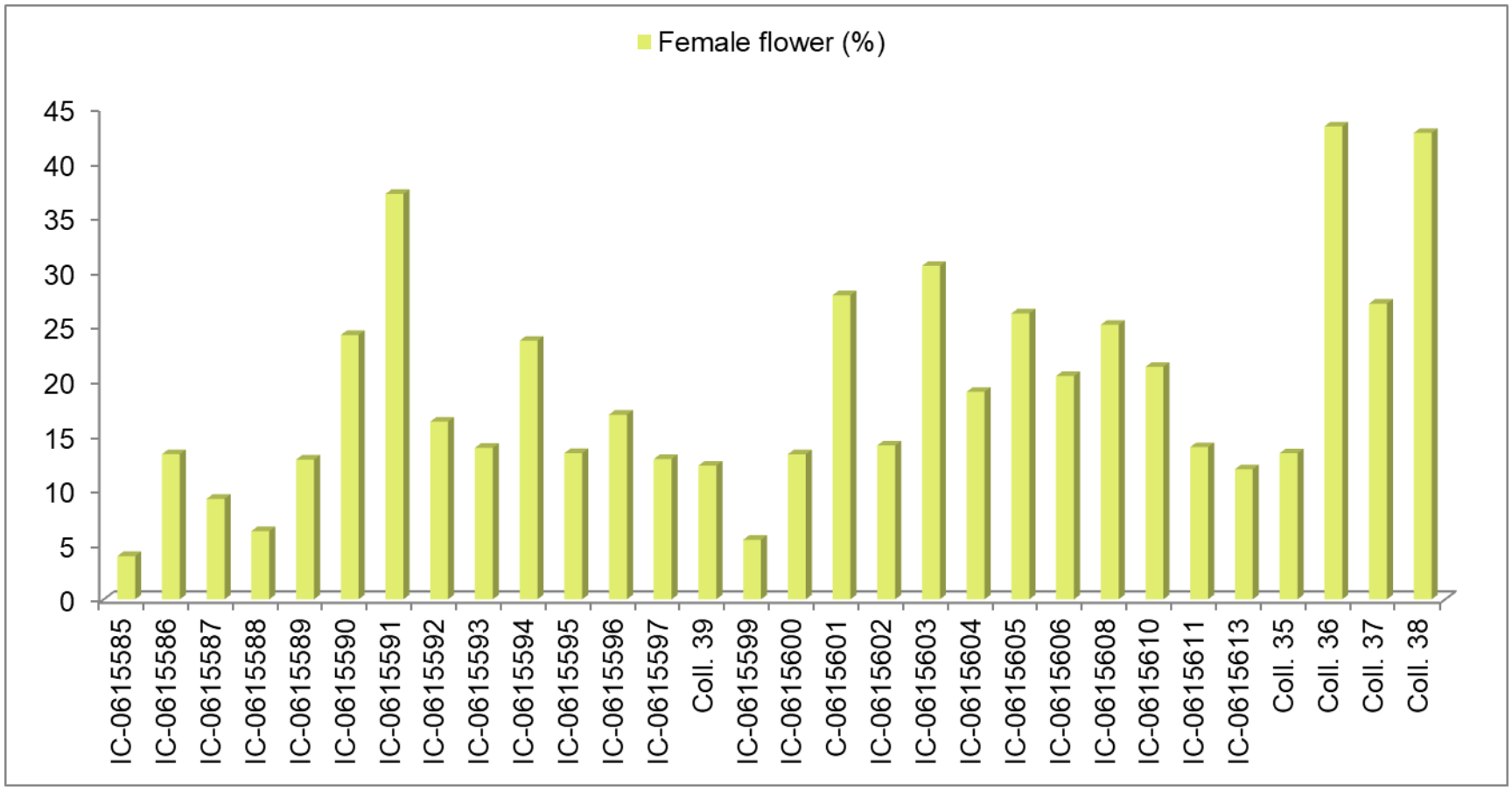


Figure 4.8: Variation in per cent of female flowers among 30 litchi germplasm

(6.25 %) in 2017. During 2018, the maximum per cent of female flower was reported in genotype IC-0615591 (44.14 %) followed by Coll. 36 and Coll. 38 whereas, lowest female per cent was found in genotype IC-0615585 (3.02 %) followed by IC-0615599 (5.22 %) and IC-0615588 (6.25 %). The pooled analysis showed the maximum per cent of female flowers in genotype Coll. 36 (43.32 %) followed by Coll. 38 (42.72 %) while the minimum per cent of female flowers was recorded in genotype IC-0615585 (3.96 %) followed by IC-0615588 (6.25 %).

4.4 Fruit characters

The observations on qualitative fruit characters among litchi germplasm under study are resented below:

4.4.1 Qualitative characters

The data regarding the qualitative characters are presented in Table 4.4.1, 4.4.2, 4.4.3 and 4.4.4.

4.4.1.1 Date of initiation and end of fruit set

The data on date of initiation of fruit set in litchi germplasm are given in table 4.4.1. A close perusal of data showed that date of initiation and end of fruit set in different germplasm of litchi under study varied from 17th March to 7th April and 20th March to 10th April during 2017 and 2018, respectively.The initiation of fruit set was first observed in genotype IC-0615602 (17th March) followed by 18th March in both genotypes IC-0615601 and IC-0615610 and 19th March in both genotypes IC-0615587 and IC-0615594 while it was late in genotype IC-0615599 (5th April) followed by IC-0615595 (2nd April) and IC-0615603 (1st April) in 2017.The end of fruit set was firstly recorded on 20th March in IC-0615601 and IC-0615602 followed by on 21st March in both genotypes IC-0615594 and IC-0615610 while it was finally ended in genotype IC-0615599 (7th April) followed by IC-0615595 (6th April) and IC-0615603 (5th April) in 2017.

During 2018, the initiation of fruit set was first observed in genotype IC-0615602 (23rd March) followed by 24th March in both

genotypes IC-0615589 and IC-0615600 and 25th March in five genotypes IC-0615587, IC-0615601, IC-0615606, IC-0615610 and IC-0615613 whereas, it was late in genotype IC-0615599 (7th April) followed by IC-0615595 (4th April) and both genotypes IC-0615591 and IC-0615603 (3rd April). The end of fruit set was firstly found on 26th March in genotype IC-0615602 followed by on 27th March in three genotypes IC-0615600, IC-0615601 and IC-0615606 while it was eventually ended on 10th April in genotype IC-0615599 followed by on 8th April in IC-0615591, IC-0615595 and IC-0615603 and on 4th April in IC-0615608 and Coll. 38.

4.4.1.2 Fruit maturity group

The data on fruit maturity group in litchi germplasm are given in table 4.4.1. The earliest ripening of fruits was recorded in ten genotypes *viz*., IC-0615586, IC-0615594, IC-0615597, IC-0615600, IC-0615601, IC-0615602, IC-0615606, IC-0615608, IC-0615610 and Coll. 35 while mid ripening was noticed in sixteen genotypes *viz*., IC-0615587, IC-0615588, IC-0615589, IC-0615590, IC-0615591, IC-0615592, IC-0615593, IC-0615596, Coll. 39, IC-0615613, IC-0615604, IC-0615605, IC-0615611, Coll. 36, Coll. 37 and Coll. 38. Late ripening of fruit was observed in four genotypes *viz*., IC-0615585, IC-0615595, IC-0615599 and IC-0615603.

4.4.1.3 Fruit ripening

The data on fruit ripening in litchi germplasm are given in table 4.4.1. Synchronous ripening of fruits was noticed in all germplasm except three genotypes *viz*., IC-0615589, IC-0615595 and Coll. 39.

4.4.1.4 Fruit bearing habit

The data on fruit bearing habit in litchi germplasm are given in table 4.4.1.The regular bearing habit was observed in all genotypes *viz*., IC-0615585, IC-0615586, IC-0615587, IC-0615588, IC-0615589, IC-0615593, IC-0615594, IC-0615595, IC-0615596, IC-0615597, Coll. 39, IC-0615599, IC-0615600, IC-0615601, IC-0615602, IC-0615603, IC-0615604, IC-0615605, IC-0615606, IC-0615608, IC-0615610, IC-0615590, IC-0615591, IC-0615592, Coll. 35, Coll. 36,

Coll. 37 and Coll. 38 except one genotype IC-0615611 which showed partially regular bearing.

4.4.1.5 Fruit bearing intensity

The data on date of initiation of fruit set in litchi germplasm are given in table 4.4.2. The heavy fruit bearing intensity was noticed in seventeen genotypes *viz*.,IC-0615590, IC-0615591, IC-0615592, IC-0615594, IC-0615597, IC-0615600, IC-0615601, IC-0615602, IC-0615603, IC-0615606, IC-0615608, IC-0615610, IC-0615611, Coll. 35, Coll 36, Coll. 37 and Coll. 38 whereas, poor fruit bearing intensity was noticed in six genotypes *viz*., IC-0615585, IC-0615587, IC-0615588, IC-0615595, IC-0615599, IC-0615605 and medium bearing intensity was found in seven genotypes *viz*., IC-0615586, IC-0615589, IC-0615593, IC-0615596, IC-0615596, IC-0615604 and IC-0615613.

4.4.1.6 Fruit clustering habit

The data on fruit clustering habit in litchi germplasm are given in table 4.4.2. All the germplasm were produced fruits in cluster except only one genotype IC-0615595 which produced single fruit per panicle at harvesting.

4.4.1.7 Fruit shape

The data on fruit shape in litchi germplasm are given in table 4.4.2.The elliptic fruit shape was found in five genotypes *viz*., IC-0615586, Coll. 39, IC-06155606, IC-0615608 and Coll. 35 while oblong shape was found in only one genotype IC-0615585. Round fruit shape was observed in three genotypes *viz*., IC-0615587, IC-0615595, and IC-0615613 whereas, conical fruit shape was found in eight genotypes *viz*., IC-0615590, IC-0615591, IC-0615592, IC-0615605, IC-0615611, Coll.36, Coll. 37 and Coll. 38 and Cordate shape was found in four genotypes *viz*., IC-0615588,IC-0615593, IC-0615596 and IC-0615604.

4.4.1.8 Fruit shoulder

The data on fruit shoulder in litchi germplasm are given in table 4.4.2.The smooth fruit shoulder was found in thirteen genotypes *viz*., IC-0615586, IC-0615587, IC-0615594, IC-0615595, IC-0615597, Coll. 39, IC-0615599, IC-0615600, IC-0615601, IC-0615602, IC-0615610, IC-0615613 and Coll. 35 while protruding fruit shoulder was found in seventeen genotypes *viz*.,IC-0615585, IC-0615586, IC-0615589, IC-0615590, IC-0615591, IC-0615592, IC-0615593, IC-0615596, IC-0615603, IC-0615604, IC-0615605, IC-0615606, IC-0615608, IC-0615611, Coll. 36, Coll. 37 and Coll. 38.

4.4.1.9 Fruit tip

The data on fruit tip in litchi germplasm are given in table 4.4.2. Obtuse fruit tip was found in twenty one genotypes *viz*., IC-0615585, IC-0615586, IC-0615588, IC-0615593, IC-0615604, IC-0615589, IC-0615592, IC-0615594, IC-0615596, IC-0615597, Coll. 39, IC-0615600, IC-0615600, IC-0615602, IC-0615605, IC-0615606, IC-0615610, IC-0615611, Coll. 35, Coll.36 and Coll.37. Round fruit tip was found in five genotypes *viz*., IC-0615587, IC-0615595, IC-0615599, IC-0615608 and IC-0615613 while acute fruit tip was found in four genotypes *viz*., IC-0615590, IC-0615591, IC-0615603 and Coll. 38.

4.4.1.10 Segmentation of fruit skin

The data on segmentation of fruit skin in litchi germplasm are given in table 4.4.2. Nipple shaped segment of fruit skin was found in nine genotypes *viz*., IC-0615585, IC-0615590, IC-0615591, IC-0615592, IC-0615603, IC-0615611, Coll. 36, Coll. 37 and Coll. 38 while sharp pointed was found in thirteen genotypes *viz*., IC-0615586, IC-0615589, IC-0615594, IC-0615597, Coll. 39, IC-0615600, IC-0615601, IC-0615602, IC-0615605, IC-0615606, IC-0615608, IC-0615610 and Coll. 38. Swelling type fruit segment was foundin seven genotypes *viz*., IC-0615588, IC-0615593, IC-0615595, IC-0615596, IC-0615599, IC-0615604, IC-0615613 and smooth in only one genotype IC-0615587.

Table 4.4.1: Qualitative fruit characteristics of 30 litchi germplasm

Germplasm	Date of initiation and end of fruit set				Fruit maturity group			Fruit ripening		Fruit bearing habit			
	2017		2018		1	2	3	1	2	1	2	3	4
	Initiation	End	Initiation	End	Early	Medium	Late	Synchronous	Non-Synchronous	Regular	Alternate	Irregular	Partially Regular
IC-0615585	25.03.17	28.03.17	28.03.18	30.03.18		3			1			1	
IC-0615586	23.03.17	27.03.17	28.03.18	31.03.8		1			1			1	
IC-0615587	19.03.17	22.03.17	25.03.18	30.03.18		2			1			1	
IC-0615588	23.03.17	27.03.17	26.03.18	29.03.18		2			1			1	
IC-0615589	23.03.17	26.03.17	24.03.18	28.03.18		2			2			1	
IC-0615590	21.03.17	25.03.17	28.03.18	31.03.18		2			1			1	
IC-0615591	22.03.17	26.03.17	03.04.18	08.04.18		2			1			1	
IC-0615592	25.03.17	29.03.17	28.03.18	02.04.18		2			1			1	
IC-0615593	27.03.17	30.03.17	27.03.18	01.04.18		2			1			1	
IC-0615594	19.03.17	21.03.17	27.03.18	30.03.18		1			1			1	
IC-0615595	02.04.17	06.04.17	04.04.18	08.04.18		3			2			1	
IC-0615596	29.03.17	01.04.17	28.03.18	31.03.18		2			1			1	
IC-0615597	21.03.17	24.03.17	27.03.18	30.03.18		1			1			1	

Coll. 39	26.03.17	29.03.17	27.03.18	31.03.18	2	2	1
IC-0615599	05.04.17	07.04.17	07.04.18	10.04.18	3	1	1
IC-0615600	20.03.17	24.03.17	24.03.18	27.03.18	1	1	1
IC-0615601	18.03.17	20.03.17	25.03.18	27.03.18	1	1	1
IC-0615602	17.03.17	20.03.17	23.03.18	26.03.18	1	1	1
IC-0615603	01.04.17	05.04.17	03.04.18	08.04.18	3	1	1
IC-0615604	27.03.17	31.03.17	29.03.18	02.04.18	2	1	1
IC-0615605	29.03.17	01.04.17	31.03.18	02.04.18	2	1	1
IC-0615606	20.03.17	23.03.17	25.03.18	27.03.18	1	1	1
IC-0615608	25.03.17	28.03.17	02.04.18	04.04.18	1	1	1
IC-0615610	18.03.17	21.03.17	25.03.18	29.03.18	1	1	1
IC-0615611	25.03.17	28.03.17	27.03.18	30.03.18	2	1	4
IC-0615613	21.03.17	25.03.17	25.03.18	28.03.18	2	1	1
Coll. 35	20.03.17	23.03.17	26.03.18	28.03.18	1	1	1
Coll. 36	30.03.17	01.04.17	02.04.18	05.04.18	2	1	1
Coll. 37	24.03.17	26.03.17	27.03.18	29.03.18	2	1	1
Coll. 38	31.03.17	04.04.17	01.04.18	04.04.18	2	1	1

Table 4.4.2: Qualitative fruit characteristics of 30 litchi germplasm

Germplasm	Fruit bearing intensity			Fruit clustering habit		Fruit shape							Fruit shoulder		Fruit tip			Segmentation on fruit skin				Cracking of fruit skin		
	1	2	3	1	2	1	2	3	4	5	6	7	1	2	1	2	3	1	2	3	4	1	2	3
	Poor	Medium	Heavy	Solitary	Clusters	Round	Oval	Oblong	Conical	Elliptic	Cordate	Long cordate	Smooth/Even	Protruding	Round	Obtuse	Acute	Sharp pointed	Nipple shaped	Swelling type	Smooth	Not prone	Prone to crack	Highly prone
IC-0615585	1			2		3							2		2			2				1		
IC-0615586	2			2		5							1		2			1				3		
IC-0615587	1			2		1							1		1			4				1		
IC-0615588	1			2		6							2		2			3				1		
IC-0615589	2			2		2							2		2			1				2		
IC-0615590	3			2		4							2		3			2				1		
IC-0615591	3			2		4							2		3			2				1		
IC-0615592	3			2		4							2		2			2				1		
IC-0615593	2			2		6							2		2			3				1		
IC-0615594	3			2		2							1		2			1				2		
IC-0615595	1			1		1							1		1			3				1		

IC-0615596	2	2	6	2	2	3	1
IC-0615597	3	2	2	1	2	1	3
Coll. 39	2	2	5	1	2	1	2
IC-0615599	1	2	2	1	1	3	1
IC-0615600	3	2	2	1	2	1	3
IC-0615601	3	2	2	1	2	1	3
IC-0615602	3	2	2	1	2	1	3
IC-0615603	2	2	4	2	3	2	1
IC-0615604	2	2	6	2	2	3	1
IC-0615605	1	2	2	2	2	1	2
IC-0615606	3	2	2	2	2	1	2
IC-0615608	3	2	5	2	1	1	1
IC-0615610	3	2	5	1	2	1	3
IC-0615611	3	2	4	2	2	2	1
IC-0615613	2	2	1	1	1	3	1
Coll. 35	3	2	5	1	2	1	3
Coll. 36	3	2	4	2	2	2	1
Coll. 37	3	2	4	2	2	2	1
Coll. 38	3	2	4	2	3	2	1

4.4.1.11 Cracking of fruit skin

The data on cracking of fruit skin in litchi germplasm are given in table 4.4.2. No cracking was observed in eighteen genotypes *viz*., IC-0615585, IC-0615587, IC-0615588, IC-0615590, IC-0615591, IC-0615592, IC-0615593, IC-0615595, IC-0615596, IC-0615599, IC-0615603, IC-0615604, IC-0615611, IC-0615613, Coll. 36, Coll. 37 and Coll. 38 while prone to skin cracking was observed in seven genotypes *viz*., IC-0615589, IC-0615594, Coll. 39, IC-0615605, IC-0615606, IC-0615610 and Coll. 35 whereas, highly prone to skin cracking was found in five genotypes *viz*., IC-00615586, IC-0615597, IC-0615600 and IC-0615601.

4.4.1.12 Mature fruit colour

The data on fruit colour at harvest in litchi germplasm are given in table 4.4.3. Rosy red colour was found in five genotypes *viz*., IC-0615590, IC-0615591, IC-0615592, IC-0615603 and Coll. 38 while deep pink colourwas observed in three genotypes *viz*., IC-0615587, IC-0615594 and IC-0615613. Crimson red colour was found in seven genotypes *viz.,* IC-0615588, IC-0615590, IC-0615596, IC-0615604, IC-0615611, Coll.36 and Coll. 37 while scarlet in only one genotype IC-0615585, greenish red in genotype IC-0615586, pinkish red in two genotypes IC-0615589 and IC-0615606 were observed. Reddish yellow colour was found in seven genotypes *viz*., IC-0615595, IC-0615597, Coll. 39, IC-0615599, IC-0615600, IC-0615601, IC-0615613 whereas, red colour was observed in four genotypes *viz*., IC-0615602, IC-0615605, IC-0615610 and Coll. 35.

4.4.1.13 Distribution of colour on fruit surface

The data on distribution of colour on fruit surface in litchi germplasm are given in table 4.4.3.The uniform distribution of colour on fruit surface was found in all germplasm except five genotypes *viz*., IC-0615585, IC-00615586, IC-0615595, IC-0615597, IC-0615599 and IC-0615605 which had partial distribution of colour on surface.

4.4.1.14 Shape of tubercles

The data on shape of tubercles on skin in litchi germplasm are given in table 4.4.3. Obtuse type of tubercle was found in seven genotypes *viz*., IC-0615588, IC-0615593, IC-0615595, IC-0615595, IC-0615599, IC-0615604 and IC-0615613 whereas, smooth in only one genotype IC-0615587. Sharp pointed shape of tubercles was observed in thirteen genotypes *viz*., IC-0615585, IC-0615589, IC-0615594, IC-0615597, Coll. 39, IC-0615600, IC-0615601, IC-0615602, IC-0615605, IC-0615606, IC-0615613, IC-0615611 and Coll. 35 whereas, slightly pointed was found in nine genotypes *viz*., IC-0615586, IC-0615590, IC-0615591, IC-0615592, IC-0615603, IC-0615611, Coll. 36, Coll. 37 and Coll. 38.

4.4.1.15 Tubercles density

The data on tubercles density on fruit surface in litchi germplasm are given in table 4.4.4. Dense tubercles were found in eight genotypes *viz*., IC-0615590, IC-0615591, IC-0615592, IC-0615603, IC-0615611, Coll. 36, Coll. 37 and Coll. 38 while medium was observed in five genotypes *viz*., IC-0615585, IC-0615597, Coll. 39, IC-0615605 and IC-0615606, and sparse tubercles was found in seventeen genotypes *viz*., IC-0615586, IC-0615593, IC-0615588, IC-0615589, IC-0615593, IC-0615594, IC-0615595, IC-0615596, IC-0615599, IC-0615600, IC-0615601, IC-0615602, IC-0615604, IC-0615608, IC-0615610, IC-0615613 and Coll. 35.

4.4.1.16 Presence of suture

The data on presence of suture on fruit surface in litchi germplasm are given in table 4.4.4. The prominent suture on fruit surface was found in fourteen genotypes *viz*., IC-0615585, IC-0615587, IC-0615588, IC-0615590, IC-0615593, IC-0615594, IC-0615596, Coll. 39, IC-0615599, IC-0615600, IC-0615604, IC-0615613, Coll.36 and Coll. 37 whereas, it was absent in three genotypes *viz*., IC-0615595, IC-0615603, IC-0615608 and weak suture was observed in thirteen genotypes *viz*., IC-0615586, IC-0615589, IC-0615591, IC-0615592, IC-0615597, IC-0615601, IC-

0615602, IC-0615605, IC-0615606, IC-0615610, IC-0615611, Col. 35 and Col. 38.

4.4.1.17 Fruit attractiveness

The data on attractiveness of fruit in different litchi germplasm are given in table 4.4.4. Excellent fruit appearance was found in fourteen genotypes *viz*., IC-0615585, IC-0615590, IC-0615591, IC-0615592, IC-0615593, IC-0615594, IC-0615596, IC-0615605, IC-0615606, IC-0615610, IC-0615611, Coll. 36, Coll. 37 and Coll. 38 whereas, poor in only one genotype IC-0615599. Good appearance of fruit was observed in nine genotypes *viz*., IC-0615586, IC-0615588, IC-0615597, IC-0615600, IC-0615601, IC-0615602, IC-0615603, IC-0615605 and Coll. 35 while intermediate was found in six genotypes *viz*., IC-0615587, IC-0615589, IC-0615595, Coll. 39, IC-0615608 and IC-0615613.

4.4.1.18 Aril texture

The data on aril texture of fruit in different litchi germplasm are given in table 4.4.4. Leathery aril texture was found in fourteen genotypes *viz*., IC-0615585, IC-0615589, IC-0615591, IC-0615592, IC-0615593, IC-0615595, IC-0615596, IC-0615605, IC-0615606, IC-0615611, IC-0615613, Coll. 35, Coll. 36 and Coll. 37 whereas, firm aril texture was found in three genotypes IC-0615594, IC-0615608 and IC-0615599. Soft aril texture was found in ten genotypes *viz*., IC-0615586, IC-0615587, IC-0615588, IC-0615597, IC-0615600, IC-0615601, IC-0615602, IC-0615605, IC-0615610 and Coll. 38 while melting texture was observed in three genotypes *viz*., IC-0615590, Coll. 39 and IC-0615603.

4.4.1.19 Aril quality

The data on aril quality of fruit in different litchi germplasm are given in table 4.4.4. Sweet aril was found in twenty three genotypes *viz*., IC-0615585, IC-0615587, IC-0615589, IC-0615590, IC-0615591, IC-0615592, IC-0615593,IC-0615595, IC-0615597, IC-0615600, IC-0615601, IC-0615602, IC-0615603, IC-0615605, IC-0615606, IC-0615608, IC-0615610, IC-0615611, IC-0615613, Coll. 35, Coll. 36,

Coll. 37 and Coll. 38 whereas, bitter quality of aril was found in four genotypes *viz*., IC-0615588, IC-0615593, IC-0615595 and IC-0615604, and acidic tatse was found in three genotypes IC-0615586, Coll. 39and IC-0615599.

4.4.1.20 Aril flavour

The data on aril texture of fruit in different litchi germplasm are given in table 4.4.4.The strong flavour was found in fourteen genotypes *viz*., IC-0615587, IC-0615590, IC-0615592, IC-0615594, IC-0615597, IC-0615600, IC-0615601, IC-0615608, IC-0615610, IC-0615611, IC-0615613, Coll. 36, Coll. 37 and Coll. 38 whereas, weak flavour was found in five genotypes *viz*., IC-0615586, IC-0615595, Coll. 39, IC-0615599 and Coll. 35 and intermediate was observed in nine genotypes *viz*., IC-0615585, IC-0615588, IC-0615589, IC-0615591, IC-0615593, IC-0615596, IC-0615602, IC-0615 605 and IC-0615606 while good flavour was found in two genotypes IC-0615603 and IC-0615604..

4.4.1.21 Aril juiciness

The data on aril juiciness of fruit in different litchi germplasm are given in table 4.4.4. All the germplasm were juicy except four genotypes *viz*., Coll. 39, IC-0615603, IC-0615611 and Coll. 35 which were very juicy.

4.4.1.22 Aril colour

The data on aril colour of fruit in different litchi germplasm are given in table 4.4.4. All the germplasm showed dull white aril colour except genotypes IC-0615610 and Coll. 38 which had creamy white colour and IC-0615613 had white aril colour.

Table 4.4.3: Qualitative fruit characteristics of 30 litchi germplasm

Germplasm	Mature fruit colour													Distribution of colour on fruit surface		Shape of tubercles					
	1	2	3	4	5	6	7	8	9	10	11	12	13	1	2	1	2	3	4	5	6	7
	Green	Greenish yellow	Greenish red	Pinkish red	Crimson	Red	Reddish yellow	Dark red	Purple red	Rosy red	Deep orange	Deep pink	Scarlet	Uniform	Partial	Slightly pointed	Sharp pointed	Extremely sharp pointed	Wedge	Obtuse	Smooth	Cuneate
IC-0615585	13													2		2						
IC-0615586	3													2		1						
IC-0615587	12													2		6						
IC-0615588	5													1		5						
IC-0615589	4													1		2						
IC-0615590	10													1		1						
IC-0615591	10													1		1						
IC-0615592	10													1		1						
IC-0615593	5													1		5						
IC-0615594	12													1		2						

IC-0615595	7	2	5
IC-0615596	5	1	5
IC-0615597	7	2	2
Coll. 39	7	1	2
IC-0615599	7	2	5
IC-0615600	7	1	2
IC-0615601	7	1	2
IC-0615602	6	1	2
IC-0615603	10	1	1
IC-0615604	5	1	5
IC-0615605	6	2	2
IC-0615606	4	1	2
IC-0615608	7	1	2
IC-0615610	6	1	1
IC-0615611	5	1	2
IC-0615613	12	1	5
Coll. 35	6	1	2
Coll. 36	5	1	1
Coll. 37	5	1	1
Coll. 38	10	1	1

Table 4.4.4: Qualitative fruit characteristics of 30 litchi germplasm

Germplasm	Presence of suture			Tubercles density			Fruit attractiveness				Aril texture								Aril quality				Aril flavour			Aril juiciness			Aril colour							
	0	3	7	3	5	7	1	2	3	4	1	2	3	4	5	6	7	8	1	2	3	4	1	2	3	0	1	2	1	2	3	4	5	6	7	8
	Absent	Weak	Prominent	Sparse	Medium	Dense	Poor	Intermediate	Good	Excellent	Soft	Firm	Coarse	Fibrous	Melting	Leathery	Crisp	Extremely crisp	Insipid	Acid	Bitter	Sweet	Weak	Intermediate	Strong	Not Juicy	Juicy	Very juicy	White	Dull white	Creamy white	Creamy yellow	Yellow	Pearl white	Waxy white	Waxy yellow
IC-0615585	7			5			4				6								4				2			1			2							
IC-0615586	3			3			3				1								2				1			1			2							
IC-0615587	7			3			2				1								4				3			1			2							
IC-0615588	7			3			3				1								3				2			1			2							
IC-0615589	3			3			2				6								4				2			1			2							
IC-0615590	7			7			4				5								4				3			1			2							
IC-0615591	3			7			4				6								4				2			1			2							
IC-0615592	3			7			4				6								4				3			1			2							
IC-0615593	7			3			4				6								3				2			1			2							
IC-0615594	7			3			4				2								4				3			1			2							
IC-0615595	0			3			2				6								4				1			1			2							
IC-0615596	7			3			4				6								3				2			1			2							

IC-0615597	3	5	3	1	4	3	1	2
Coll. 39	7	5	2	5	2	1	2	2
IC-0615599	7	3	1	2	2	1	1	2
IC-0615600	7	3	3	1	4	3	1	2
IC-0615601	3	3	3	1	4	3	1	2
IC-0615602	3	3	3	1	4	2	1	2
IC-0615603	0	7	3	5	4	3	2	2
IC-0615604	7	3	4	6	3	3	1	2
IC-0615605	3	5	3	1	4	2	1	2
IC-0615606	3	5	4	6	4	2	1	2
IC-0615608	0	3	2	2	4	3	1	1
IC-0615610	3	3	4	1	4	3	1	2
IC-0615611	3	7	4	6	4	3	2	3
IC-0615613	7	3	2	6	4	3	1	2
Coll. 35	3	3	3	6	4	1	2	2
Coll. 36	7	7	4	6	4	3	1	2
Coll. 37	7	7	4	6	4	3	1	2
Coll. 38	3	7	4	1	4	3	1	3

4.4.2 Quantitative characters

4.4.2.1 Number of days from fruit set to maturity

The data of number of days from fruit set to maturity are shown in table-4.4.5. An observation of the data during 2017 revealed that there was highly significant difference in maturity period of different germplasm. The fruits of genotypes IC-0615585 and Coll. 37 matured in 72.00 days which was *at par* with genotype IC-0615590 (71.00 days) and it was *at par* with IC-0615587 and IC-0615591 (70.00 days) whereas, minimum days for maturity was recorded in genotype IC-0615608 (60.00 days) followed by IC-0615586, IC-0615599 and Coll 36 (62.00) which was *at par* with genotypes IC-0615596, Coll. 39 and IC-0615605 (63.00 days). While during 2018, similar trend with maximum days for maturity was found in IC-0615585 (69.00 days) which was *at par* with IC-0615611 (67.00 days) and IC-0615588 (66.00 days) and minimum in IC-0615608 (51.00 days) followed by IC-0615586 and IC-0615591 (57.00 days).

Statistical analysis of pooled data reflected that there was highly significant difference in maturity period. Genotype IC-0615585 took more days to mature its fruit *i.e.* 72.00 followed by Coll. 37 (68.5 days) which was *at par* with IC-0615588 and IC-0615590 (67.50 days) while minimum days were taken by in IC- 0615608 *i.e*. 55.5 followed by IC-0615586 (59.5 days) which was *at par* with Coll. 37 (60.0 days).

4.4.2.2 Number of fruits per cluster

A glance at table 4.4.6 and and Figure 4.9 reveals that the number of fruits per cluster at harvest was significantly varied among the litchi germplasm during both the years.The maximum number of fruits per cluster was found in genotype IC-0615611 (13.76) followed by IC-0615590 (13.75) and IC-0615610 (13.24) whereas, minimum in genotype IC-0615595 (1) followed by IC-0615613 (3), IC-0615588 (3.12) and IC-0615599 (3.76) during first year, while during second year, the maximum fruits per cluster was found in genotype

Table 4.4.5: Number of days from fruit set to maturity in different litchi germplasm

Germplasm	Number of days from fruit set to maturity (Days)		
	2017	2018	Pooled
IC-0615585	72.0	69.0	70.5
IC-0615586	62.0	57.0	59.5
IC-0615587	70.0	64.0	67.0
IC-0615588	69.0	66.0	67.5
IC-0615589	66.0	65.0	65.5
IC-0615590	71.0	64.0	67.5
IC-0615591	70.0	57.0	63.5
IC-0615592	67.0	64.0	65.5
IC-0615593	65.0	65.0	65.0
IC-0615594	66.0	58.0	62.0
IC-0615595	65.0	62.0	63.5
IC-0615596	63.0	64.0	63.5
IC-0615597	64.0	58.0	61.0
Coll. 39	63.0	62.0	62.5
IC-0615599	62.0	59.0	60.5
IC-0615600	65.0	61.0	63.0
IC-0615601	67.0	60.0	63.5
IC-0615602	68.0	62.0	65.0
IC-0615603	65.0	62.0	63.5
IC-0615604	65.0	62.0	63.5
IC-0615605	63.0	61.0	62.0
IC-0615606	65.0	60.0	62.5
IC-0615608	60.0	51.0	55.5
IC-0615610	67.0	60.0	63.5
IC-0615611	67.0	67.0	67.0
IC-0615613	68.0	64.0	66.0
Coll. 35	65.0	59.0	62.0
Coll. 36	62.0	58.0	60.0
Coll. 37	72.0	65.0	68.5
Coll. 38	66.0	64.0	65.0
SEm ±	0.64	1.12	0.37
CD at 5%	1.82	3.17	1.06

Table 4.4.6: Number of fruits per cluster in different litchi germplasm

Germplasm	Number of fruits per cluster		
	2017	2018	Pooled
IC-0615585	5.73	5.27	5.50
IC-0615586	7.00	7.11	7.06
IC-0615587	4.15	4.08	4.12
IC-0615588	3.12	2.92	3.02
IC-0615589	8.98	8.73	8.86
IC-0615590	13.75	13.27	13.51
IC-0615591	12.65	12.73	12.69
IC-0615592	13.00	12.44	12.72
IC-0615593	4.53	4.19	4.36
IC-0615594	11.00	10.75	10.88
IC-0615595	1.00	1.00	1.00
IC-0615596	4.75	4.63	4.69
IC-0615597	11.00	10.56	10.78
Coll. 39	5.00	4.88	4.94
IC-0615599	3.76	3.63	3.70
IC-0615600	9.76	10.00	9.88
IC-0615601	10.00	9.75	9.88
IC-0615602	7.00	7.50	7.25
IC-0615603	13.00	13.77	13.39
IC-0615604	4.74	4.38	4.56
IC-0615605	7.00	7.57	7.29
IC-0615606	9.00	8.50	8.75
IC-0615608	8.74	8.10	8.42
IC-0615610	13.24	12.63	12.94
IC-0615611	13.76	13.19	13.48
IC-0615613	3.00	2.93	2.97
Coll. 35	10.12	9.69	9.91
Coll. 36	9.00	8.27	8.64
Coll. 37	13.00	12.47	12.74
Coll. 38	10.00	9.19	9.60
SEm ±	0.28	0.22	0.21
CD at 5%	0.79	0.62	0.59

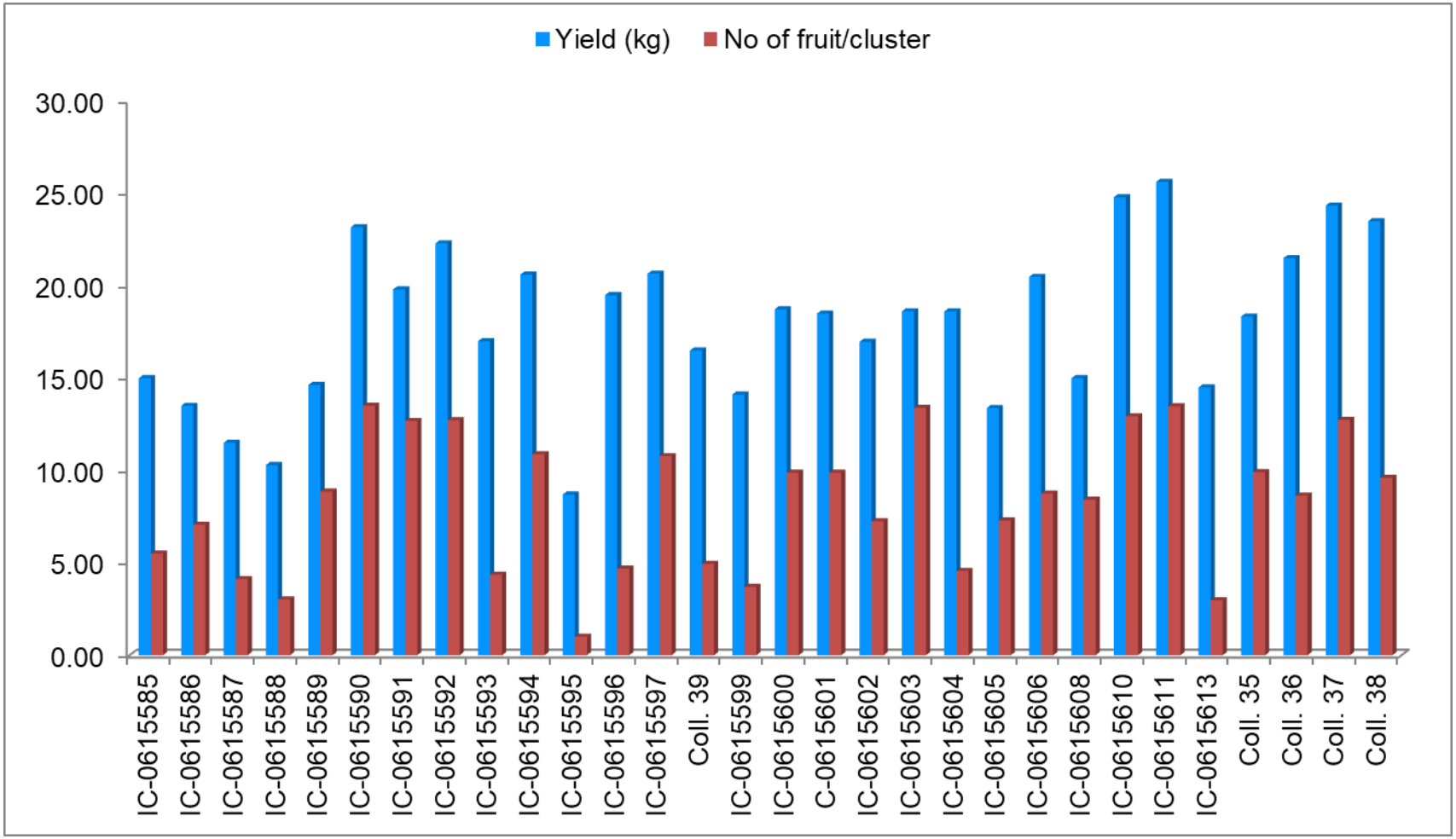


Figure 4.9: Variation in number of fruits per cluster and yield per plant among 30 litchi germplasm

IC-0615585

IC-0615586

IC-0615587

IC-0615588

IC-0615589

IC-0615590

IC-0615591

IC-0615592

IC-0615593

Plate 11: Variations in fruit bunch among 30 litchi germplasm

IC-0615594 IC-0615595 IC-0615596

IC-0615597 Coll. 39 IC-0615599

IC-0615600 IC-0615601 IC-0615602

Plate 11 (Contd): Variations in fruit bunch among 30 litchi germplasm

IC-0615603 IC-0615604 IC-0615605

IC-0615606 IC-0615608 IC-0615610

IC-0615611 IC-0615613 Coll. 35

Plate 11 (Contd): Variations in fruit bunch among 30 litchi germplasm

Coll. 36 **Coll. 37** **Coll. 38**

Plate 11 (Contd): Variations in fruit bunch among 30 litchi germplasm

IC-0615603 (13.77) followed by IC-0615590 (13.27) and IC-0615611 (13.19) whereas, minimum number of fruits was recorded in genotype IC-0615595 (1) followed by IC-0615588 (2.92), IC-0615613 (2.93) and IC-0615599 (3.63).

The results of pooled analysis showed that maximum number of fruit per cluster was observed in genotype IC-0615590 (13.51) followed by IC-0615611 (13.48) and IC-0615603 (13.39) whereas, the lowest number of fruits per cluster was found in genotype IC-0615595 (1) followed by IC-0615613 (2.97), IC-0615588 (3.02) and IC-0615599 (3.70).

4.4.2.3 Fruit length (mm)

A perusal of data presented in table 4.4.7 and Figure 4.10 indicates that the fruit length was significantly varied among the litchi germplasm during both the years.The maximum fruit length was observed in genotype IC-0615585 (42.55 mm) succeeded by IC-0615591 (37.42 mm) and IC-0615911(38.15 mm) whereas, minimum in genotype IC-0615587 (27.74 mm) followed by IC-0615588 (28.96 mm) and IC-0615595 (29.21 mm) in 2017. While during 2018, the similar trend with maximum fruit length was found in genotype IC-0615585 (42.35 mm) followed by IC-0615611 (38.46 mm) and IC-0615591 (38.65 mm) whereas, lowest fruit length was recorded in genotype IC-0615587 (28.15 mm) followed by IC-0615595 (28.35 mm) and IC-0615588 (29.00 mm).

However, the pooled analysis showed the maximum fruit length was in genotype IC-0615585 (42.45 mm) followed by IC-0615591 (38.85 mm) and IC-0615611 (38.50 mm) while minimum was found in genotype IC-0615587 (27.94 mm) followed by IC-0615595 (28.78 mm) and IC-0615588 (28.98 mm).

4.4.2.4 Fruit diameter (mm)

The data of fruit diameter have been presented in table 4.4.8 and depicted in Figure 4.10 revealed that the fruit diameter was significantly differed among the germplasm evaluated.The maximum fruit diameter was recorded in genotype IC-0615613 in both the years (35.49 mm and 36.13 mm) succeeded by IC-0615585 (33.97 mm and 33.76 mm) whereas, lowest diamterer in genotype IC-0615605 (27.94

Table 4.4.7: Fruit length in different litchi germplasm

Germplasm	Fruit length (mm)		
	2017	2018	Pooled
IC-0615585	42.55	42.35	42.45
IC-0615586	32.66	31.45	32.06
IC-0615587	27.74	28.15	27.95
IC-0615588	28.96	29.00	28.98
IC-0615589	31.25	30.45	30.85
IC-0615590	36.23	35.98	36.11
IC-0615591	39.06	38.65	38.86
IC-0615592	37.42	38.45	37.94
IC-0615593	32.67	33.00	32.84
IC-0615594	34.93	33.45	34.19
IC-0615595	29.21	28.35	28.78
IC-0615596	34.83	35.12	34.98
IC-0615597	33.86	34.23	34.05
Coll. 39	31.67	31.12	31.40
IC-0615599	35.14	35.84	35.49
IC-0615600	34.08	33.86	33.97
IC-0615601	36.68	36.23	36.46
IC-0615602	33.73	33.62	33.68
IC-0615603	35.52	36.45	35.99
IC-0615604	33.82	34.20	34.01
IC-0615605	30.45	30.15	30.30
IC-0615606	35.05	34.65	34.85
IC-0615608	33.22	32.95	33.09
IC-0615610	35.15	36.56	35.86
IC-0615611	38.15	38.86	38.51
IC-0615613	34.06	34.52	34.29
Coll. 35	34.68	33.86	34.27
Coll. 36	34.80	35.12	34.96
Coll. 37	34.10	35.00	34.55
Coll. 38	38.00	37.68	37.84
SEm ±	0.49	0.83	0.38
CD at 5%	1.40	2.35	1.09

Table 4.4.8: Fruit diameter in different litchi germplasm

Germplasm	Fruit diameter (mm)		
	2017	2018	Pooled
IC-0615585	33.97	33.76	33.87
IC-0615586	29.30	29.00	29.15
IC-0615587	31.55	31.75	31.65
IC-0615588	32.10	32.23	32.17
IC-0615589	29.03	29.12	29.08
IC-0615590	32.86	33.06	32.96
IC-0615591	32.29	32.10	32.20
IC-0615592	31.95	32.64	32.30
IC-0615593	33.00	33.45	33.23
IC-0615594	30.08	30.15	30.12
IC-0615595	28.37	27.56	27.97
IC-0615596	32.78	33.52	33.15
IC-0615597	28.62	29.16	28.89
Coll. 39	28.57	28.14	28.36
IC-0615599	30.12	30.56	30.34
IC-0615600	29.73	30.10	29.92
IC-0615601	30.72	30.43	30.58
IC-0615602	31.23	31.56	31.40
IC-0615603	28.65	29.56	29.11
IC-0615604	32.76	33.00	32.88
IC-0615605	27.94	28.14	28.04
IC-0615606	32.64	31.86	32.25
IC-0615608	29.35	29.12	29.24
IC-0615610	31.85	32.14	32.00
IC-0615611	32.61	33.00	32.81
IC-0615613	35.49	36.13	35.81
Coll. 35	29.53	28.52	29.03
Coll. 36	32.80	33.00	32.90
Coll. 37	29.47	30.14	29.81
Coll. 38	30.42	30.42	30.42
SEm ±	0.41	0.40	0.36
CD at 5%	1.17	1.13	1.01

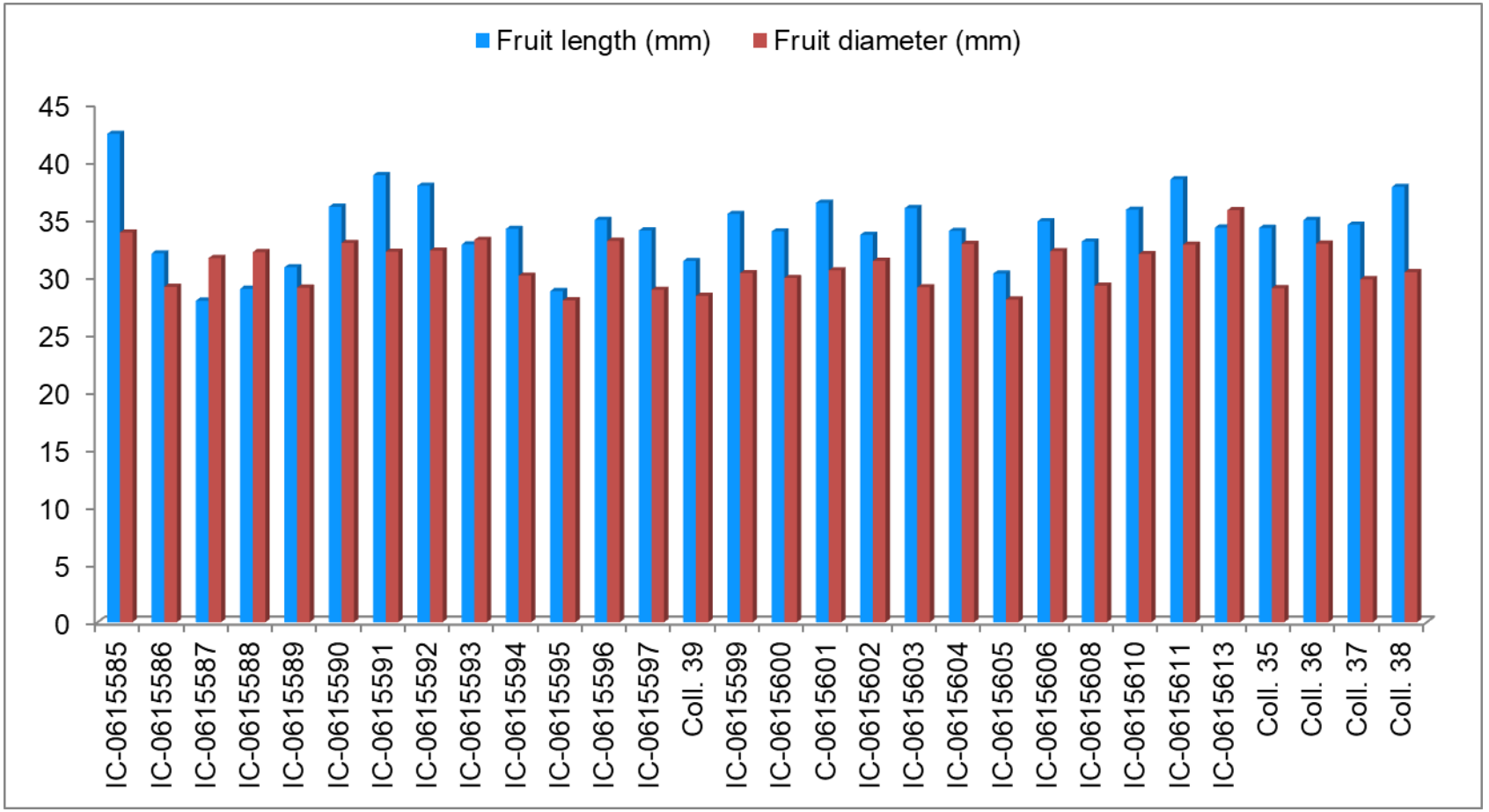


Figure 4.10: Variation in length and diameter of fruit among 30 litchi germplasm

IC-0615585 IC-0615586 IC-0615587

IC-0615588 IC-0615589 IC-0615590

IC-0615591 IC-0615592 IC-0615593

IC-0615594 IC-0615595 IC-0615596

IC-0615597 Coll. 39 IC-0615599

Plate 12: Variation in fruit shape among 30 litchi genotypes

IC-0615600

IC-0615601

IC-0615602

IC-0615603

IC-0615604

IC-0615605

IC-0615606

IC-0615608

IC-0615610

IC-0615611

IC-0615613

Coll. 35

Coll. 36

Coll. 37

Coll. 38

Plate 12 (Contd): Variation in fruit shape among 30 litchi genotypes

mm) followed by IC-0615595 (28.37 mm) and Coll. 39 (28.57 mm) in 2017. While during 2018, minimum fruit diamterer was found in genotype IC-0615595 (27.56 mm) followed by 28.14 mm in both genotypes IC-0615605 and Coll. 39. However, the pooled analysis showed the maximum fruit diameter was observed in genotype IC-0615613 (35.81 mm) succeeded by IC-0615585 (33.87 mm) and IC-0615593 (33.23 mm) whereas, lowest diameter in IC-0615595 (27.97 mm) followed by IC-0615605 (28.04 mm) and Coll. 39 (28.36 mm).

4.4.2.5 Fruit weight (g)

The data on fruit weight are presented in table 4.4.9 and depicted in Figure 4.11 revealed that the fruit weight was significantly varied among the germplasm evaluated. The maximum fruit weight was found in genotype IC-0615585 (25.52 g) followed by IC-0615601 (23.45 g) and IC-0615613 (23.43 g) while lowest weight was reported in genotype IC-0615595 (15.10 g) followed by IC-06155857 (16.57 g) which was *at par* with IC-0615588 (17.26 g) during 2017 but in 2018, the maximum fruit weight was recorded in genotype IC-0615613 (26.10 g) which was *at par* with IC-0615585 (26.00 g) whereas, the lowest weight was recorded in IC-0615587 (15.80 g) which was *at par* with IC-0615595 (16.00 g).

A glance of the pooled data indicated that fruit weight was found maximum in genotype IC-0615585 (25.76 g) followed by IC-0615613 (24.77 g) and IC-0615601 (23.8 g) whereas, lowest in genotype IC-0615595 (15.55g) followed by IC-0615587 (16.19 g) and IC-0615588 (17.26 g).

4.4.2.6 Aril weight (g)

A glance at table 4.4.10 and Figure 4.11 evinced that the aril weight was significantly varied among the litchi germplasm during both the years.The maximum aril weight was found in genotype IC-0615613 (17.86 g) succeeded by IC-0615611 (15.08 g) and IC-0615610 (14.97 g) whereas, minimum in genotype IC-0615595 (7.15 g) followed by IC- 0615603 (9.70 g) and IC- 06015589 (9.90 g) in 2017. While during 2018, the similar trend with maximum aril weight

Table 4.4.9: Fruit weight in different litchi germplasm

Germplasm	Fruit weight (g)		
	2017	2018	Pooled
IC-0615585	25.52	26.00	25.76
IC-0615586	18.76	18.00	18.38
IC-0615587	16.57	15.80	16.19
IC-0615588	17.26	16.80	17.03
IC-0615589	18.80	19.00	18.90
IC-0615590	22.40	22.50	22.45
IC-0615591	22.28	22.20	22.24
IC-0615592	23.15	22.90	23.03
IC-0615593	21.10	21.00	21.05
IC-0615594	21.45	21.00	21.23
IC-0615595	15.10	16.00	15.55
IC-0615596	20.14	19.80	19.97
IC-0615597	20.82	21.00	20.91
Coll. 39	19.20	19.00	19.10
IC-0615599	21.00	20.00	20.50
IC-0615600	22.67	22.10	22.39
IC-0615601	23.45	22.70	23.08
IC-0615602	21.97	22.00	21.99
IC-0615603	19.16	19.25	19.21
IC-0615604	21.64	20.70	21.17
IC-0615605	19.20	18.60	18.90
IC-0615606	21.46	20.60	21.03
IC-0615608	22.16	21.70	21.93
IC-0615610	22.85	22.16	22.51
IC-0615611	22.32	22.17	22.25
IC-0615613	23.43	26.10	24.77
Coll. 35	19.83	20.00	19.92
Coll. 36	18.74	19.00	18.87
Coll. 37	19.75	20.00	19.88
Coll. 38	18.60	19.80	19.20
SEm ±	0.37	0.34	0.31
CD at 5%	1.05	0.96	0.88

Table 4.4.10: Aril weight in different litchi germplasm

Germplasm	Aril weight (g)		
	2017	2018	Pooled
IC-0615585	14.47	14.80	14.64
IC-0615586	10.53	10.10	10.32
IC-0615587	12.32	12.35	12.34
IC-0615588	12.96	12.16	12.56
IC-0615589	9.90	9.95	9.93
IC-0615590	12.92	12.10	12.51
IC-0615591	13.23	12.40	12.82
IC-0615592	13.10	13.00	13.05
IC-0615593	14.86	14.35	14.61
IC-0615594	13.59	12.68	13.14
IC-0615595	7.15	7.38	7.27
IC-0615596	14.36	14.08	14.22
IC-0615597	12.70	12.00	12.35
Coll. 39	11.84	11.10	11.47
IC-0615599	12.92	12.26	12.59
IC-0615600	12.46	12.40	12.43
IC-0615601	14.52	13.82	14.17
IC-0615602	13.50	13.00	13.25
IC-0615603	9.70	10.00	9.85
IC-0615604	14.80	13.95	14.38
IC-0615605	10.00	9.75	9.88
IC-0615606	14.90	13.63	14.27
IC-0615608	14.75	13.69	14.22
IC-0615610	14.97	14.23	14.60
IC-0615611	15.08	14.38	14.73
IC-0615613	17.86	17.45	17.66
Coll. 35	12.56	12.76	12.66
Coll. 36	10.89	10.92	10.91
Coll. 37	12.26	12.35	12.31
Coll. 38	10.70	10.96	10.83
SEm ±	0.28	0.27	0.31
CD at 5%	0.81	0.78	0.88

Figure 4.11: Variation in fruit and aril weight among 30 litchi germplasm

IC-0615585

IC-0615586

IC-0615587

IC-0615588

IC-0615589

IC-0615590

IC-0615591

IC-0615592

IC-0615593

IC-0615594

IC-0615595

IC-0615596

IC-0615597

Coll. 39

IC-0615599

Plate 13: Variations in fruit, aril and seed among 30 litchi germplasm

IC-0615600

IC-0615601

IC-0615602

IC-0615603

IC-0615604

IC-0615605

IC-0615606

IC-0615608

IC-0615610

IC-0615611

IC-0615613

Coll. 35

Coll. 36

Coll. 37

Coll. 38

Plate 13 (Contd): Variations in fruit, aril and seed among 30 litchi germplasm

Table 4.4.11: Aril thickness in different litchi germplasm

Germplasm	Aril thickness (mm)		
	2017	2018	Pooled
IC-0615585	9.42	9.51	9.47
IC-0615586	4.62	4.70	4.66
IC-0615587	8.12	8.46	8.29
IC-0615588	8.24	8.72	8.48
IC-0615589	5.00	5.17	5.09
IC-0615590	5.24	5.71	5.48
IC-0615591	7.00	7.08	7.04
IC-0615592	7.12	7.24	7.18
IC-0615593	10.86	11.14	11.00
IC-0615594	5.62	5.88	5.75
IC-0615595	7.12	7.44	7.28
IC-0615596	9.08	9.24	9.16
IC-0615597	7.00	7.15	7.08
Coll. 39	4.15	4.35	4.25
IC-0615599	7.25	7.56	7.40
IC-0615600	6.07	6.22	6.15
IC-0615601	6.00	6.02	6.01
IC-0615602	6.40	6.94	6.67
IC-0615603	4.60	4.89	4.75
IC-0615604	9.32	9.66	9.49
IC-0615605	6.00	6.28	6.14
IC-0615606	6.26	6.88	6.57
IC-0615608	5.23	5.64	5.43
IC-0615610	7.08	7.28	7.18
IC-0615611	6.20	6.53	6.36
IC-0615613	8.86	9.17	9.01
Coll. 35	6.52	6.72	6.62
Coll. 36	7.00	7.16	7.08
Coll. 37	7.45	7.88	7.67
Coll. 38	5.20	5.62	5.41
SEm ±	0.12	0.21	0.08
CD at 5%	0.35	0.59	0.21

was recorded in genotype IC-0615613 (17.45 g) succeeded by IC-0615585 (14.80 g) and IC-0615611 (14.38 g) whereas, lowest in IC-0615595 (7.38 g) followed by IC-0615605 (9.75 g) and IC-0615589 (9.95 g).

A perusal of pooled data showed that the aril weight was found maximum in genotype IC-0615613 (17.66 g) followed by IC-0615611 (14.73 g) which was *at par* with IC-0615585 (14.64 g) whereas, the lowest aril weight was recorded in genotype IC-0615595 (7.27 g) followed by IC-0615603 (9.85 g) which was *at par* with IC-0615605 (9.88 g).

4.4.2.7 Aril thickness (mm)

A glance at table 4.4.11 evinced that the aril thickness was significantly varied among the litchi germplasm during both the years. The maximum aril thickness was found in genotype IC-0615593 (10.86 mm) succeeded by IC-0615585 (9.42 mm) and IC-0615604 (9.32 mm) whereas, minimum in genotype Coll. 39 (4.15 mm) followed by IC- 0615603 (4.60 mm) and IC- 06015586 (4.62 mm) in 2017. While during 2018, the similar trend with maximum aril thickness was recorded in genotype IC-0615593 (11.14 mm) succeeded by IC-0615604 (9.66 mm) and IC-0615585 (9.51) whereas, lowest in genotype Coll. 39 (4.35 mm) followed by IC-0615586 (4.70 mm) and IC-0615603 (4.89 mm). A perusal of pooled data showed that the aril thickness was found maximum in genotype IC-0615593 (11.00 mm) followed by IC-0615604 (9.49 mm) and IC-0615585 (9.47 mm) whereas, the lowest aril thickness was recorded in genotype Coll. 39(4.25 mm) followed by IC-0615586 (4.66 mm) and IC-0615603 (4.75 mm).

4.4.2.8 Yield per plant (kg)

The data of both the years and their mean collected with respect to yield per plant are shown in table 4.4.12 and graphically depicted in Figure 4.9.The analysis of variance in respect of yield evinced that the germplasm differed highly significantly in both the years as well as in pooled analysis.The maximum fruit yield was

observed in genotype IC-0615611 (30.75 kg/plant) followed by IC-0615610 (24.00 kg/plant) and Coll. 37 (22.75 kg/plant), whereas, lowest yield was recorded in genotype IC-0615595 (8.40 kg/plant) followed by IC-0615588 (10.10 kg/plant) and IC-0615587 (11.00 kg/plant) during the first year, while during the second year, the maximum yield was found in genotype Coll. 37 (25.94 kg/plant) which was *at par* with IC-6015610 (25.60 kg/plant) and Coll. 38 (25.00 kg/plant) whereas, minimum yield in genotype IC-0615595 (9.00 kg/plant) followed by IC-0615588 (10.50 kg/plant) and IC-0615587(12.00 kg/plant).

However, the pooled data revealed that maximum fruit yield was in genotype IC-0615611(25.64 kg/plant) followed by IC-0615610(24.80 kg/plant) and Coll. 37 (24.35 kg/plant) whereas, minimum yield was recorded in genotype IC-0615595 (8.70 kg/plant) followed by IC-0615588 (10.30 kg/plant) and IC-0615587 (11.50 kg/plant).

4.4.2.8 Total soluble solid (°Brix)

The perusal of data in table 4.4.13 and Figure 4.12 reveals that the total soluble solids were significantly differed among the germplasm. The maximum TSS was observed in genotype IC-0615596 (20.00 ^{0}Brix) followed by IC-0615593 (19.80 ^{0}Brix) and IC-0615599 (19.76 ^{0}Brix) whereas, the lowest TSS was found in genotype IC-0615589 (17.00 ^{0}Brix) which was *at par* with IC-0615605 (17.10 ^{0}Brix) during the first year, while during second year, the maximum TSS was recorded in genotype IC-0615610 (20.15 ^{0}Brix) followed by IC-0615602 (20.00 ^{0}Brix) and IC-0615596 (19.88 ^{0}Brix) whereas, minimum in genotype IC-0615589 (17.08 ^{0}Brix) followed by IC-0615605 (17.28 ^{0}Brix) and IC-0615595 (17.60 ^{0}Brix).

The pooled data evinced that the genotype IC-0615610 ranked first inrespect of TSS percentage *i.e.* 19.98 which was par with IC-0615596 (19.94 ^{0}Brix) and lowest TSS was recorded in genotype IC-0615589 (17.04 ^{0}Brix) followed by IC-0615605 (17.19 ^{0}Brix) and IC-0615587 (17.52 ^{0}Brix).

Table 4.4.12: Yield per plant in different litchi germplasm

Germplasm	Yield (kg)/plant		
	2017	2018	Pooled
IC-0615585	14.00	16.00	15.00
IC-0615586	13.00	14.00	13.50
IC-0615587	11.00	12.00	11.50
IC-0615588	10.10	10.50	10.30
IC-0615589	13.27	16.00	14.64
IC-0615590	22.00	24.35	23.18
IC-0615591	18.62	21.00	19.81
IC-0615592	20.75	23.86	22.31
IC-0615593	16.00	18.00	17.00
IC-0615594	19.22	22.00	20.61
IC-0615595	8.40	9.00	8.70
IC-0615596	18.00	21.00	19.50
IC-0615597	19.32	22.00	20.66
Coll. 39	16.00	17.00	16.50
IC-0615599	13.00	15.23	14.12
IC-0615600	17.46	20.00	18.73
IC-0615601	17.00	20.00	18.50
IC-0615602	15.67	18.27	16.97
IC-0615603	17.24	20.00	18.62
IC-0615604	17.85	19.37	18.61
IC-0615605	12.76	14.00	13.38
IC-0615606	18.56	22.41	20.49
IC-0615608	14.00	16.00	15.00
IC-0615610	24.00	25.60	24.80
IC-0615611	30.75	20.52	25.64
IC-0615613	13.00	16.00	14.50
Coll. 35	16.84	19.83	18.34
Coll. 36	20.00	23.00	21.50
Coll. 37	22.75	25.94	24.35
Coll. 38	22.00	25.00	23.50
SEm ±	0.42	0.49	0.28
CD at 5%	1.19	1.38	0.80

4.4.13: TSS in different litchi germplasm

Germplasm	TSS (°Brix)		
	2017	2018	Pooled
IC-0615585	19.23	19.75	19.49
IC-0615586	17.50	18.00	17.75
IC-0615587	17.36	17.67	17.52
IC-0615588	17.62	17.65	17.64
IC-0615589	17.00	17.08	17.04
IC-0615590	17.80	18.00	17.90
IC-0615591	18.70	18.30	18.50
IC-0615592	18.16	18.00	18.08
IC-0615593	19.80	19.75	19.78
IC-0615594	18.10	18.20	18.15
IC-0615595	17.50	17.60	17.55
IC-0615596	20.00	19.88	19.94
IC-0615597	18.20	18.30	18.25
Coll. 39	17.55	17.75	17.65
IC-0615599	19.76	19.72	19.74
IC-0615600	18.08	18.00	18.04
IC-0615601	18.64	18.45	18.55
IC-0615602	19.56	20.00	19.78
IC-0615603	19.50	19.26	19.38
IC-0615604	19.70	19.86	19.78
IC-0615605	17.10	17.28	17.19
IC-0615606	18.50	18.86	18.68
IC-0615608	18.40	18.74	18.57
IC-0615610	19.80	20.15	19.98
IC-0615611	18.70	19.76	19.23
IC-0615613	18.60	19.84	19.22
Coll. 35	17.70	18.26	17.98
Coll. 36	19.23	19.20	19.22
Coll. 37	18.06	19.24	18.65
Coll. 38	18.55	19.20	18.88
SEm ±	0.04	0.04	0.08
CD at 5%	0.12	0.11	0.22

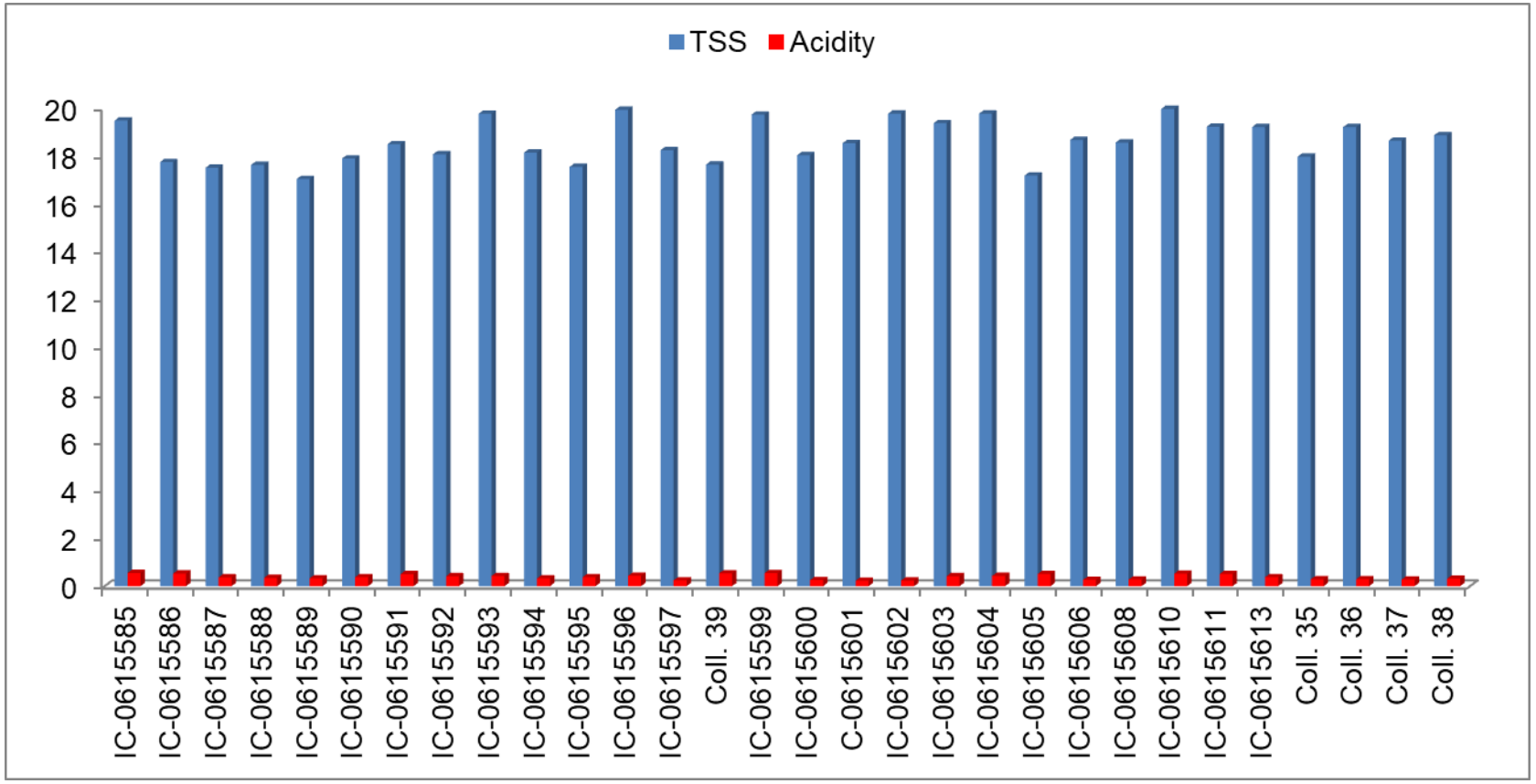


Figure 4.12: Variation in TSS and acidity among 30 litchi germplasm

4.4.2.9 Ascorbic acid (mg/100g)

The perusal of data in table 4.4.14 and Figure 4.13 evinces that the ascorbic acid was significantly differed among the germplasm. A perusal of data of 2017 revealed that ascorbic acid was found maximum in genotype IC-0615613 (48.00 mg/100 g) followed by IC-0615602 (44.00 mg/100 g) and IC-0615586 (42.00 mg/100 g) whereas, lowest ascorbic acid was found in genotype IC-0615595 (14.00 mg/100 g) followed by IC-0615590 and IC-0615597 (16.00 mg/100 g) and Coll. 37 and Coll. 38 (20.00 mg/100 g). While during 2018, similar trend with maximum ascorbic acid content was recorded in genotype IC-0615613 (47.00 mg/100 g) followed by IC-0615602 (43.15 mg/100 g) and IC-0615596 (41.00 mg/100 g) and lowest in genotype IC-0615595 (15.23 mg/100 g) followed by IC-0615597 (17.56 mg/100 g).

The pooled data analysis showed maximum content of ascorbic acid in genotypes IC-0615613 (47.50 mg/100 g) followed by IC-0615602 (43.58 mg/100 g) and IC-0615586 (41.06 mg/100 g) whereas, minimum in IC-0615595 (14.62 mg/100 g) followed by IC-0615597 (16.78 mg/100 g) and IC-0615590 (17.32 mg/100 g).

4.4.2.10 Total sugar (%)

The data in respect of total sugar in percentage are presented in table 4.4.15 and graphically depicted in Figure 4.14. The analysis of variance with respect of total sugar indicated that the germplasm differed highly significantly in both the years. The maximum total sugars was observed in genotype Coll. 35 in both the years (13.61 % and 13.46 %) followed by IC-0615610 (13.02 % and 13.00 %) and IC-0615594 (13.00 % and 12.54 %) whereas, lowest total sugar was found ingenotype IC-0615587 (10.00%) and in IC-0615589 (10.00 %) during 2017 and 2018, respectively. However, the pooled analysis showed the maximum total sugars in genotype Coll. 35 (13.54 %) whereas, lowest in genotype IC-0615586 (10.05 %) followed by IC-0615587 (10.12 %) and IC-0615589 (10.13 %).

Table 4.4.14: Ascorbic acid in different litchi germplasm

Germplasm	Ascorbic acid (mg/100g)		
	2017	2018	Pooled
IC-0615585	24.00	25.32	24.66
IC-0615586	42.00	40.12	41.06
IC-0615587	30.00	30.45	30.23
IC-0615588	28.60	29.00	28.80
IC-0615589	24.00	25.15	24.58
IC-0615590	16.00	18.64	17.32
IC-0615591	22.10	22.45	22.28
IC-0615592	24.00	25.34	24.67
IC-0615593	38.60	27.66	33.13
IC-0615594	20.00	21.14	20.57
IC-0615595	14.00	15.23	14.62
IC-0615596	40.00	41.00	40.50
IC-0615597	16.00	17.56	16.78
Coll. 39	30.00	31.24	30.62
IC-0615599	24.00	26.45	25.23
IC-0615600	24.00	25.24	24.62
IC-0615601	26.00	25.34	25.67
IC-0615602	44.00	43.15	43.58
IC-0615603	24.00	24.65	24.33
IC-0615604	39.32	40.00	39.66
IC-0615605	26.30	26.00	26.15
IC-0615606	32.00	30.82	31.41
IC-0615608	24.00	24.35	24.18
IC-0615610	24.00	25.00	24.50
IC-0615611	36.00	25.10	30.55
IC-0615613	48.00	47.00	47.50
Coll. 35	22.00	23.24	22.62
Coll. 36	20.00	21.26	20.63
Coll. 37	20.00	19.45	19.73
Coll. 38	20.00	21.75	20.88
SEm ±	0.49	0.46	0.37
CD at 5%	1.38	1.30	1.07

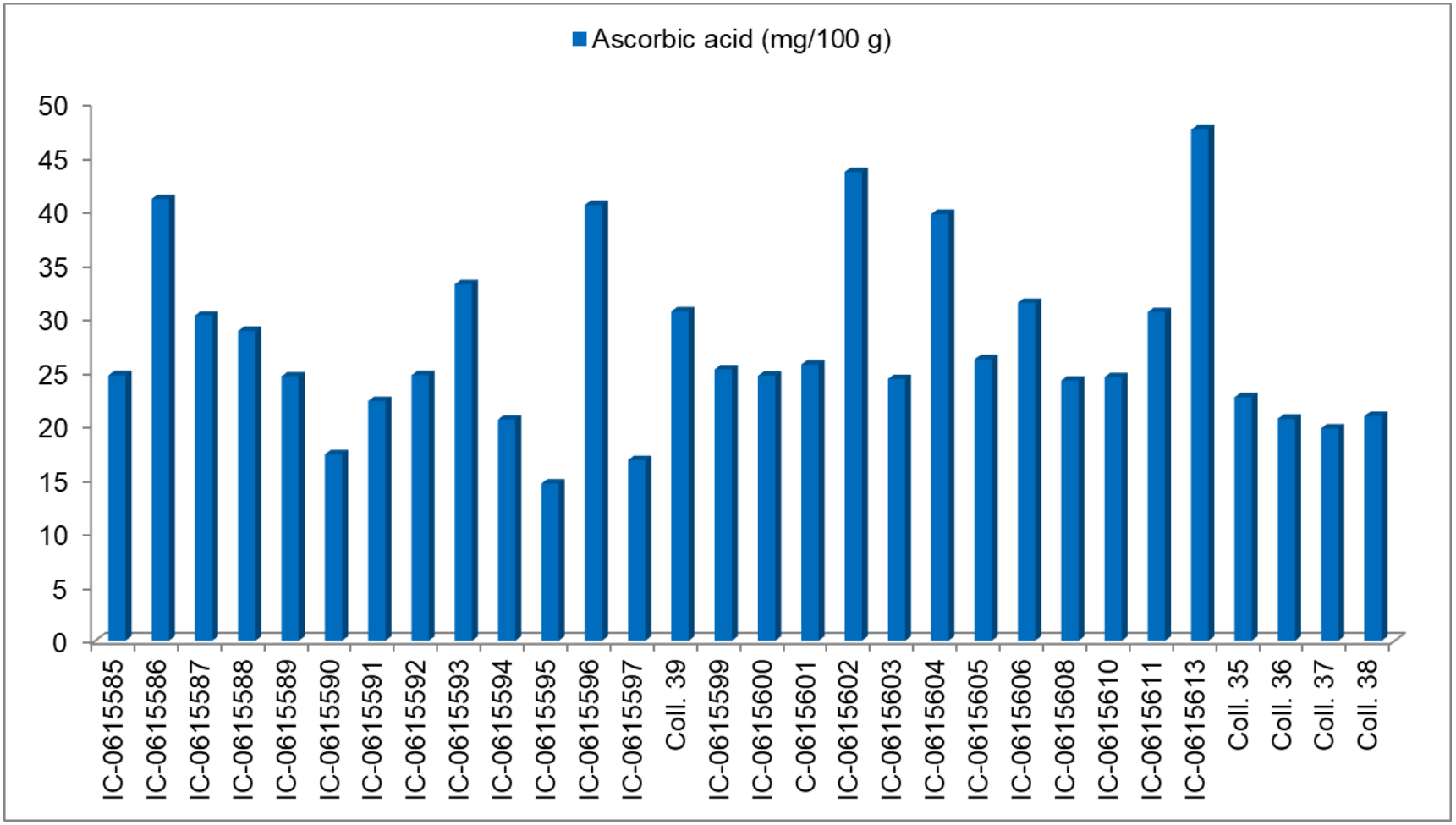


Figure 4.13: Variation in ascorbic acid among 30 litchi germplasm

Table 4.4.15: Total sugar in different litchi germplasm

Germplasm	Total sugar (%)		
	2017	2018	Pooled
IC-0615585	11.34	12.00	11.67
IC-0615586	10.10	10.00	10.05
IC-0615587	10.00	10.24	10.12
IC-0615588	10.60	10.67	10.64
IC-0615589	10.25	10.00	10.13
IC-0615590	11.30	10.85	11.08
IC-0615591	11.00	11.10	11.05
IC-0615592	12.90	12.26	12.58
IC-0615593	10.70	10.50	10.60
IC-0615594	13.00	12.54	12.77
IC-0615595	10.25	10.84	10.55
IC-0615596	10.40	10.52	10.46
IC-0615597	12.65	12.23	12.44
Coll. 39	10.60	11.00	10.80
IC-0615599	11.60	12.00	11.80
IC-0615600	12.30	11.76	12.03
IC-0615601	12.50	12.00	12.25
IC-0615602	11.60	11.92	11.76
IC-0615603	12.10	12.00	12.05
IC-0615604	10.60	10.45	10.53
IC-0615605	10.70	11.00	10.85
IC-0615606	11.65	12.00	11.83
IC-0615608	11.10	11.00	11.05
IC-0615610	13.02	13.00	13.01
IC-0615611	11.00	10.76	10.88
IC-0615613	11.53	11.25	11.39
Coll. 35	13.61	13.46	13.54
Coll. 36	11.20	11.00	11.10
Coll. 37	11.10	11.00	11.05
Coll. 38	11.60	11.28	11.44
SEm ±	0.29	0.39	0.37
CD at 5%	0.83	1.12	1.07

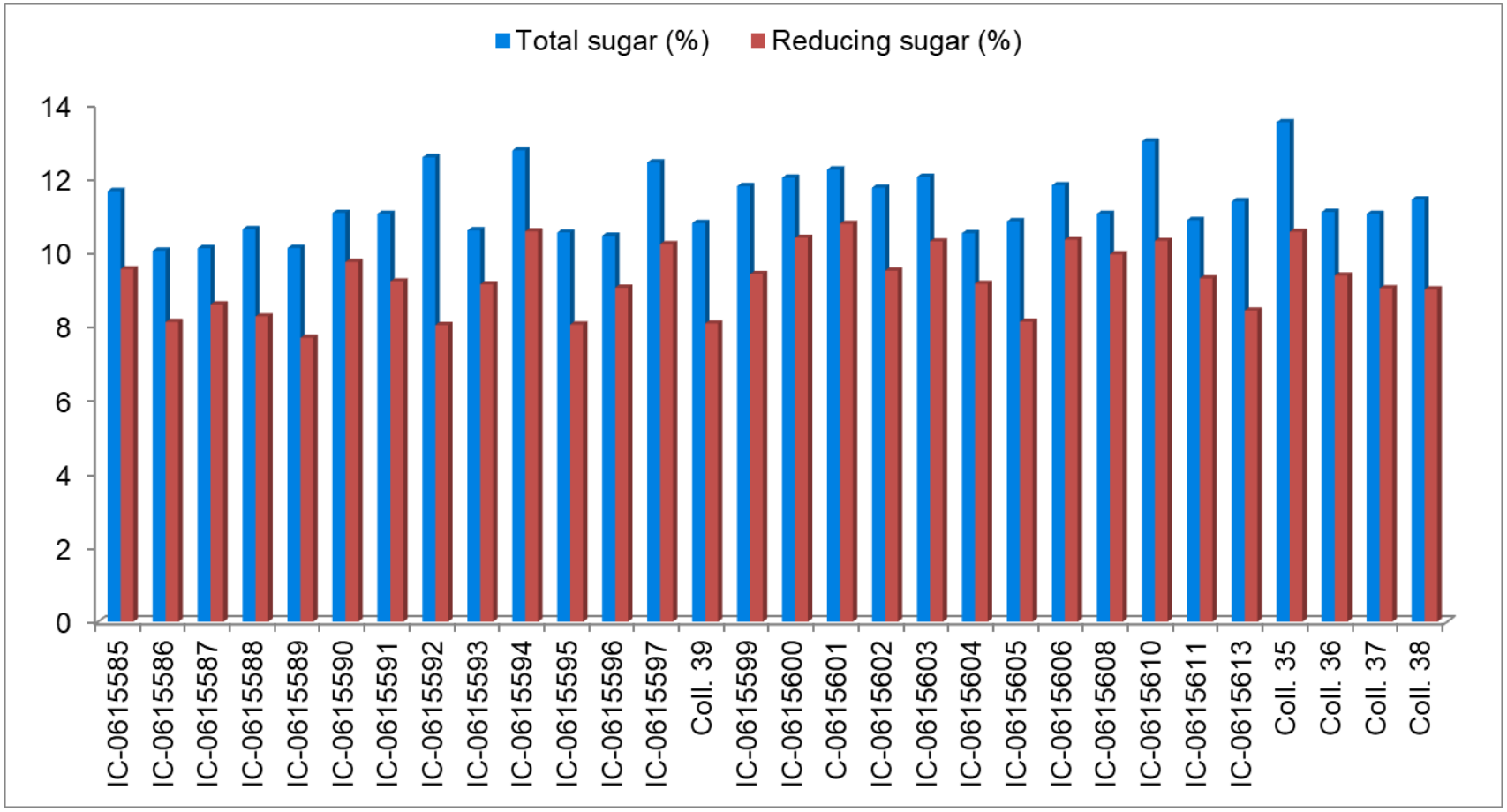


Figure 4.14: Variation in total sugar and reducing sugar among 30 litchi germplasm

4.4.2.11 Titratable acidity (%)

The data on titratable acidity percentage are presented in table 4.4.16 and depicted in Figure 4.12. The analysis of variance in respect of titratable acidity percentage clearly indicated that the germplasm varied highly significantly in both the years as well as in pooled analysis. A glance of the data indicated that maximum titratable acidity was found in genotype IC-0615585 (0.56 %) followed by IC-0615599 (0.55 %) and Coll. 39 (0.54 %) whereas, lowest acidity in genotype IC-0615601 (0.22 %) followed by IC-0615602 (0.23 %) and IC-0615597 (0.24 %) during first year, while in second year, the maximum acidity was recorded 0.54 per cent in both the genotypes IC-0615585 and IC-0615599 followed by 0.53 per cent in genotype Coll. 39 whereas, minimum acidity was 0.24 per cent in both the genotypes IC-0615601 and IC-0615602 followed by 0.25 per cent in both the genotypes IC-0615597 and IC-0615600.

However, the pooled analysis showed the maximum titratable acidity *i.e.* 0.55 per cent in both the genotypes IC-0615585 and IC-0615599 followed by 0.54 per cent in Coll. 39 and 0.53 per cent in IC-0615586 whereas, mimnimum in genotype IC-0615601 (0.23 %) followed by 0.24 percent in both the genotypes IC-0615602 and IC-0615597.

4.4.2.12 Reducing sugar (%)

The analysis of variance in respect of reducing sugar percentage clearly indicated that the germplasm varied highly significantly in both the years as well as in pooled analysis (Table 4.4.17 and Figure 4.14). A glance of the data indicated that maximum reducing sugar was found in genotype IC-0615594 (10.90 %) which was *at par* with IC-06015601 (10.80 %) and IC-0615600 (10.60 %) whereas, minimum in genotype IC-0615589 (7.86 %) followed by Coll. 39 (8.00 %) and IC-0615592 (8.07 %) during first year, while in second year, the maximum reducing sugar was found in genotype IC-0615601 (10.76 %) succeeded by Coll. 35 and IC-0615606 (10.30 %)

Table 4.4.16: Titratable acidity in different litchi germplasm

Germplasm	Titratable acidity (%)		
	2017	2018	Pooled
IC-0615585	0.56	0.54	0.55
IC-0615586	0.53	0.52	0.53
IC-0615587	0.37	0.36	0.37
IC-0615588	0.35	0.34	0.35
IC-0615589	0.32	0.33	0.33
IC-0615590	0.38	0.37	0.38
IC-0615591	0.51	0.5	0.51
IC-0615592	0.41	0.42	0.42
IC-0615593	0.42	0.43	0.43
IC-0615594	0.32	0.33	0.33
IC-0615595	0.38	0.37	0.38
IC-0615596	0.44	0.43	0.43
IC-0615597	0.24	0.25	0.24
Coll. 39	0.54	0.53	0.54
IC-0615599	0.55	0.54	0.55
IC-0615600	0.26	0.25	0.25
IC-0615601	0.22	0.24	0.23
IC-0615602	0.23	0.24	0.24
IC-0615603	0.43	0.41	0.42
IC-0615604	0.42	0.43	0.43
IC-0615605	0.51	0.5	0.51
IC-0615606	0.26	0.27	0.26
IC-0615608	0.27	0.28	0.27
IC-0615610	0.53	0.51	0.52
IC-0615611	0.50	0.52	0.51
IC-0615613	0.38	0.37	0.38
Coll. 35	0.29	0.27	0.28
Coll. 36	0.30	0.28	0.29
Coll. 37	0.28	0.27	0.28
Coll. 38	0.32	0.3	0.31
SEm ±	0.006	0.006	0.007
CD at 5%	0.016	0.018	0.021

Table 4.4.17: Reducing sugar in different litchi germplasm

Germplasm	Reducing sugar (%)		
	2017	2018	Pooled
IC-0615585	9.60	9.50	9.55
IC-0615586	8.13	8.11	8.12
IC-0615587	8.63	8.56	8.60
IC-0615588	8.26	8.28	8.27
IC-0615589	7.86	7.52	7.69
IC-0615590	9.87	9.62	9.75
IC-0615591	9.21	9.23	9.22
IC-0615592	8.07	8.00	8.04
IC-0615593	9.16	9.12	9.14
IC-0615594	10.90	10.25	10.58
IC-0615595	8.10	8.00	8.05
IC-0615596	9.10	9.00	9.05
IC-0615597	10.32	10.14	10.23
Coll. 39	8.00	8.16	8.08
IC-0615599	9.48	9.35	9.42
IC-0615600	10.60	10.20	10.40
IC-0615601	10.80	10.76	10.78
IC-0615602	9.36	9.65	9.51
IC-0615603	10.40	10.20	10.30
IC-0615604	9.23	9.08	9.16
IC-0615605	8.12	8.14	8.13
IC-0615606	10.40	10.30	10.35
IC-0615608	9.92	9.98	9.95
IC-0615610	10.35	10.28	10.32
IC-0615611	9.26	9.34	9.30
IC-0615613	8.36	8.50	8.43
Coll. 35	10.50	10.62	10.56
Coll. 36	9.30	9.45	9.38
Coll. 37	8.96	9.10	9.03
Coll. 38	8.90	9.10	9.00
SEm ±	0.15	0.14	0.17
CD at 5%	0.42	0.41	0.49

Table 4.4.18: TSS/acidity ratio in different litchi germplasm

Germplasm	TSS/ acidity ratio		
	2017	2018	Pooled
IC-0615585	34.34	36.57	35.44
IC-0615586	33.02	34.62	33.49
IC-0615587	46.92	49.08	47.35
IC-0615588	50.34	51.91	50.40
IC-0615589	53.13	51.76	51.64
IC-0615590	46.84	48.65	47.11
IC-0615591	36.67	36.60	36.27
IC-0615592	44.29	42.86	43.05
IC-0615593	47.14	45.93	46.00
IC-0615594	56.56	55.15	55.00
IC-0615595	46.05	47.57	46.18
IC-0615596	45.45	46.23	46.37
IC-0615597	75.83	73.20	76.04
Coll. 39	32.50	33.49	32.69
IC-0615599	35.93	36.52	35.89
IC-0615600	69.54	72.00	72.16
IC-0615601	84.73	76.88	80.65
IC-0615602	85.04	83.33	82.42
IC-0615603	45.35	46.98	46.14
IC-0615604	46.90	46.19	46.00
IC-0615605	33.53	34.56	33.71
IC-0615606	71.15	69.85	71.85
IC-0615608	68.15	66.93	68.78
IC-0615610	37.36	39.51	38.42
IC-0615611	37.40	38.00	37.71
IC-0615613	48.95	53.62	50.58
Coll. 35	61.03	67.63	64.21
Coll. 36	64.10	68.57	66.28
Coll. 37	64.50	71.26	66.61
Coll. 38	57.97	64.00	60.90
SEm ±	0.76	0.39	0.43
CD at 5%	2.17	1.11	1.22

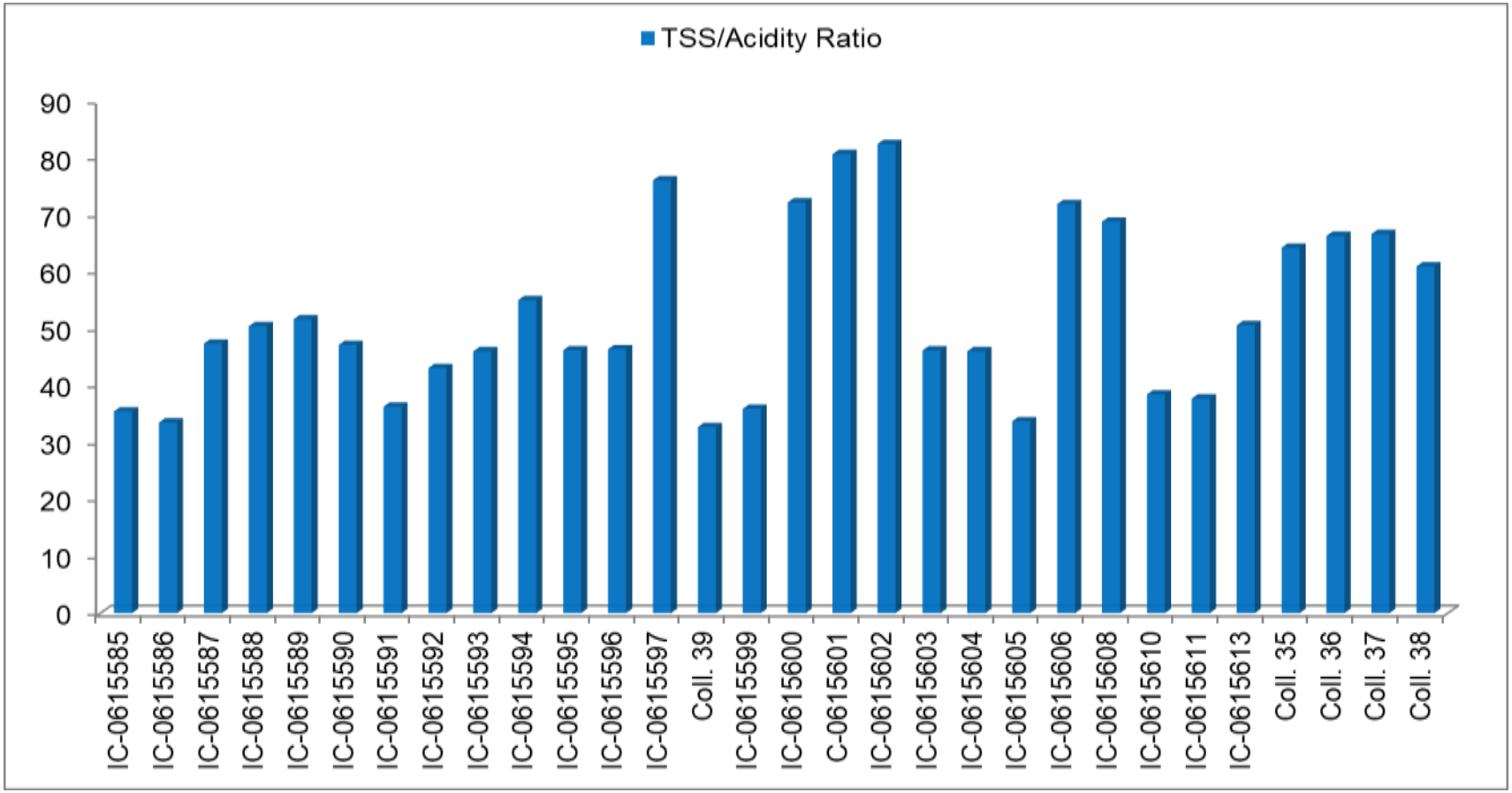


Figure 4.15: Variation in TSS/acidity ratio among 30 litchi germplas

while lowest in genotype IC-0615589 (7.52 %) followed by 8.88 per cent in both the genotypes IC-0615592 and IC-0615595. A perusal of pooled data showed that the maximum reducing sugar percentage was in genotype IC-0615601 (10.78 %) succeeded by IC-0615594 (10.58 %) and Coll. 35 (10.56 %) while lowest in genotype IC-0615589 (7.69 %) followed by IC-0615592 (8.04 %) and IC-061595 (8.05 %).

4.4.2.13 TSS/acidity ratio

A glance at table 4.4.18 and Figure 4.15 revealed that the TSS/acidity was significantly varied among the litchi germplasm during both the years. The maximum TSS/acidity ratio was observed in genotype IC-0615602 in both the years (85.04 and 83.33) followed by IC-0615601 (84.73 and 76.88) and IC-0615597 (75.83 and 73.20) whereas, lowest TSS/acidity ratio was found in genotype Coll. 39 (32.5 and 33.49).

However, the pooled analysis showed the highest TSS/acidity ratio of the fruit was observed in genotype IC-0615602 (84.42) followed by IC-0615601 (80.65) and IC-0615597 (70.04) whereas, lowest TSS/acidity ratio was found in genotype Coll. 39 (32.69) which was found *at par* with IC-0615586 (33.49) and IC-0615605 (33.71).

4.5 Seed characters

The observations on qualitative seed characters among the germplasm under study are presented below:

4.5.1 Qualitative characters

4.5.1.1 Seed shape

The shapes of seed are observed and presented in table 4.5.1 and Plate 13. Oval seed shape was found in nine genotypes *viz*., IC-0615586, IC-0615589, Coll. 39, IC-0615599, IC-0615600, IC-0615601, IC-0615602, IC-0615605 and Coll. 35 whereas, irregular shape was seen in six genotypes *viz*., IC-0615587, IC-0615588, IC-0615593, IC-0615595, IC-0615596 and IC-0615604 and only genotype IC-0615613 had round shape seed and rest genotypes had oblong seed shape.

4.5.1.2 Seed coat colour

The seed coat colour is presented in table 4.5.1. The colour of seed coat was dull brown in six genotypes *viz*., IC-0615589, IC-0615590, IC-0615595, IC-0615596, IC-0615602 and IC-0615603 whereas, dark brown seed coat was observed in two genotypes Coll. 39 and Coll. 36 and rest genotypes had brown seed coat under study.

4.5.2 Quantitative characters

4.5.2.1 Seed length (mm)

The data regarding the length of seed are presented in table 4.5.2 and in Figure 4.16.The analysis of variance showed that the variation among the germplasm were highly significant in respect of length of seed in both the years as well as in pooled analysis. Maximum seed length was recorded in genotype IC-0615600 (23.68 mm) followed by IC-0615585 (23.63 mm) and Coll. 36 (23.52 mm) while the minimum seed length was found in IC-0615613 (16.80 mm) followed by IC-0615587 (17.13 mm) and IC-0615595 (17.52 mm) in 2017. During 2018, the data indicated that the maximum seed length was in IC-0615585 (24.00 mm) followed by Coll. 36(23.16 mm) and IC-0615602 (23.12 mm) while minimum seed length was recorded with IC-0615613 (16.45 mm) followed by IC-0615595(16.75 mm) and IC-0615587 (16.86 mm).

The pooled data revealed that the maximum seed length was observed in IC-0615585 (23.82 mm) followed by IC-0615600 (23.34 mm) and Coll. 36 (23.34 mm) whereas, minimum seed length was found in IC-0615613 (16.63 mm) followed by IC-0615587 (17.00 mm) and IC-0615596 (17.14 mm).

4.5.2.2 Seed Breadth (mm)

The perusal of data in table 4.5.3 and Figure 4.16 reveals that the seed breadth was significantly varied among the germplasm. The maximum seed breadth was recorded in genotype IC-0615600 in both the years (13.94 mm and 13.74 mm) while the minimum seed breadth was observed in IC-0615595 (8.25 mm and 8.10 mm) followed by

Table 4.5.1: Qualitative seed characteristics of 30 litchi germplasm

Germplasm	Seed shape						Seed coat colour				
	1	2	3	4	5	6	1	2	3	4	5
	Round	Oval	Oblong	Elongate	Chicken	Irregular	Off-white	Creamish	Dull brown	Brown	Dark brown
IC-0615585	3						4				
IC-0615586	2						4				
IC-0615587	6						4				
IC-0615588	6						4				
IC-0615589	2						3				
IC-0615590	3						3				
IC-0615591	3						4				
IC-0615592	3						4				
IC-0615593	6						4				
IC-0615594	3						4				
IC-0615595	6						3				
IC-0615596	6						3				
IC-0615597	3						4				
Coll. 39	2						5				
IC-0615599	2						4				
IC-0615600	2						4				
IC-0615601	2						4				
IC-0615602	2						3				
IC-0615603	3						3				
IC-0615604	6						4				
IC-0615605	2						4				
IC-0615606	3						4				
IC-0615608	3						4				
IC-0615610	3						4				
IC-0615611	3						4				
IC-0615613	1						4				
Coll. 35	2						4				
Coll. 36	3						5				
Coll. 37	3						4				
Coll. 38	3						4				

Table 4.5.2: Seed length in different litchi germplasm

Germplasm	Length of seed (mm)		
	2017	2018	Pooled
IC-0615585	23.63	24.00	23.82
IC-0615586	19.06	19.00	19.03
IC-0615587	17.13	16.86	17.00
IC-0615588	18.10	17.82	17.96
IC-0615589	21.25	21.38	21.32
IC-0615590	21.48	21.53	21.51
IC-0615591	20.68	20.70	20.69
IC-0615592	28.12	17.58	22.85
IC-0615593	18.10	18.00	18.05
IC-0615594	22.59	22.75	22.67
IC-0615595	17.86	17.24	17.55
IC-0615596	17.52	16.76	17.14
IC-0615597	22.43	22.95	22.69
Coll. 39	22.76	22.15	22.46
IC-0615599	20.19	20.56	20.38
IC-0615600	23.68	23.00	23.34
IC-0615601	21.32	22.10	21.71
IC-0615602	23.26	23.12	23.19
IC-0615603	21.63	21.20	21.42
IC-0615604	18.00	17.45	17.73
IC-0615605	20.00	21.00	20.50
IC-0615606	20.87	21.15	21.01
IC-0615608	22.72	22.43	22.58
IC-0615610	22.76	22.37	22.57
IC-0615611	23.48	22.84	23.16
IC-0615613	16.80	16.45	16.63
Coll. 35	23.12	23.00	23.06
Coll. 36	23.52	23.16	23.34
Coll. 37	21.86	22.10	21.98
Coll. 38	20.88	21.23	21.06
SEm ±	0.27	0.25	0.24
CD at 5%	0.75	0.70	0.68

Table 4.5.3: Breadth of seed in different litchi germplasm

Germplasm	Breadth of seed (mm)		
	2017	2018	Pooled
IC-0615585	12.14	12.45	12.30
IC-0615586	10.12	10.42	10.27
IC-0615587	8.93	8.90	8.92
IC-0615588	9.10	9.25	9.18
IC-0615589	13.65	13.24	13.45
IC-0615590	13.15	13.08	13.12
IC-0615591	11.94	12.00	11.97
IC-0615592	13.27	13.15	13.21
IC-0615593	9.86	9.62	9.74
IC-0615594	13.16	12.86	13.01
IC-0615595	8.25	8.10	8.18
IC-0615596	10.21	9.84	10.03
IC-0615597	13.64	13.22	13.43
Coll. 39	13.10	13.00	13.05
IC-0615599	11.66	11.25	11.46
IC-0615600	13.94	13.74	13.84
IC-0615601	13.14	12.94	13.04
IC-0615602	13.76	13.32	13.54
IC-0615603	11.56	11.72	11.64
IC-0615604	10.24	10.00	10.12
IC-0615605	11.63	11.72	11.68
IC-0615606	12.36	12.38	12.37
IC-0615608	13.08	13.00	13.04
IC-0615610	13.92	13.26	13.59
IC-0615611	12.52	12.63	12.58
IC-0615613	8.26	8.34	8.30
Coll. 35	13.16	13.10	13.13
Coll. 36	12.62	12.72	12.67
Coll. 37	12.08	12.00	12.04
Coll. 38	12.34	12.25	12.30
SEm ±	0.10	0.12	0.11
CD at 5%	0.28	0.34	0.32

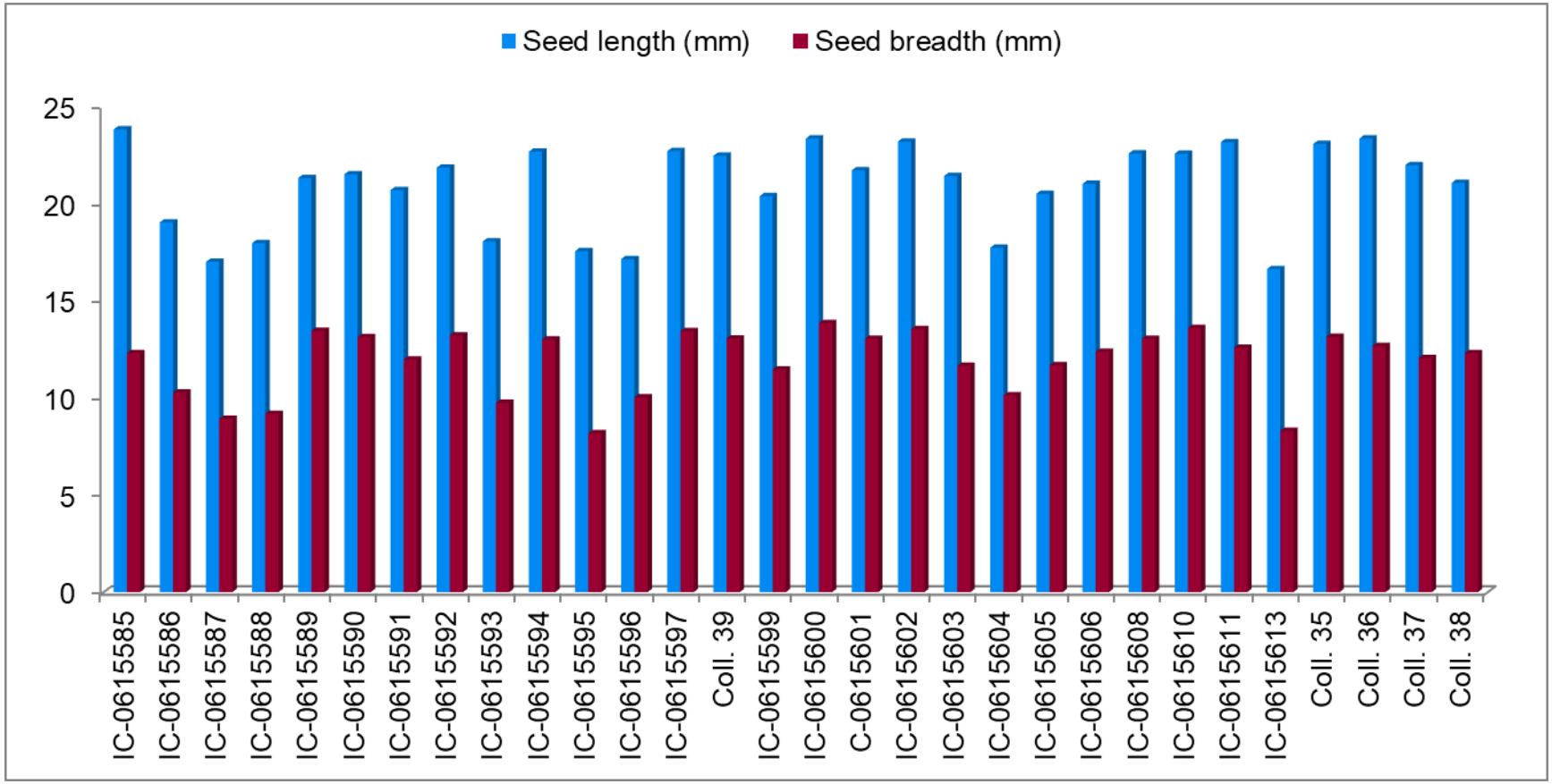


Figure 4.16: Variation in length and breadth of seed among 30 litchi germplasm

Table 4.5.4: Weight of seed in different litchi germplasm

Germplasm	Seed weight (g)		
	2017	2018	Pooled
IC-0615585	4.42	4.35	4.39
IC-0615586	2.91	2.86	2.88
IC-0615587	1.78	1.75	1.76
IC-0615588	2.06	2.00	2.03
IC-0615589	3.03	3.08	3.06
IC-0615590	3.42	3.38	3.40
IC-0615591	3.58	3.62	3.60
IC-0615592	3.94	3.98	3.96
IC-0615593	2.03	2.04	2.04
IC-0615594	3.82	3.62	3.72
IC-0615595	2.62	2.46	2.54
IC-0615596	1.91	1.87	1.89
IC-0615597	3.76	3.85	3.81
Coll. 39	2.64	2.84	2.74
IC-0615599	3.84	3.88	3.86
IC-0615600	3.81	3.68	3.74
IC-0615601	3.14	3.42	3.28
IC-0615602	3.83	3.92	3.87
IC-0615603	3.40	3.53	3.47
IC-0615604	1.89	1.96	1.93
IC-0615605	3.12	3.42	3.27
IC-0615606	3.95	3.87	3.91
IC-0615608	3.97	4.02	4.00
IC-0615610	4.13	3.96	4.05
IC-0615611	3.48	3.55	3.52
IC-0615613	1.69	1.76	1.72
Coll. 35	3.81	3.76	3.79
Coll. 36	3.40	3.51	3.46
Coll. 37	3.25	3.26	3.25
Coll. 38	4.42	4.25	4.34
SEm ±	0.37	0.04	0.03
CD at 5%	1.06	0.11	0.09

IC-0615613 (8.26 mm and 8.34 mm) and IC-0615587 (8.93 mm and 8.90 mm).The pooled data revealed that the maximum seed breadth was observed in IC-0615600 (13.84 mm) followed by IC-0615610 (13.59 mm) and IC-0615602 (13.54 mm) while, the minimum seed breadth was found in IC-0615595 (8.18 mm) followed by IC-0615613 (8.30 mm) and IC-0615587 (8.92 mm).

4.5.2.3 Seed weight (g)

The observations in relation to seed weight were recorded and presented in Table 4.5.4. A glance of the data indicated that seed weight was found maximum in two genotypes IC-0615585 and Coll. 38 (4.42 g) succeeded by IC-0615610 (4.13 g) whereas, lowest seed weight was found in IC-0615613 (1.68 g) in 2017. During 2018, the data reflected maximum seed weight in IC-0615585 (4.35 g) followed by Coll. 38 (4.25 g) and IC-0615608 (4.02 g) while lowest seed weight was in IC-0615587 (1.75 g) followed by IC-0615613 (1.76 g) and IC-0615596 (1.87 g).The pooled data analysis showed highest seed weight in genotype IC-0615585 (4.38 g) succeeded by Coll. 38 (4.33 g) and IC-0615610 (4.05 g) whereas, lowest in IC-0615613 (1.72 g) followed by IC-0615587 (1.76 g) and IC-0615596 (1.88 g).

4.6. Physiological and biochemical parameters:

4.6.1 Chlorophyll A in leaf (mg/100 g)

The data regarding chlorophyll content in mature leaf are presented in table 4.6.1 and represented in Figure 4.17. The statistical analysis of the data evinced that the differences among the germplasm in respect of chlorophyll A content in leaf was found to be highly significant in both the years as well as in pooled analysis.The maximum chlorophyll A of the leaf was recorded in genotype IC-0615596 (11.73 mg/100 g) followed by Coll. 36 (11.60 mg/100 g) and Coll. 37 (11.53 mg/100 g) in 2017 whereas, lowest chlorophyll A was recorded in genotype IC-0615595 in both the years (11.73 mg/100 g and 11.59 mg/100 g). However, maximum chlorophyll A was found in genotype Coll. 36 (11.78 mg/100 g) followed by IC-0615596 (11.59 mg/100 g) and Coll. 37 (11.43 mg/100 g) in 2018.

The analysis of pooled data indicated that the maximum chlorophyll A was in genotype Coll. 36 (11.69 mg/100 g) followed by IC-0615596 (11.73 mg/100 g) and Coll. 37 (11.48 mg/100 g) while lowest chlorophyll A was recorded in IC-0615595 (1.94 mg/100 g) followed by IC-0615589 and IC-0615605 (2.92 mg/100 g) and IC-0615586 (4.78 mg/100 g).

4.6.2 Chlorophyll B in leaf (mg/100 g)

The data regarding chlorophyll B are presented in table 4.6.2 and in Figure 4.17. The statistical analysis of the data revealed that the differences among the germplasm in respect of Chlorophyll B content in leaf was found to be highly significant in both the years as well as in pooled analysis.The maximum chlorophyll B of the leaf was recorded in genotype IC-0615611 in both the years (3.97 mg/100 g and 3.94 mg/100 g) followed by IC-0615596 (3.42 mg/100 g and 3.52 mg/100 g) whereas, the lowest chlorophyll B was observed in genotype IC-0615595 in both the years (0.37 mg/100 g and 0.33 mg/100 g) followed by IC-0615589 (0.55 mg/100 g and 0.56 mg/100 g).The analysis of pooled data indicated that the maximum chlorophyll B was ingenotype IC-0615611 (3.95 mg/100 g) followed by IC-0615596 (3.47 mg/100 g) and IC-0615604 (3.37 mg/100 g) whereas, minimum was recorded in IC-0615595 (0.35 mg/100 g) followed by IC-0615589(0.55 mg/100 g) and IC-0615586 (0.89 mg/100 g).

4.6.3 Total Chlorophyll in leaf (mg/100 g)

The data of both the years and their mean collected with respect to total chlorophyll are shown in table 4.6.3 and graphically depicted in Figure 4.17.The analysis of variance in respect of total Chlorophyll evinced that the genotypes differed highly significantly in both the years as well as in pooled analysis.The total chlorophyll of the leaf was recorded maximum in genotype IC-0615596 in both the years (15.21 mg/100 g and 15.18 mg/100 g) followed by Coll. 36 (14.82 mg/100 g both the year) whereas, the minimum was found in IC-0615595 (2.33 mg/100 g and 2.28 mg/100 g) followed by IC-0615589 (3.15 mg/100 g and 3.83 mg/100 g) and IC-0615605 (5.03 mg/100 g and 4.96 mg/100 g).

Table 4.6.1: Chlorophyll A content in leaf of different litchi germplasm

Germplasm	Chlorophyll A (mg/100g)		
	2017	2018	Pooled
IC-0615585	9.46	9.50	9.48
IC-0615586	4.78	4.78	4.78
IC-0615587	6.95	6.94	6.94
IC-0615588	6.33	6.31	6.32
IC-0615589	2.59	3.26	2.92
IC-0615590	7.88	7.87	7.87
IC-0615591	5.81	6.65	6.23
IC-0615592	9.11	9.11	9.11
IC-0615593	9.64	9.64	9.64
IC-0615594	6.60	6.63	6.61
IC-0615595	1.95	1.94	1.94
IC-0615596	11.73	11.59	11.66
IC-0615597	6.61	6.55	6.58
Coll. 39	7.62	8.45	8.03
IC-0615599	4.85	4.83	4.84
IC-0615600	7.13	6.54	6.83
IC-0615601	5.87	5.90	5.88
IC-0615602	5.85	5.83	5.84
IC-0615603	7.47	8.11	7.79
IC-0615604	6.90	6.86	6.88
IC-0615605	3.94	3.90	3.92
IC-0615606	7.11	7.14	7.12
IC-0615608	8.52	8.55	8.53
IC-0615610	5.17	5.14	5.15
IC-0615611	10.46	10.39	10.42
IC-0615613	6.60	6.74	6.67
Coll. 35	6.36	4.84	5.60
Coll. 36	11.6	11.78	11.69
Coll. 37	11.53	11.43	11.48
Coll. 38	11.55	11.28	11.41
SEm ±	0.33	0.06	0.08
CD at 5%	0.95	0.18	0.23

Table 4.6.2: Chlorophyll B content in leaf of different litchi germplasm

Germplasm	Chlorophyll B (mg/100g)		
	2017	2018	Pooled
IC-0615585	3.24	3.20	3.22
IC-0615586	0.93	0.84	0.89
IC-0615587	1.88	1.91	1.89
IC-0615588	1.01	0.97	0.99
IC-0615589	0.55	0.56	0.55
IC-0615590	1.46	1.44	1.45
IC-0615591	1.27	1.07	1.17
IC-0615592	2.60	2.55	2.57
IC-0615593	1.57	1.59	1.58
IC-0615594	1.39	1.33	1.36
IC-0615595	0.37	0.33	0.35
IC-0615596	3.42	3.52	3.47
IC-0615597	1.62	1.6	1.61
Coll. 39	1.73	1.6	1.66
IC-0615599	0.91	0.89	0.9
IC-0615600	2.32	1.06	1.69
IC-0615601	1.29	1.23	1.26
IC-0615602	1.06	1.02	1.04
IC-0615603	1.74	1.55	1.64
IC-0615604	3.32	3.42	3.37
IC-0615605	1.07	1.04	1.05
IC-0615606	1.87	1.97	1.92
IC-0615608	2.24	2.28	2.26
IC-0615610	0.96	0.91	0.93
IC-0615611	3.97	3.94	3.95
IC-0615613	2.1	2.18	2.14
Coll. 35	2.11	1.19	1.65
Coll. 36	3.15	2.98	3.06
Coll. 37	2.72	3.19	2.95
Coll. 38	2.78	2.88	2.83
SEm ±	0.02	0.07	0.03
CD at 5%	0.06	0.21	0.09

Table 4.6.3: Total Chlorophyll in leaf of different litchi germplasm

Germplasm	Total Chlorophyll (mg/100g)		
	2017	2018	Pooled
IC-0615585	12.94	12.85	12.89
IC-0615586	5.74	5.65	5.69
IC-0615587	8.87	8.9	8.88
IC-0615588	7.37	7.31	7.34
IC-0615589	3.15	3.83	3.49
IC-0615590	9.38	9.35	9.36
IC-0615591	7.12	7.75	7.43
IC-0615592	11.76	11.71	11.73
IC-0615593	11.25	11.28	11.26
IC-0615594	8.02	8.00	8.01
IC-0615595	2.33	2.28	2.30
IC-0615596	15.21	15.18	15.19
IC-0615597	8.27	8.19	8.23
Coll. 39	9.39	10.09	9.74
IC-0615599	5.78	5.74	5.76
IC-0615600	9.5	7.63	8.56
IC-0615601	7.19	7.17	7.18
IC-0615602	6.94	6.88	6.91
IC-0615603	9.25	9.7	9.47
IC-0615604	10.27	10.33	10.3
IC-0615605	5.03	4.96	4.99
IC-0615606	9.03	9.15	9.09
IC-0615608	10.81	10.87	10.84
IC-0615610	6.16	6.07	6.11
IC-0615611	14.5	14.4	14.45
IC-0615613	8.75	8.96	8.85
Coll. 35	8.51	6.06	7.28
Coll. 36	14.82	14.82	14.82
Coll. 37	14.31	14.68	14.49
Coll. 38	14.39	14.22	14.30
SEm ±	0.02	0.02	0.02
CD at 5%	0.06	0.06	0.07

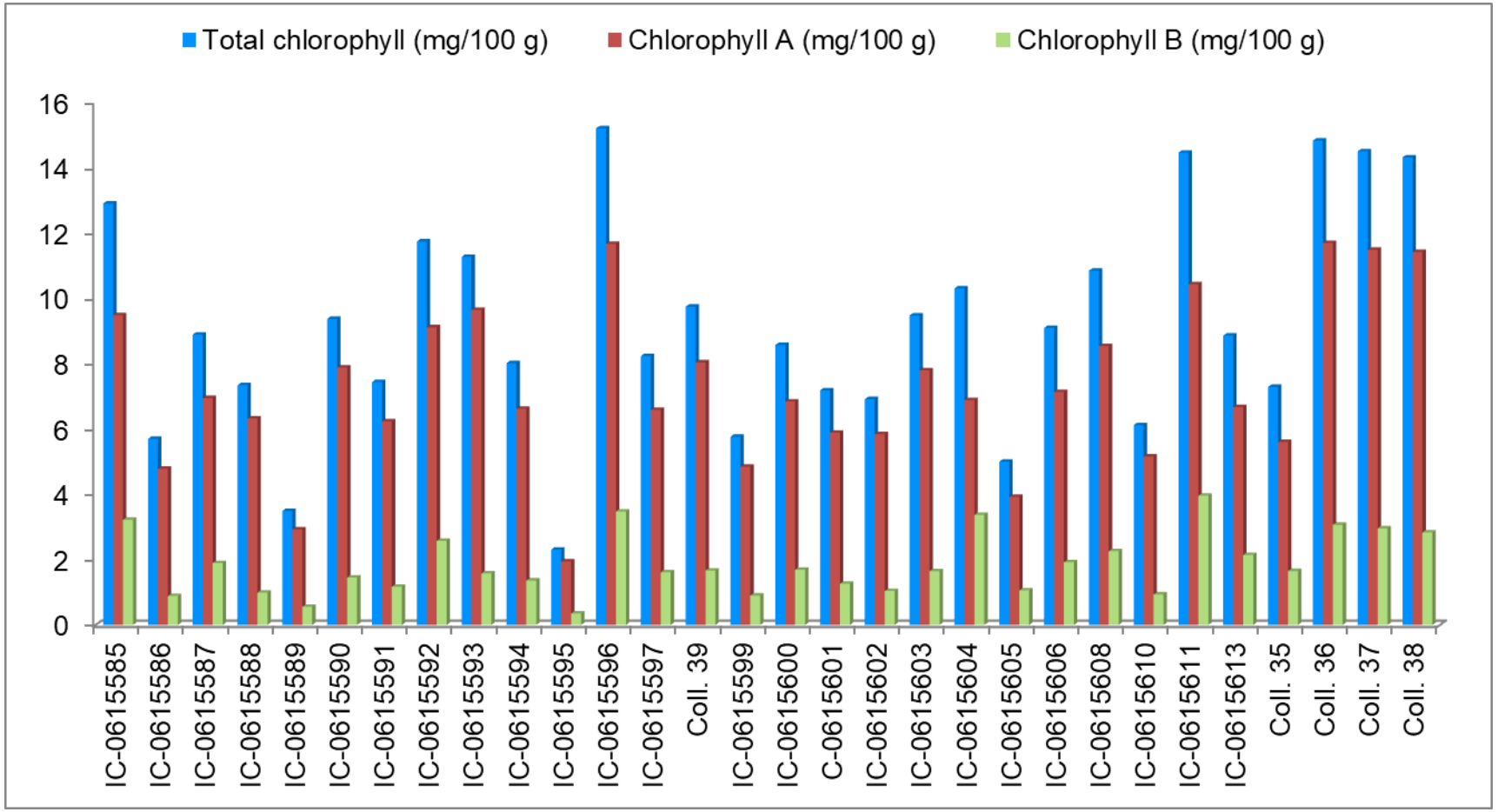


Figure 4.17: Variation in chlorophyll content in leaf among 30 litchi germplasm

A glance of the data indicated that total chlorophyll content was found maximum in IC-0615596 (15.19 mg/100 g) followed by Coll. 36 (14.82 mg/100 g) and Coll. 37 (14.49 mg/100 g) whereas, lowest was observed in IC-0615595 (2.30 mg/100 g) followed by IC-0615589 (3.49 mg/100 g) and IC-0615605 (4.99 mg/100 g).

4.6.4 Total phenol in pulp (mg GAE/g)

The data related to total penol in pulp for both the years and their mean are presented in table 4.6.4 and depicted in Figure 4.18.The analysis of variance in respect to total phenol content in pulp indicated that the germplasm differed highly significantly in both the years and pooled analysis as well.The maximum phenol content in pulp was recorded in genotype IC-0615593 in both the years (8.70mg GAE/g and 8.12 mg GAE/g) followed by IC-0615604 (8.15 mg GAE/g) and IC-0615596 (7.95 mg GAE/g) during 2017 and 2018, respectively whereas, lowest phenol in pulp was found in IC-0615600 (0.14 mg GAE/g) and in IC-0615594 (0.24 mg GAE/g) during 2017 and 2018, respectively.

A glance of the pooled data indicated that phenol content in pulp was found maximum in genotype IC-0615593 (8.41mg GAE/g) followed by IC-0615604 (7.90 mg GAE/g) and IC-0615596 (7.80mg GAE/g) whereas, the lowest phenol was recorded in genotype IC-06155600 (0.20 mg GAE/g).

4.6.5 Total phenol in pericarp (mg GAE/g)

The data in relation to total phenol in pericarp are presented in table 4.6.5 and depicted in Figure 4.18 reveals that the pericarp phenol content was significantly differed among the germplasm during both the years. The maximum phenol in pericarp was recorded in genotype IC-0615613in both the years (62.20 mg GAE/g and 60.28 mg GAE/g) followed by IC-0615586 (55.77 mg GAE/g and 57.12 mg GAE/g) and IC-0615587 (54.90 mg GAE/g and 55.65 mg GAE/g)

Table 4.6.4: Total Phenol in pulp of different litchi germplasm

Germplasm	Total phenol (mg GAE/g)		
	2017	2018	Pooled
IC-0615585	4.65	4.25	4.45
IC-0615586	6.68	6.23	6.46
IC-0615587	0.72	0.76	0.74
IC-0615588	3.75	3.84	3.80
IC-0615589	1.39	0.99	1.19
IC-0615590	4.43	4.25	4.34
IC-0615591	1.42	1.25	1.34
IC-0615592	1.40	1.26	1.33
IC-0615593	8.70	8.12	8.41
IC-0615594	0.22	0.25	0.24
IC-0615595	1.07	0.99	1.03
IC-0615596	7.65	7.95	7.80
IC-0615597	0.26	0.30	0.28
Coll. 39	4.36	4.15	4.25
IC-0615599	0.88	0.90	0.89
IC-0615600	0.15	0.25	0.20
IC-0615601	1.66	1.35	1.50
IC-0615602	1.04	0.98	1.01
IC-0615603	0.99	1.04	1.02
IC-0615604	8.15	7.64	7.90
IC-0615605	0.91	1.00	0.95
IC-0615606	0.85	0.84	0.84
IC-0615608	0.64	0.65	0.65
IC-0615610	0.48	0.50	0.49
IC-0615611	0.64	0.67	0.66
IC-0615613	1.71	1.35	1.53
Coll. 35	0.25	0.32	0.28
Coll. 36	0.27	0.25	0.26
Coll. 37	0.84	0.82	0.83
Coll. 38	1.34	1.13	1.23
SEm ±	0.04	0.11	0.03
CD at 5%	0.11	0.31	0.09

Table 4.6.5: Total Phenol in pericarp of different litchi germplasm

Germplasm	Total phenol (mg GAE/g)		
	2017	2018	Pooled
IC-0615585	49.99	50.24	50.12
IC-0615586	41.82	38.56	40.19
IC-0615587	54.90	55.65	55.27
IC-0615588	55.77	57.12	56.44
IC-0615589	44.14	43.85	44.00
IC-0615590	47.78	49.53	48.65
IC-0615591	35.12	38.72	36.92
IC-0615592	38.17	37.28	37.72
IC-0615593	39.41	40.27	39.84
IC-0615594	13.81	14.67	14.24
IC-0615595	33.70	34.62	34.16
IC-0615596	39.80	40.36	40.08
IC-0615597	13.01	12.52	12.77
Coll. 39	35.57	34.26	34.92
IC-0615599	30.07	31.85	30.96
IC-0615600	12.33	14.22	13.28
IC-0615601	10.19	12.2	11.19
IC-0615602	17.65	15.83	16.74
IC-0615603	36.89	34.86	35.88
IC-0615604	39.91	40.86	40.38
IC-0615605	29.46	27.66	28.56
IC-0615606	7.50	9.64	8.57
IC-0615608	12.41	13.28	12.85
IC-0615610	15.24	14.3	14.77
IC-0615611	26.46	28.45	27.46
IC-0615613	62.20	60.28	61.24
Coll. 35	8.75	9.85	9.30
Coll. 36	23.75	24.2	23.97
Coll. 37	29.26	30.26	29.76
Coll. 38	25.41	24.76	25.08
SEm ±	0.34	0.35	0.28
CD at 5%	0.97	0.97	0.79

Table 4.6.6: Total Phenol in seed of different litchi germplasm

Germplasm	Total phenol (mg GAE/g)		
	2017	2018	Pooled
IC-0615585	64.89	67.45	66.17
IC-0615586	37.73	36.85	37.29
IC-0615587	43.44	44.24	43.84
IC-0615588	42.53	44.23	43.38
IC-0615589	41.88	40.27	41.07
IC-0615590	34.78	33.25	34.01
IC-0615591	39.41	40.2	39.80
IC-0615592	36.24	35.45	35.85
IC-0615593	60.05	62.75	61.40
IC-0615594	43.87	45.12	44.49
IC-0615595	60.39	61.26	60.82
IC-0615596	60.37	62.56	61.47
IC-0615597	85.57	87.56	86.56
Coll. 39	61.86	60.45	61.16
IC-0615599	43.86	45.25	44.56
IC-0615600	27.27	25.4	26.33
IC-0615601	49.75	50.76	50.26
IC-0615602	41.88	43.28	42.58
IC-0615603	75.30	73.52	74.41
IC-0615604	59.65	61.52	60.58
IC-0615605	62.34	60.15	61.25
IC-0615606	24.53	26.45	25.49
IC-0615608	23.01	25.22	24.12
IC-0615610	26.51	24.56	25.53
IC-0615611	44.48	45.35	44.91
IC-0615613	26.09	28.53	27.31
Coll. 35	24.92	22.45	23.68
Coll. 36	42.34	40.15	41.24
Coll. 37	49.94	47.56	48.75
Coll. 38	51.16	52.14	51.65
SEm ±	0.25	0.70	0.24
CD at 5%	0.71	1.99	0.69

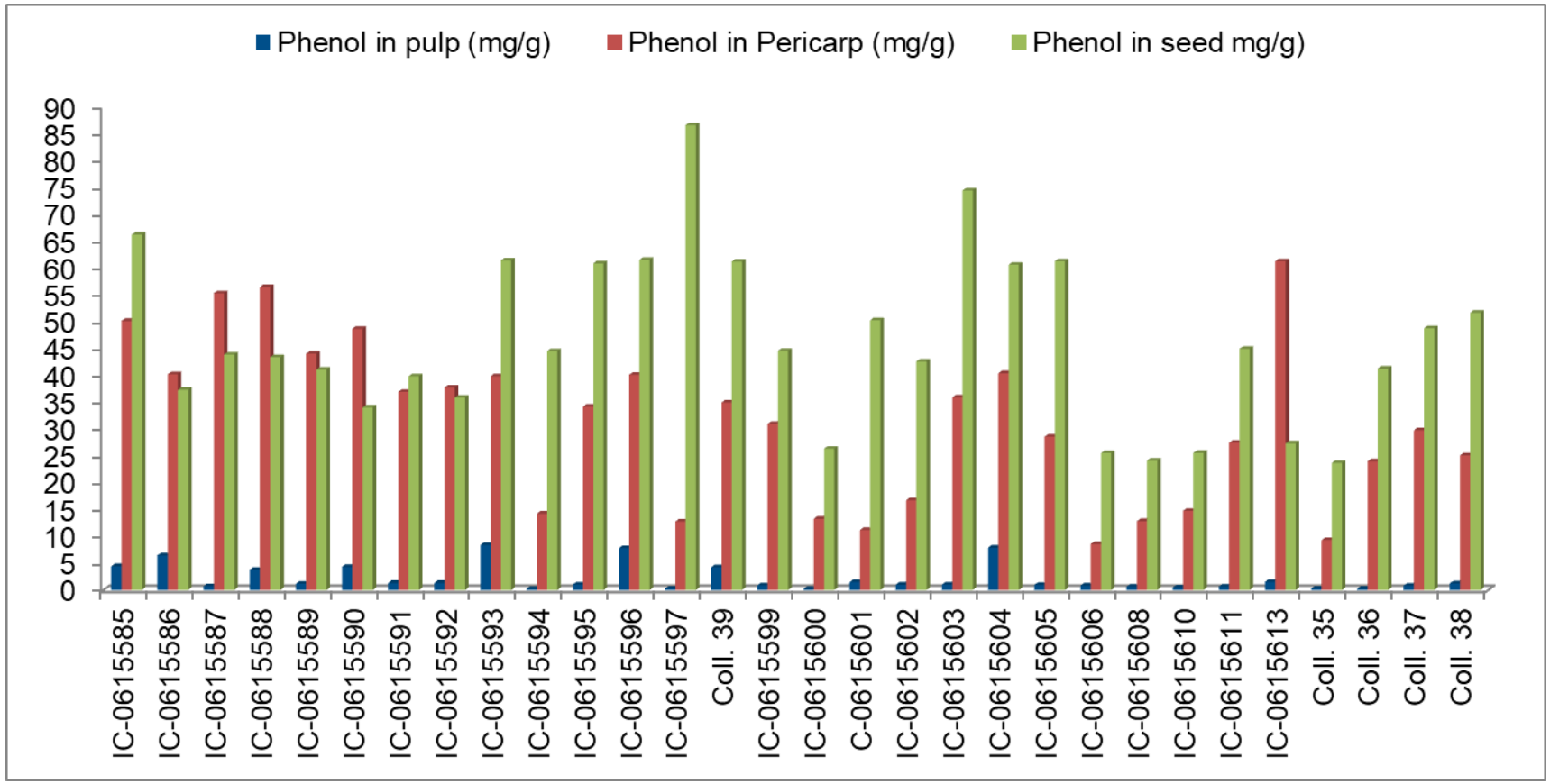


Figure 4.18: Variation in total phenol content among 30 litchi germplasm

whereas, minimum in genotype IC-0615606 (7.50 mg GAE/g and 9.64 mg GAE/g) followed by Coll. 35 (8.75 mg GAE/g and 9.85 mg GAE/g) and IC-0615601 (10.19 mg GAE/g and 12.20 mg GAE/g).

Similarly, a perusal of pooled data showed that the maximum phenol in pericarp was in genotypeIC-0615613 (61.24 mg GAE/g) followed by IC-0615586 (56.44 mg GAE/g) and IC-0615587 (55.27 mg GAE/g) whereas, lowest phenol was found in genotype IC-0615606 (8.57 mg GAE/g) followed by Coll. 35 (9.30 mg GAE/g) and IC-0615601 (11.19 mg GAE/g).

4.6.6 Total phenol in seed (mg GAE/g)

The analysed data presented in table 4.6.6 and Figure 4.18 evinced that total phenol content inseed was significantly varied among the evaluated germplasm. The maximum phenol in seed was found in genotype IC-0615597 in both the years (85.57 mg GAE/g and 87.56 mg GAE/g) followed by IC-0615603 (75.30 mg GAE/g and 75.52 mg GAE/g) and IC-0615585 (64.89 mg GAE/g and 67.45 mg GAE/g) and minimum was recorded in IC-0615608 (23.01 mg GAE/g) and in Coll. 35 (22.45 mg GAE/g) in 2017 and 2018, respectively.

Based on pooled data, maximum phenol in seed was found in genotype IC-0615597 (86.56 mg GAE/g) followed by IC-0615603 (74.41 mg GAE/g) and IC-0615585 (66.17 mg GAE/g) whereas, the minimum phenol in seed was recorded in Coll. 35 (23.68 mg GAE/g) followed by IC-0615608 (24.12 mg GAE/g) and IC-0615606 (25.49 mg GAE/g).

4.6.7 Total flavonoids in pulp (mg CE/g)

The analysed data presented in table 4.6.7 and Figure 4.19 clearly indicated that the germplasm differed highly significantly in both the years as well as in pooled analysis. The maximum flavonoid in pulp was recorded in genotype IC-0615613 in both the years (23.64 mg CE/g and 24.12mg CE/g) followed by IC-0615586 (20.83 mg CE/g and 21.22mg CE/g) and IC-0615600 (14.24 mg CE/gand 14.10 mg CE/g) whereas, lowest flavonoid in pulp was found in genotype

Coll. 36 (0.49 mg CE/g and 0.51 mg CE/g) followed by IC-0615602 (0.68 mg CE/g and 0.70 mg CE/g).

The pooled data reflected that the maximum flavonoid in pulp was in genotype IC-0615613 (23.88 mg CE/g) followed by IC-0615586 (21.02 mg CE/g) and IC-0615600 (14.17 mg CE/g) whereas, the minimum flavonoid in pulp was found in genotype Coll. 36 (0.50 mg CE/g) followed by IC-0615602 (0.69 mg CE/g) and IC-0615611 (0.71 mg CE/g).

4.6.8 Total flavonoid in pericarp (mg CE/g)

The perusal of data in table 4.6.8 and Figure 4.19 evinces that the flavonoid in pericarp was significantly varied among the evaluated germplasm. The maximum pericarp flavonoid content was observed in four genotypes *viz*., IC-0615591, IC-0615595, IC-0615613 and Coll.37 (96.62 mg CE/g) followed by Coll. 39 (59.93 mg CE/g) and IC-0615585 (44.50 mg CE/g) while, the minimum flavonoid in pericarp was found in genotype IC-0615600 and IC-0615610 (0.73 mg CE/g) followed by IC-0615602 (0.86 mg CE/g) and IC-0615608 (0.91 mg CE/g) during 2017.

The data of 2018 further revealed that the maximum flavonoid in pericarp was found in genotype Coll. 37 (96.35 mg CE/g) followed by IC-0615613 (96.12 mg CE/g) and IC-0615595 (95.26 mg CE/g) whereas, the minimum flavonoid in pericarp was observed in genotype IC-0615610 (0.76 mg CE/g) followed by IC-0615602 (0.84 mg CE/g) and IC-0615600 (0.85 mg CE/g).

The pooled data reflected that the maximum flavonoid in pericarp was in Coll. 37 (96.49 mg CE/g) succeeded by IC-0615613 (96.37 mg CE/g) and IC-0615595 (95.94 mg CE/g) whereas, the minimum flavonoid in pericarp was observed in genotype IC-0615610 (0.75 mg CE/g) followed by IC-0615608 (0.79 mg CE/g) and IC-0615602 (0.85 mg CE/g).

4.6.9 Total flavonoid in seed (mg CE/g)

The perusal of data in table 4.6.9 and Figure 4.19 reveals that flavonoid in seed was significantly varied among the germplasm. The

Table 4.6.7: Total flavonoids content in pulp of different litchi germplasm

Germplasm	Total flavonoids (mg/g)		
	2017	2018	Pooled
IC-0615585	3.59	3.76	3.67
IC-0615586	20.83	21.22	21.02
IC-0615587	4.71	4.74	4.72
IC-0615588	4.91	5.98	5.44
IC-0615589	5.51	5.75	5.63
IC-0615590	3.27	3.42	3.34
IC-0615591	2.70	2.65	2.67
IC-0615592	2.97	2.87	2.92
IC-0615593	2.66	2.86	2.76
IC-0615594	5.32	5.25	5.29
IC-0615595	2.58	2.55	2.56
IC-0615596	2.55	2.67	2.61
IC-0615597	2.19	2.12	2.15
Coll. 39	7.41	7.34	7.38
IC-0615599	0.80	0.82	0.81
IC-0615600	14.24	14.10	14.17
IC-0615601	8.26	8.28	8.27
IC-0615602	0.68	0.70	0.69
IC-0615603	0.82	0.83	0.82
IC-0615604	2.57	2.72	2.64
IC-0615605	1.08	1.10	1.09
IC-0615606	2.29	2.42	2.36
IC-0615608	1.13	1.21	1.17
IC-0615610	3.88	3.75	3.82
IC-0615611	0.70	0.72	0.71
IC-0615613	23.64	24.12	23.88
Coll. 35	8.74	8.55	8.65
Coll. 36	0.49	0.51	0.50
Coll. 37	1.46	1.44	1.45
Coll. 38	1.75	1.78	1.76
SEm ±	0.16	0.09	0.07
CD at 5%	0.47	0.24	0.21

Table 4.6.8: Total flavonoids content in pericarp of different litchi germplasm

Germplasm	Total flavonoids (mg CE/g)		
	2017	2018	Pooled
IC-0615585	44.50	43.52	44.01
IC-0615586	8.18	8.65	8.42
IC-0615587	6.87	6.98	6.93
IC-0615588	10.23	10.25	10.24
IC-0615589	2.85	2.97	2.91
IC-0615590	40.21	41.66	40.93
IC-0615591	96.62	94.76	95.69
IC-0615592	40.16	40.45	40.31
IC-0615593	2.06	2.42	2.24
IC-0615594	0.96	1.08	1.02
IC-0615595	96.62	95.26	95.94
IC-0615596	18.93	19.35	19.14
IC-0615597	1.89	1.76	1.83
Coll. 39	59.93	58.42	59.17
IC-0615599	11.93	10.86	11.39
IC-0615600	0.73	0.85	0.79
IC-0615601	1.36	1.39	1.37
IC-0615602	0.86	0.84	0.85
IC-0615603	19.60	20.10	19.85
IC-0615604	2.21	2.25	2.23
IC-0615605	12.04	12.43	12.24
IC-0615606	1.54	1.58	1.56
IC-0615608	0.91	1.03	0.97
IC-0615610	0.73	0.76	0.75
IC-0615611	44.21	44.76	44.48
IC-0615613	96.62	96.12	96.37
Coll. 35	2.22	2.45	2.33
Coll. 36	9.51	10.12	9.81
Coll. 37	96.62	96.35	96.49
Coll. 38	9.41	9.86	9.64
SEm ±	0.18	0.23	0.22
CD at 5%	0.53	0.66	0.63

Table 4.6.9: Total flavonoids content in seed of different litchi germplasm

Germplasm	Total flavonoids (mg CE/g)		
	2017	2018	Pooled
IC-0615585	10.23	11.20	10.71
IC-0615586	27.01	28.00	27.50
IC-0615587	14.13	15.12	14.62
IC-0615588	15.17	14.35	14.76
IC-0615589	10.57	10.23	10.40
IC-0615590	4.35	4.10	4.23
IC-0615591	2.74	3.10	2.92
IC-0615592	3.15	3.24	3.20
IC-0615593	8.96	9.05	9.01
IC-0615594	9.84	9.64	9.74
IC-0615595	6.60	6.97	6.79
IC-0615596	9.23	9.03	9.13
IC-0615597	2.26	2.56	2.41
Coll. 39	10.34	10.12	10.23
IC-0615599	7.69	7.30	7.50
IC-0615600	18.03	17.24	17.63
IC-0615601	13.17	14.25	13.71
IC-0615602	21.14	20.45	20.79
IC-0615603	9.04	10.63	9.84
IC-0615604	8.57	9.05	8.81
IC-0615605	9.36	8.46	8.91
IC-0615606	14.75	13.72	14.23
IC-0615608	8.70	9.25	8.98
IC-0615610	3.93	4.12	4.03
IC-0615611	3.81	4.34	4.07
IC-0615613	7.40	7.90	7.65
Coll. 35	11.15	11.53	11.34
Coll. 36	9.35	10.22	9.78
Coll. 37	3.83	4.25	4.04
Coll. 38	10.35	10.32	10.34
SEm ±	0.17	0.21	0.26
CD at 5%	0.49	0.60	0.74

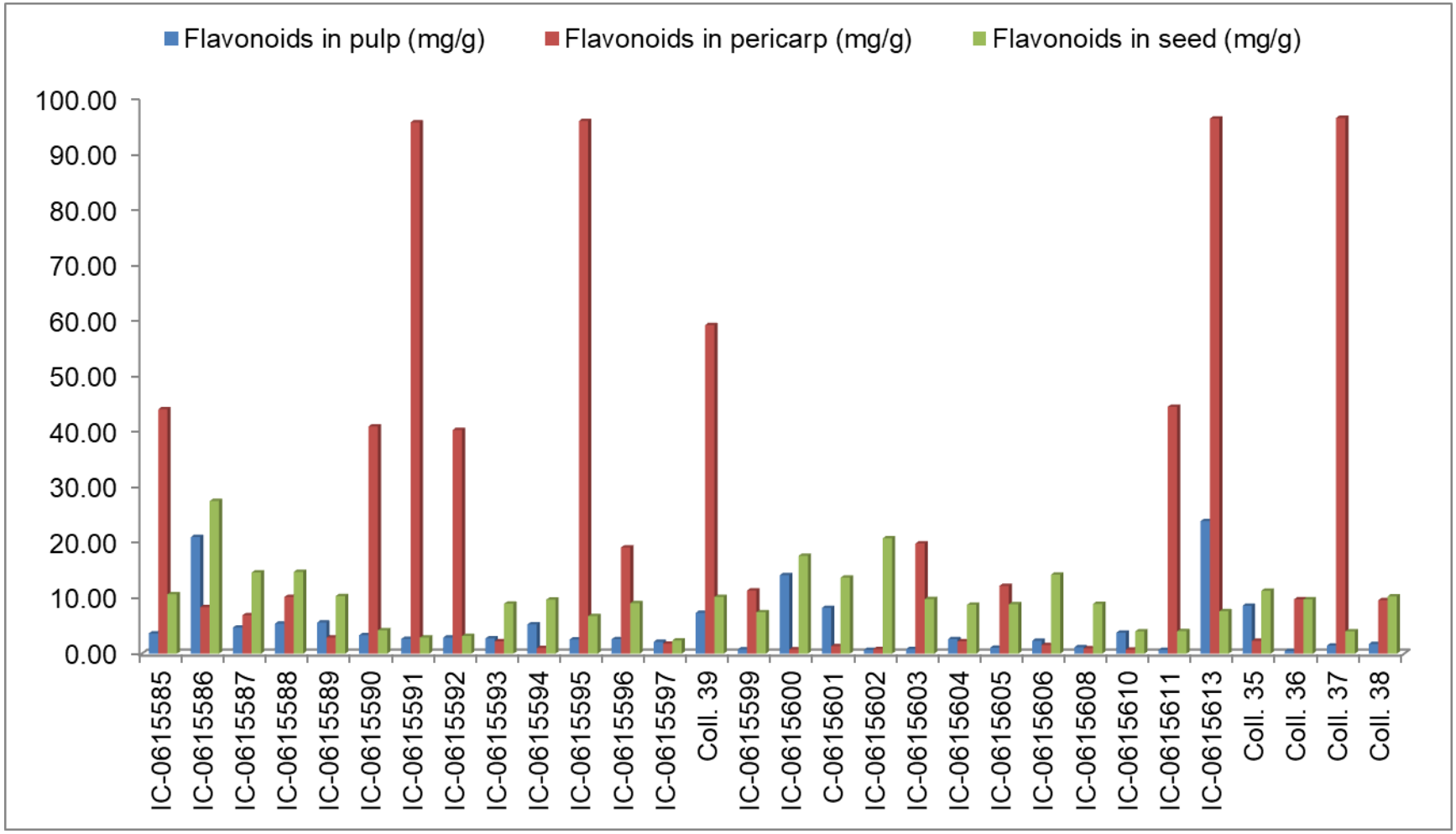


Figure 4.19: Variation in total flavonoid content among 30 litchi germplasm

Table 4.6.10: Total anthocyanin content in pericarp of different litchi germplasm

Germplasm	Total anthocyanin (mg/100g)		
	2017	2018	Pooled
IC-0615585	55.43	55.62	55.52
IC-0615586	25.92	26.03	25.97
IC-0615587	23.76	23.52	23.64
IC-0615588	27.52	27.85	27.69
IC-0615589	25.57	27.23	26.40
IC-0615590	68.73	68.87	68.80
IC-0615591	75.10	74.86	74.98
IC-0615592	69.85	69.53	69.69
IC-0615593	51.52	52.10	51.81
IC-0615594	61.78	61.86	61.82
IC-0615595	57.07	57.10	57.08
IC-0615596	52.26	52.18	52.22
IC-0615597	55.81	55.76	55.79
Coll. 39	46.50	45.80	46.15
IC-0615599	39.27	39.53	39.40
IC-0615600	52.41	52.53	52.47
IC-0615601	54.92	55.02	54.97
IC-0615602	25.77	25.91	25.84
IC-0615603	69.18	69.31	69.24
IC-0615604	51.68	51.72	51.70
IC-0615605	36.58	36.24	36.41
IC-0615606	80.55	79.86	80.20
IC-0615608	17.77	17.56	17.66
IC-0615610	109.52	105.62	107.57
IC-0615611	61.11	61.23	61.17
IC-0615613	55.27	55.30	55.29
Coll. 35	88.48	89.10	88.79
Coll. 36	102.68	102.21	102.44
Coll. 37	59.54	59.73	59.64
Coll. 38	64.05	62.02	63.04
SEm ±	0.16	0.16	0.24
CD at 5%	0.46	0.46	0.69

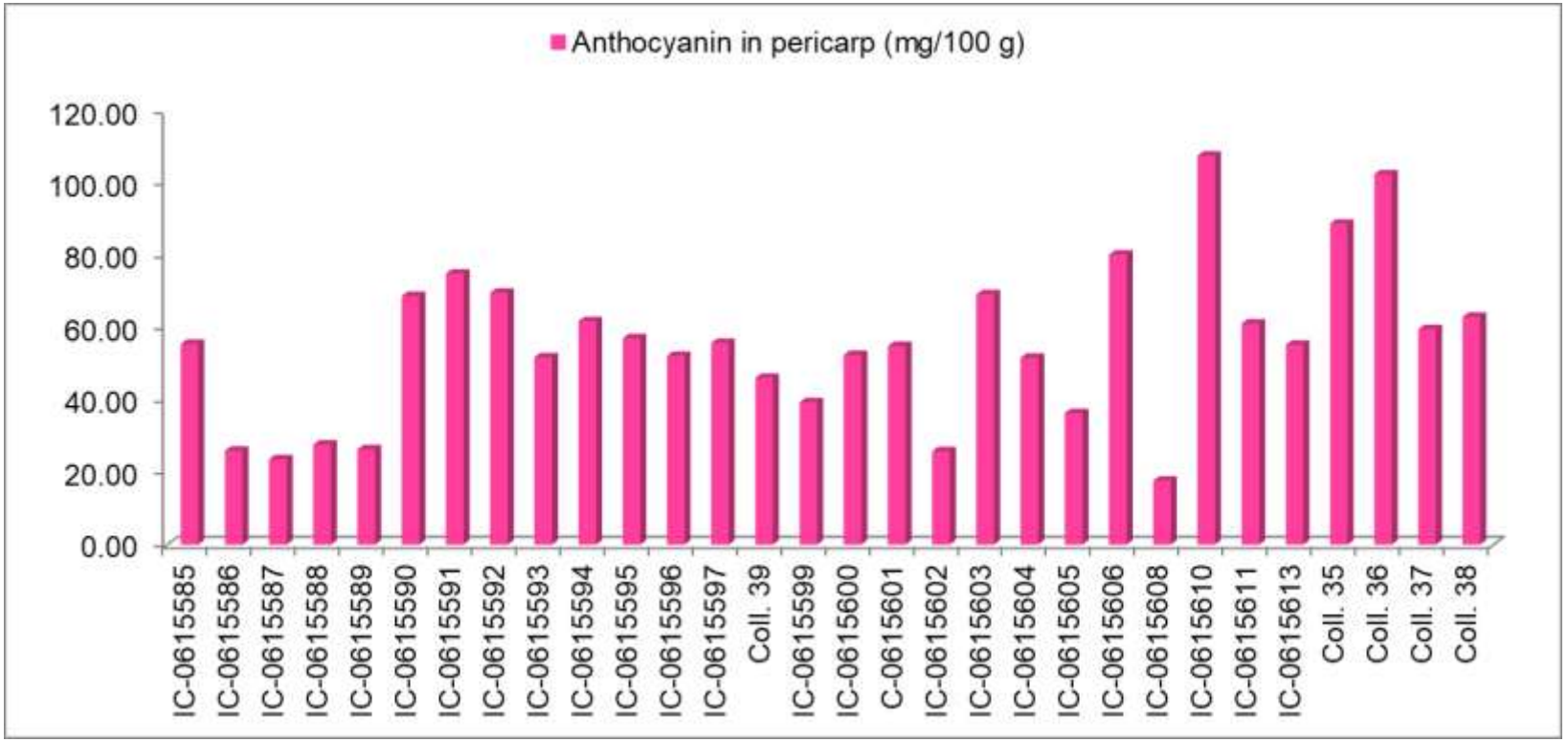


Figure 4.20: Variation in anthocyanin in pericarp among 30 litchi germplasm

maximum flavonoid in seed was observed in genotype IC-0615586 in both the years (27.01 mg CE/g and 28.00 mg CE/g) followed by IC-06155602 (21.14 mg CE/g and 20.45 mg CE/g) whereas, the lowest flavonoids was found in genotype IC-0615597 (2.26 mg CE/g and 2.56 mg CE/g) followed by IC-0615591 (2.74 mg CE/g and 3.10 mg CE/g).

The pooled data reflected that the maximum flavonoid content was observed in genotype IC-0615586 (27.50 mg CE/g) followed by IC-0615602 (20.79 mg CE/g) and IC-0615600 (17.63 mg CE/g) whereas, the minimum flavonoid content was found in genotype IC-0615597 (2.41 mg CE/g) followed by IC-0615591(2.92 mg CE/g) and IC-0615592 (3.20 mg CE/g).

4.6.10 Total anthocyanin (mg/100 g)

The observations recorded on total anthocyanin content in pericarp are presented in table 4.6.10 and Figure 4.20.The analysis of variance in respect of total anthocyanin clearly indicated that the germplasm differed highly significantly in both the years as well as in pooled analysis.The maximum anthocyanin content was observed in genotype IC-0615610 in both the years (109.5 mg/100 g and 105.6 mg/100 g) succeeded by Coll. 36 (102.7 mg/100 g and 102.2 mg/100 g) whereas, the minimum anthocyanin content was observed in IC-0615608 in both the years (17.8 mg/100 g and 17.6 mg/100 g) followed by IC-0615587 (23.8 mg/100 g and 23.5 mg/100 g).

The pooled data showed that the maximum anthocyanin content in pericarp was observed in genotype IC-0615610 (107.6 mg/100 g) followed by Coll. 36 (102.4 mg/100 g) and Coll. 35 (88.8 mg/100 g) whereas, the minimum anthocyanin in pericarp was found in genotype IC-0615608 (17.7 mg/100g) followed by genotype IC-0615587 (23.6 mg/100 g) and IC-0615602 (25.8 mg/100 g).

4.7 Correlation coefficient

The correlation coefficient analysis is presented in table 4.7.1. The plant height has highly significant positive correlation with trunk

girth (0.70), crown diameter (0.62), tree volume (0.93), leaflet number (0.48) and significant positive correlation with length of leaflet (0.39), panicle length (0.41), width of panicle (0.39), number of fruits per cluster (0.37), yield per plant (0.38), length of seed (0.39) and seed breadth (0.41).

Trunk girth had highly significant positive correlation with crown diameter (0.62), tree volume (0.64) and significant positive correlation with panicle length (0.44), panicle width (0.43), number of fruits per cluster (0.37), fruit weight (0.37), yield per plant (0.43) and seed breadth (0.37).

The crown diameter had highly significant correlation with tree volume (0.70) and significant positive correlation with yield per plant (0.45) and TSS (0.39).Tree volume had highly significant positive correlation with number of leaflet (0.47) and significant positive correlation with panicle length (0.37), panicle width (0.36), yield per plant (0.37) and seed breadth (0.38).

Number of leaflet had highly significant positive correlation with rachis length (0.67), petiole length (0.58), leaflet length (0.65), panicle length (0.51), number of fruits per cluster (0.59), yield per plant (0.54), seed length (0.56), seed breadth (0.63), seed weight (0.49) and significant positive correlation with duration of flowering (0.39).

Rachis length had significant positive correlation with petiole length (0.76), leaflet length (0.66), panicle length (0.63), panicle width (0.53), number of fruits per cluster (0.59), seed length (0.72), seed breadth (0.74), seed weight (0.65) and significant positive correlation with yield (0.42), reducing sugar (0.39), TSS/acidity ratio (0.42) and significant negative correlation with phenol content in pericarp (-0.64) and days from fruit set to maturity (-0.44).

Petiole length had significant positive correlation with leaflet length (0.61), panicle length (0.67), panicle width (0.61), number of fruits per cluster (0.62), seed length (0.77), seed breadth (0.77), seed weight (0.76) and significant positive correlation with total sugar (0.37), reducing sugar (0.39), TSS/acidity ratio (0.38) and significant negative correlation with phenol in pericarp (-0.49).

Leaflet length had significant positive correlation with panicle length (0.60), panicle width (0.49), number of fruits per cluster (0.66), seed length (0.60), seed breadth (0.65), seed weight (0.54) and significant positive correlation with panicle width (0.43), days from fruit set to maturity (0.37), yield per plant (0.45), reducing sugar (0.44) and significant negative correlation with phenol in pericarp (-0.49) and flavonoids in pericarp (-0.40).

The duration of flowering had significant positive correlation with panicle length (0.49), number of fruits per cluster (0.48), seed breadth (0.48) and significant positive correlation with panicle width (0.38),yield per plant (0.43),total sugar (0.38),seed length (0.41) and anthocyanin (0.37).

Length of panicle had significant positive correlation with panicle width (0.87), number of fruits per cluster (0.75), yield per plant (0.63), total sugar (0.49), reducing sugar (0.55), seed length (0.72), seed breadth (0.81), seed weight (0.63) and significant positive correlation with TSS/ acidity ratio (0.42) and significant negative correlation with phenolin pericarp (-0.68).

Width of panicle has very significant positive correlation with number of fruits per cluster (0.58), yield per plant (0.47), total sugar (0.57), reducing sugar (0.52), TSS/acidity ratio (0.56), seed length (0.71), seed breadth (0.76), seed weight (0.58) and significant negative correlation with total phenol in pericarp (-0.68) and titratable acidity (-0.46).

Per cent of female flower has very significant positive correlation with number of fruits per cluster (0.50), yield per plant (0.50) and significant positive correlation with anthocyanin content in pericarp (0.46).

Days from fruit set to maturity has very significant positive correlation with fruit diameter (0.47), phenol in pericarp (0.55) and significant positive correlation with total flavonoids in pericarp (0.38).

Number of fruits per cluster have very significant positive correlation with fruit length (0.52), yield per plant (0.79), total sugar (0.48), reducing sugar (0.47), seed length (0.67), seed breadth (0.72),

seed weight (0.62) and anthocyanin in pericarp (0.48) and significant negative correlation with ascorbic acid (-0.43) and phenol in pericarp (-0.44).

Fruit length had highly significant positive correlation with fruit weight (0.76), yield per plant (0.64), TSS (0.54), seed length (0.50), seed weight (0.59), Chlorophyll A (0.48), chlorophyll B (0.50), total chlorophyll (0.50), anthocyanin (0.50) and significant positive correlation with fruit diameter (0.43), aril weight (0.42), total sugar (0.44), reducing sugar (0.43) and seed breadth (0.44).

Fruit diameter had highly significant positive correlation with fruit weight (0.53), aril weight (0.74), TSS (0.56), chlorophyll B (0.48), chlorophyll total (0.47) and significant positive correlation with ascorbic acid (0.45), chlorophyll A (0.44) and phenol in pericarp (0.44).

Fruit weight had significant positive correlation with aril weight (0.75), TSS (0.47) and significant positive correlation with yield per plant (0.44), total sugar (0.45), reducing sugar (0.43), seed length (0.41), seed breadth (0.41) and seed weight (0.39).

Aril weight had highly significant positive correlation with TSS (0.56), ascorbic acid (0.49) and significant positive correlation with chlorophyll B (0.42), and total chlorophyll (0.38).

Yield per plant had significant positive correlation with seed length (0.53), seed breadth (0.60), seed weight (0.47), chlorophyll A (0.58), chlorophyll B (0.49), total chlorophyll (0.57), anthocyanin in pericarp (0.65) and significant positive correlation with TSS (0.38), total sugar (0.43), reducing sugar (0.46) and significant negative correlation with phenol in pericarp (-0.41) and flavonoids in seed (-0.43).

TSS had highly significant positive correlation with total chlorophyll (0.46) and significant positive correlation with reducing sugar (0.38), chlorophyll A (0.45) and chlorophyll B (0.45).

Ascorbic acid had highly significant positive correlation with flavonoids in seed (0.48) and significant positive correlation with

flavonoids in pulp (0.45) and very significant negative correlation with seed weight (-0.51) and significant negative correlation with seed length (-0.46) and seed breadth (-0.39).

Total sugar had highly significant positive correlation with reducing sugar (0.70), seed length (0.59), seed breadth (0.56), seed weight (0.63), anthocyanin in pericarp (0.56) and very significant negative correlation with phenol in pericarp (-0.62) and significant negative correlation with phenol in pulp (-0.45).

Titratable acidity had highly significant positive correlation with phenol in pericarp (0.46) and significant correlation with phenol in pulp (0.43), and very significant negative correlation with TSS/acidity ratio (-0.95) and significant correlation with reducing sugar (-0.40) and

Reducing sugar had highly significant positive correlation TSS/acidity ratio (0.52), seed length (0.48), seed breadth (0.50), seed weight (0.50) and significant correlation with anthocyanin in pericarp (0.44) and very significant negative correlation with phenol in pericarp (-0.68) and significant correlation with total phenol in pulp (-0.37) and flavonoids in pericarp (-0.39).

TSS/acidity ratio has very significant negative correlation with phenol in pericarp (-0.59) and significant correlation with phenol in pulp (-0.43).

Seed length had significant positive correlation with seed breadth (0.92), seed weight (0.86) and very significant negative correlation with total phenol in pericarp (-0.62). Seed breadth had highly significant positive correlation with seed weight (0.80) and very significant negative correlation with total phenol in pericarp (-0.66). Seed weight had highly significant negative correlation with phenol in pericarp (-0.64).

Chlorophyll A had highly significant positive correlation with chlorophyll B (0.84), total chlorophyll (0.99). Chlorophyll B had highly significant positive correlation with total chlorophyll (0.91). Total phenol in pulp had significant positive correlation with phenol in pericarp (0.40) and flavonoids in pulp (0.41). Total phenol in pericarp had significant positive correlation with flavonoids in pericarp (0.41).

Flavonoids in pulp have significant positive correlation with flavonoids in seed (0.46). Flavonoids in pericarp had significant negative correlation with flavonoids in seed (-0.44) and flavonoids in seed have significant negative correlation with anthocyanin in pericarp (-0.45).

4.8 Path coefficient analysis for yield and yield attributing characters

The significant correlation coefficient between two characters does not always indicate presence of linkage between them. Two characters having a common physiological or biochemical chain may also show such genetic correlation (Hohenboken 1985). Relationship of this character with their components such as plant height, tree volume, leaflet number, percent of female flower, number of fruits per cluster, fruit weight and fruit length can be explained as physiological and developmental traits. In order to find out a clear picture of the relationship between fruit yield and their components, path analysis study was done. This allows the partitioning of the correlations between yield and its components into direct and indirect effects.

The residual effects of path analysis were -0.02124 revealed higher genetic variability and also proved lower percent of environmental influence on the selected characters of litchi. Direct and indirect effects of different yield contributing characters toward yield of litchi have been presented in table 4.8.1. A perusal of path coefficient analysis indicated that positive direct effect on yield were exhibited by crown diameter, tree volume, petiole length, length of leaflet,duration of flowering, panicle length, days from fruit set to maturity, number of fruits per cluster, fruit diameter and aril weight

Table 4.7.1: Correlation Coefficient between different quantitative and qualitative characters of litchi germplasm

Traits	PHT	TRG	CD	TV	NLF	RLG	PTLG	LLG	LWD	FRD	PNLG	PNWD	FMFP	DFFM	FTPC	FTLG	FTD	FTWT	AWT	YPP
PHT	1																			
TRG	.70**	1																		
CD	.62**	.62**	1																	
TV	.93**	.64**	.70**	1																
NLF	.48**	.33	.34	.47**	1															
RLG	.25	.19	.06	.24	.67**	1														
PTLG	.29	.22	-.01	.20	.58**	.76**	1													
LLG	.39*	.22	.17	.28	.65**	.66**	.61**	1												
LWD	.24	.22	.27	.14	.07	.16	.20	.43*	1											
FRD	.17	.21	.16	.19	.39*	.19	.20	.21	.24	1										
PNLG	.41*	.44*	.23	.37*	.51**	.63**	.67**	.60**	.26	.49**	1									
PNWD	.39*	.43*	.29	.36*	.34	.53**	.61**	.49**	.29	.38*	.87**	1								
FMFP	-.03	.11	.16	-.08	.33	.29	.29	.37*	.17	.19	.23	.16	1							
DFFM	.23	.07	.19	.15	-.28	-.44*	-.21	-.22	.11	.13	-.16	-.18	-.25	1						
FTPC	.37*	.37*	.13	.24	.59**	.59**	.62**	.66**	.29	.48**	.75**	.58**	.50**	.01	1					
FTLG	.19	.33	.18	.18	.29	.26	.36	.28	.11	.19	.29	.20	.28	.22	.52**	1				
FTD	-.07	.07	.21	-.03	-.15	-.31	-.28	-.24	-.04	.01	-.23	-.30	-.06	.47**	-.10	.43*	1			
FTWT	.24	.37*	.21	.25	.28	.30	.24	.32	.07	.13	.27	.25	-.03	.17	.34	.76**	.53**	1		
AWT	.06	.13	.23	.15	.08	.08	-.08	.05	-.01	.02	.020	-.05	-.20	.19	.01	.42*	.74**	.75**	1	
YPP	.38*	.43*	.45*	.37*	.54**	.42*	.38	.45*	.22	.43*	.63**	.47**	.50**	.10	.79**	.64**	.23	.44*	.29	1

PHT= Plant height, TRG=Trunk girth, CD= Crown diameter, TV=Tree volume, NLF= No of leaflet, RLG= Rachis length, PTLG= Petiole length, LLG= Length of leaflet, LWD= Width of leaflet, FRD= Duration of flowering, PNLG=Panicle length, PNWD=Panicle width, FMFP= Per cent of female flower, DFFM= Days from fruit set to maturity, FTPC= No of fruit/cluster, FTLG= Fruit length, FTD= Fruit diameter, FTWT= Fruit weight, AWT= Aril weight, YPP= Yield per plant, * Significant at 5%, ** Significant at 1%

Table 4.7.1 (Contd): Correlation Coefficient between different quantitative and qualitative characters of litchi germplasm

Traits	PHT	TRG	CD	TV	NLF	RLG	PTLG	LLG	LWD	FRD	PNLG	PNWD	FMFP	DFFM	FTPC	FTLG	FTD	FTWT	AWT	YPP
TSS	-0.07	0.14	0.39*	0.12	0.03	0.01	-0.05	-0.05	0.23	0.05	0.03	0.01	0.09	0.04	0.00	0.54**	0.56**	0.47**	0.56**	0.38*
AA	0.01	0.12	0.27	0.09	-0.16	-0.21	-0.30	-0.21	-0.07	-0.29	-0.30	-0.22	-0.33	0.04	-0.43*	-0.12	0.45*	0.17	0.49**	-0.21
TS	0.19	0.27	0.14	0.23	0.31	0.36	0.37*	0.27	0.22	0.38*	0.49**	0.57**	0.08	-0.13	0.48**	0.44*	-0.07	0.45*	0.24	0.43*
TA	0.07	-0.05	-0.24	0.12	-0.05	-0.32	-0.28	-0.20	-0.25	-0.04	-0.33	-0.46*	-0.23	0.13	-0.16	0.18	0.14	0.05	-0.00	-0.12
RS	0.16	0.19	0.24	0.20	0.32	0.39*	0.39*	0.44*	0.33	0.19	0.55**	0.52**	0.23	-0.23	0.47**	0.43*	0.02	0.43*	0.34	0.46*
TSS/A	-0.01	0.13	0.32	-0.02	0.13	0.42*	0.38*	0.25	0.24	0.02	0.42*	0.56**	0.23	-0.18	0.18	-0.03	-0.11	0.10	0.11	0.20
SLG	0.39*	0.25	0.09	0.35	0.56**	0.72**	0.77**	0.60**	0.21	0.41*	0.72**	0.71**	0.22	-0.11	0.67**	0.50**	-0.24	0.41*	-0.02	0.53**
SBRT	0.41*	0.37*	0.17	0.38*	0.63**	0.74**	0.77**	0.65**	0.15	0.48**	0.81**	0.76**	0.27	-0.18	0.72**	0.44*	-0.26	0.41*	0.01	0.60**
SWT	0.16	0.17	-0.03	0.17	0.49**	0.65**	0.76**	0.54**	0.09	0.33	0.63**	0.58**	0.23	-0.18	0.62**	0.59**	-0.25	0.39**	-0.08	0.47**
CHA	0.09	0.07	0.29	0.09	0.12	0.16	0.09	0.10	0.26	0.04	-0.03	-0.06	0.35	0.21	0.24	0.48**	0.44*	0.24	0.34	0.58**
CHB	0.04	0.01	0.21	0.01	-0.02	0.07	-0.04	0.07	0.21	-0.12	-0.06	-0.12	0.18	0.23	0.13	0.50**	0.48**	0.31	0.424*	0.49**
CHT	0.08	0.06	0.28	0.08	0.09	0.14	0.06	0.09	0.25	-0.004	-0.04	-0.08	0.31	0.23	0.22	0.51**	0.47**	0.27	0.38*	0.57**
TPPL	0.35	0.26	0.10	0.35	0.12	-0.08	-0.12	0.01	-0.19	-0.30	-0.19	-0.19	-0.12	-0.007	-0.14	-0.06	0.01	-0.04	-0.10	-0.12
TPPR	-0.18	-0.24	-0.28	-0.25	-0.48	-0.64**	-0.49**	-0.49**	-0.14	-0.24	-0.68**	-0.68**	-0.32	0.55**	-0.44*	-0.15	0.44*	-0.13	0.03	-0.41*
TPS	0.14	0.21	0.03	0.08	-0.29	-0.31	-0.06	-0.16	0.26	-0.35	-0.20	-0.10	-0.03	0.14	-0.18	-0.01	-0.21	-0.21	-0.30	-0.11
FPL	0.14	-0.01	0.08	0.14	0.04	-0.12	-0.17	-0.13	-0.23	-0.28	-0.25	-0.08	-0.30	-0.04	-0.22	-0.16	0.11	0.15	0.20	-0.28
FPR	-0.07	0.003	-0.17	-0.11	-0.18	-0.18	-0.31	-0.40*	-0.28	-0.07	-0.29	-0.36	0.04	0.38*	-0.04	0.14	0.15	0.08	-0.03	-0.02
FS	0.10	-0.04	0.18	0.12	-0.06	-0.03	0.08	0.05	0.02	-0.24	-0.06	0.15	-0.22	-0.16	-0.33	-0.33	-0.16	-0.23	-0.14	-0.43*
ANTP	0.28	0.31	0.36	0.31	0.33	0.10	0.06	0.04	0.07	0.37*	0.30	0.18	0.46*	0.03	0.49**	0.50**	0.25	0.25	0.11	0.65**

Table 4.7.1 (Contd): Correlation Coefficient between different quantitative and qualitative characters of litchi germplasm

Traits	TSS	AA	TS	TA	RS	TSS/A	SLG	SBRT	SWT	CHA	CHB	CHT	TPPL	TPPR	TPS	FPL	FPR	FS	ANTP
TSS	1																		
AA	.36	1																	
TS	.20	-.31	1																
TA	.15	.18	-.26	1															
RS	.38*	-.25	.70**	-.40*	1														
TSS/A	.03	-.11	.35	-.95**	.52**	1													
SLG	.01	-.46*	.59**	-.19	.48**	.31	1												
SBRT	-.02	-.39*	.56**	-.25	.50**	.36	.92**	1											
SWT	.08	-.51**	.63**	-.12	.50**	.25	.86**	.80**	1										
CHA	.45*	.03	-.04	-.07	.13	.11	.18	.11	.07	1									
CHB	.45*	.17	-.07	.02	.07	.02	.11	.02	.00	.84**	1								
CHT	.46**	.07	-.05	-.04	.12	.09	.17	.09	.05	.99**	.91**	1							
TPPL	-.14	.35	-.45*	.43*	-.37*	-.43*	-.25	-.18	-.28	-.03	-.09	-.05	1						
TPPR	-.09	.31	-.62**	.46**	-.68**	-.59**	-.62**	-.66**	-.64**	.04	.07	.05	.40*	1					
TPS	.10	-.12	-.19	.19	-.12	-.16	-.13	-.19	-.17	.11	.11	.12	.06	.16	1				
FPL	-.22	.45*	-.03	.02	-.15	-.05	-.27	-.26	-.32	-.26	-.19	-.25	.41*	.24	-.36	1			
FPR	-.08	-.08	-.21	.27	-.39*	-.32	-.17	-.32	-.18	.07	.10	.08	.14	.41*	.05	.13	1		
FS	-.15	.48**	-.19	-.17	-.04	.21	-.11	-.11	-.12	-.22	-.25	-.24	.33	-.03	-.20	.46*	-.44*	1	
ANTP	.31	-.35	.56**	-.01	.44*	.03	.34	.29	.34	.26	.22	.25	-.24	-.32	-.15	-.15	.13	-.45*	1

TSS=Total soluble solids, AA=Ascorbic acid, TS=Total sugar, TA=Titratable acidity, RS=Reducing sugar, TSS/A=Total soluble solids/titratable acidity, SLG= Seed length, SBRT=Seed breadth, SWT=Seed weight, CHA= Chlorophyll A, CHB= Chlorophyll B, CHT=Total chlorophyll, TPPL=Total phenol in pulp, TPPR= Total phenol in pericarp, TPS=Total phenol in seed, FPL= Flavonoids in pulp, FPR= Flavonoids in pericarp, FS= Flavonoids in seed, ANTP= Anthocyanin in pericarp

had negative direct effect on yield were exhibited by plant height, trunk girth, number of leaflet per leaf, rachis length, width of leaflet, width of panicle, per cent of female flower, fruit length and fruit weight. From path coefficient analysis, it was observed that plant height had highly negative direct effect (-0.949) on yield per plant and highly positive indirect effect via tree volume, length of leaflet, seed breadth and number of fruit per cluster. On the other hand, negative indirect effect on yields was observed via number of leaflet, rachis length and panicle width.Trunk girth had negative direct effect (-0.003) on yield and this trait exerted positive indirect effect via tree volume, length of leaflet, panicle length, number of fruits per cluster and seed breadth. This trait exerted negative indirect effect via plant height, rachis length, panicle width, length and weight of fruit.

Crown diameter had direct low positive effect (0.044) on yield and this trait exerted positive indirect effect via tree volume and TSS/acidity ratio.Tree volume had highly positive direct effect (0.625) on yield and this trait exerted indirect positive effect via length of leaflet, number of fruits per cluster, and seed breadth and negative indirect effect via plant height, number of leaflet, rachis length and panicle width. Number of leaflet per leaf had negative direct effect (-0.244) on yield and this trait exerted positive indirect effect via tree volume, petiole length, length of leaflet, duration of flowering, panicle length, number of fruits per cluster, seed breadth, seed weight and negative indirect effect via plant height, rachis length and seed length.Rachis length had highly negative direct effect (-0.427) on yield and this trait exerted positive indirect effect via tree volume, petiole length, length of leaflet, number of fruits per cluster, TSS/acidity ratio, seed breadth, seed weight and negative indirect effect via plant height and number of leaflet.

Petiole length had highly positive direct effect (0.311) on yield and this trait exerted positive indirect effect via tree volume, length of leaflet, panicle length, number of fruits per cluster, TSS/acidity ratio, seed breadth, seed weight. Length of leaflet had highly positive direct effect (0.459) on yield and this trait exerted positive indirect effect via

tree volume, petiole length, panicle length, number of fruits per cluster, seed breadth, seed weight and negative indirect effect via plant height, number of leaflet, rachis length, panicle width and seed length.Width of leaflet had low negative direct effect (-0.041) on yield and this trait exerted positive indirect effect via tree volume, petiole length, length of leaflet, duration of flowering, number of fruits per cluster, seed breadth and negative indirect effect via plant height, rachis length, panicle width and fruit length.

Duration of flowering had highly positive direct effect (0.316) on yield and this trait exerted positive indirect effect via tree volume, panicle length, number of fruits per cluster, seed breadth, seed weight and negative indirect effect via plant height and panicle width. Panicle length had high positive direct effect (0.199) on yield and this trait exerted positive indirect effect via tree volume, petiole length, length of leaflet, duration of flowering, number of fruits per cluster, TSS/acidity ratio, seed breadth seed weight and negative indirect effect via plant height, number of leaflet, rachis length, panicle width, fruit length and seed length.Width of panicle had highly negative direct effect (-0.299) on yield per plant and this trait exerted positive indirect effect via tree volume, petiole length, length of leaflet, duration of flowering, number of fruits per cluster, seed breadth, seed weight and negative indirect effect via plant height, rachis length, fruit diameter and seed length.Per cent of female flower had highly negative direct effect (-0.206) on yield and this trait exerted positive indirect effect via length of leaflet, number of fruits per cluster, seed breadth, seed weight and low negative indirect effect via rachis length.

Days from fruit set to maturity had high positive direct effect (0.151) on yield per plant and this trait exerted positive indirect effect via rachis length and fruit diameter. Number of fruits per cluster had highly positive direct effect (0.595) on yield and this trait exerted positive indirect effect via tree volume, petiole length, length of leaflet,

Table 4.8.1: Direct and indirect effects of quantitative and qualitative traits on yield of litchi genotypes

Traits	PHT	TRG	CD	TV	NLFT	RLG	PTLG	LLG	LWD	FRD	PNLG	PNWD	FMFP	DFFM	FTPC
PHT	**-0.949**	-0.003	0.028	0.587	-0.118	-0.108	0.093	0.181	-0.013	0.057	0.095	-0.118	0.006	0.035	0.223
TRG	-0.935	**-0.003**	0.038	0.559	-0.109	-0.115	0.103	0.122	-0.023	0.094	0.147	-0.176	-0.031	0.016	0.292
CD	-0.595	-0.003	**0.044**	0.444	-0.083	-0.027	-0.002	0.078	-0.012	0.05	0.052	-0.089	-0.033	0.028	0.075
TV	-0.891	-0.003	0.031	**0.625**	-0.118	-0.103	0.064	0.132	-0.007	0.062	0.086	-0.11	0.018	0.023	0.144
NLFT	-0.461	-0.002	0.015	0.303	**-0.244**	-0.3	0.183	0.302	-0.01	0.125	0.114	-0.103	-0.069	-0.044	0.357
RLG	-0.24	-0.001	0.003	0.15	-0.171	**-0.427**	0.243	0.314	-0.013	0.064	0.147	-0.16	-0.061	-0.069	0.361
PTLG	-0.283	-0.001	0	0.128	-0.143	-0.333	**0.311**	0.286	-0.015	0.067	0.157	-0.185	-0.06	-0.033	0.371
LLG	-0.374	-0.001	0.007	0.18	-0.161	-0.292	0.194	**0.459**	-0.024	0.068	0.145	-0.151	-0.076	-0.035	0.399
LWD	-0.304	-0.002	0.013	0.113	-0.06	-0.134	0.115	0.263	**-0.041**	0.132	0.094	-0.116	-0.084	0.01	0.338
FRD	-0.171	-0.001	0.007	0.122	-0.096	-0.087	0.066	0.099	-0.017	**0.316**	0.115	-0.12	-0.041	0.019	0.294
PNLG	-0.453	-0.003	0.011	0.27	-0.14	-0.314	0.246	0.334	-0.02	0.183	**0.199**	-0.302	-0.054	-0.024	0.509
PNWD	-0.373	-0.002	0.013	0.229	-0.084	-0.228	0.192	0.232	-0.016	0.126	0.202	**-0.299**	-0.033	-0.027	0.345
FMFP	0.028	-0.001	0.007	-0.053	-0.082	-0.127	0.09	0.17	-0.017	0.063	0.053	-0.048	**-0.206**	-0.038	0.303
DFFM	-0.219	0.000	0.008	0.095	0.07	0.196	-0.068	-0.108	-0.003	0.04	-0.032	0.053	0.051	**0.151**	0.01
FTPC	-0.356	-0.002	0.006	0.152	-0.146	-0.259	0.194	0.308	-0.023	0.156	0.17	-0.173	-0.105	0.002	**0.595**

PHT= Plant height, TRG=Trunk girth, CD= Crown diameter, TV=Tree volume, NLFT= No of leaflet, RLG= Rachis length, PTLG= Petiole length, LLG= Length of leaflet, LWD= Width of leaflet, FRD= Duration of flowering, PNLG=Panicle length, PNWD=Panicle width, FMFP= Per cent of female flower, DFFM= Days from fruit set to maturity, FTPC= No of fruit/cluster

Table 4.8.1 (Contd): Direct and indirect effects of quantitative and qualitative traits on yield of litchi genotypes

Traits	PHT	TRG	CD	TV	NLFT	RLG	PTLG	LLG	LWD	FRD	PNLG	PNWD	FMFP	DFFM	FTPC
FTLG	-0.182	-0.002	0.008	0.114	-0.073	-0.115	0.112	0.13	-0.015	0.062	0.064	-0.06	-0.058	0.034	0.314
FTD	0.064	0	0.01	-0.021	0.038	0.14	-0.089	-0.117	0	0.008	-0.056	0.091	0.013	0.073	-0.06
FTWT	-0.224	-0.002	0.009	0.156	-0.069	-0.129	0.075	0.152	-0.011	0.042	0.062	-0.076	0.006	0.026	0.204
AWT	-0.059	-0.001	0.01	0.094	-0.021	-0.033	-0.026	0.026	-0.004	0.004	0.008	0.013	0.043	0.028	0.009
TSS	0.068	-0.001	0.017	0.073	-0.007	-0.003	-0.016	-0.022	-0.014	0.017	0.008	-0.004	-0.02	0.006	0
AA	-0.016	-0.001	0.012	0.058	0.04	0.089	-0.095	-0.1	0.004	-0.095	-0.069	0.065	0.069	0.007	-0.258
TS	-0.211	-0.001	0.007	0.16	-0.081	-0.171	0.133	0.143	-0.014	0.128	0.114	-0.187	-0.018	-0.02	0.315
TA	-0.072	0	-0.011	0.077	0.012	0.135	-0.087	-0.091	0.007	-0.013	-0.075	0.136	0.048	0.018	-0.092
RS	-0.151	-0.001	0.011	0.129	-0.081	-0.17	0.128	0.207	-0.02	0.062	0.13	-0.159	-0.048	-0.036	0.283
TSS/A	0.015	-0.001	0.014	-0.008	-0.031	-0.183	0.119	0.115	-0.009	0.006	0.096	-0.167	-0.047	-0.027	0.109
SLG	-0.377	-0.001	0.004	0.222	-0.144	-0.314	0.247	0.287	-0.014	0.128	0.168	-0.212	-0.048	-0.018	0.398
SBRT	-0.394	-0.002	0.007	0.239	-0.155	-0.32	0.241	0.305	-0.014	0.156	0.186	-0.23	-0.056	-0.028	0.433
SWT	-0.148	-0.001	-0.001	0.091	-0.121	-0.28	0.237	0.253	-0.01	0.108	0.146	-0.175	-0.061	-0.028	0.372
CHA	-0.082	0	0.013	0.061	-0.03	-0.069	0.031	0.045	-0.015	0.014	-0.007	0.018	-0.072	0.033	0.144
CHB	-0.038	0	0.009	0.006	0.004	-0.032	-0.011	0.035	-0.012	-0.039	-0.015	0.035	-0.037	0.035	0.081
CHT	-0.074	0	0.012	0.048	-0.021	-0.06	0.02	0.043	-0.014	-0.001	-0.01	0.024	-0.064	0.035	0.13

Table 4.8.1 (Contd): Direct and indirect effects of quantitative and qualitative traits on yield of litchi genotypes

Traits	FTLG	FTD	FTWT	AWT	TSS	AA	TS	TA	RS	TSS/A	SLG	SBRT	SWT	CHA	CHB	CHT
PHT	-0.063	-0.022	-0.066	0.004	0	0.004	-0.049	0.008	-0.02	-0.005	-0.095	0.154	0.061	0.005	0.008	0.014
TRG	-0.144	0.024	-0.147	0.011	-0.001	0.044	-0.083	-0.004	-0.034	0.057	-0.082	0.194	0.091	0.006	0.001	0.014
CD	-0.059	0.072	-0.059	0.014	-0.002	0.071	-0.034	-0.025	-0.031	0.1	-0.024	0.062	-0.011	0.017	0.045	0.051
TV	-0.059	-0.011	-0.07	0.009	-0.001	0.024	-0.057	0.013	-0.026	-0.004	-0.085	0.142	0.057	0.005	0.002	0.014
NLFT	-0.097	-0.052	-0.079	0.005	0	-0.043	-0.074	-0.005	-0.042	0.04	-0.141	0.237	0.195	0.007	-0.004	0.015
RLG	-0.088	-0.109	-0.085	0.005	0	-0.054	-0.088	-0.033	-0.05	0.133	-0.175	0.278	0.258	0.009	0.016	0.025
PTLG	-0.117	-0.095	-0.068	-0.005	0	-0.079	-0.095	-0.029	-0.051	0.118	-0.189	0.288	0.299	0.006	-0.008	0.012
LLG	-0.093	-0.084	-0.092	0.003	0	-0.056	-0.069	-0.021	-0.056	0.077	-0.149	0.247	0.216	0.005	0.016	0.017
LWD	-0.121	0.001	-0.078	0.006	-0.002	-0.023	-0.074	-0.018	-0.061	0.068	-0.079	0.123	0.093	0.02	0.06	0.062
FRD	-0.065	0.008	-0.037	0.001	0	-0.077	-0.089	-0.004	-0.024	0.006	-0.097	0.184	0.135	0.002	-0.026	-0.001
PNLG	-0.105	-0.093	-0.086	0.002	0	-0.09	-0.126	-0.039	-0.081	0.149	-0.2	0.347	0.287	-0.002	-0.015	-0.009
PNWD	-0.066	-0.101	-0.071	-0.003	0	-0.056	-0.138	-0.047	-0.066	0.172	-0.169	0.285	0.23	-0.003	-0.025	-0.014
FMFP	-0.091	-0.021	0.008	-0.013	-0.001	-0.086	-0.02	-0.024	-0.029	0.071	-0.055	0.101	0.117	0.019	0.037	0.055
DFFM	-0.073	0.16	-0.048	0.011	0	0.012	0.029	0.013	0.03	-0.056	0.029	-0.068	-0.073	0.012	0.049	0.041
FTPC	-0.172	-0.033	-0.096	0.001	0	-0.111	-0.117	-0.016	-0.059	0.056	-0.159	0.27	0.246	0.013	0.028	0.039

Table 4.8.1 (Contd): Direct and indirect effects of quantitative and qualitative traits on yield of litchi genotypes

Traits	FTLG	FTD	FTWT	AWT	TSS	AA	TS	TA	RS	TSS/A	SLG	SBRT	SWT	CHA	CHB	CHT
FTLG	**-0.326**	0.146	-0.215	0.026	-0.003	-0.031	-0.11	0.02	-0.055	-0.01	-0.12	0.165	0.235	0.027	0.106	0.091
FTD	-0.144	**0.332**	-0.152	0.046	-0.003	0.117	0.016	0.015	-0.003	-0.035	0.062	-0.099	-0.1	0.025	0.103	0.085
FTWT	-0.251	0.18	**-0.279**	0.046	-0.003	0.044	-0.111	0.006	-0.054	0.031	-0.096	0.155	0.153	0.013	0.066	0.048
AWT	-0.139	0.253	-0.213	**0.061**	-0.003	0.128	-0.061	0	-0.044	0.035	0.006	0.005	-0.032	0.019	0.09	0.068
TSS	-0.18	0.19	-0.134	0.035	**-0.006**	0.093	-0.049	0.017	-0.049	0.011	-0.005	-0.008	0.031	0.025	0.096	0.083
AA	0.039	0.15	-0.048	0.03	-0.002	**0.258**	0.075	0.019	0.032	-0.033	0.11	-0.147	-0.202	0.002	0.036	0.013
TS	-0.162	-0.024	-0.141	0.017	-0.001	-0.088	**-0.221**	-0.029	-0.098	0.117	-0.152	0.233	0.274	-0.002	-0.017	-0.01
TA	-0.063	0.049	-0.017	0	-0.001	0.047	0.062	**0.104**	0.049	-0.296	0.046	-0.091	-0.046	-0.004	0.006	-0.007
RS	-0.143	0.008	-0.121	0.022	-0.002	-0.066	-0.173	-0.041	**-0.125**	0.165	-0.123	0.188	0.198	0.007	0.016	0.022
TSS/A	0.01	-0.037	-0.028	0.007	0	-0.028	-0.084	-0.099	-0.066	**0.309**	-0.077	0.133	0.097	0.006	0.004	0.015
SLG	-0.164	-0.087	-0.113	-0.002	0	-0.119	-0.141	-0.02	-0.065	0.1	**-0.238**	0.346	0.339	0.01	0.021	0.029
SBRT	-0.145	-0.089	-0.116	0.001	0	-0.102	-0.139	-0.025	-0.063	0.111	-0.222	**0.371**	0.317	0.006	0.004	0.016
SWT	-0.195	-0.084	-0.109	-0.005	0	-0.132	-0.154	-0.012	-0.063	0.077	-0.205	0.299	**0.393**	0.004	0	0.01
CHA	-0.159	0.148	-0.067	0.021	-0.003	0.008	0.01	-0.007	-0.017	0.034	-0.042	0.041	0.028	**0.055**	0.177	0.176
CHB	-0.165	0.163	-0.087	0.026	-0.003	0.044	0.018	0.003	-0.009	0.006	-0.024	0.008	0	0.046	**0.21**	0.163
CHT	-0.167	0.158	-0.075	0.023	-0.003	0.018	0.012	-0.004	-0.015	0.027	-0.038	0.033	0.022	0.055	0.192	**0.178**

FTLG= Fruit length, FTD= Fruit diameter, FTWT= Fruit weight, AWT= Aril weight, TSS=Total soluble solids, AA=Ascorbic acid, TS=Total sugar, TA=Titratable acidity, RS=Reducing sugar, TSS/A=Total soluble solids/titratable acidity, SLG= Seed length, SBRT=Seed breadth, SWT=Seed weight, CHA= Chlorophyll A, CHB= Chlorophyll B, CHT=Total chlorophyll

duration of flowering, panicle length, seed breadth, seed weight and negative indirect effect via plant height, number of leaflet, rachis length, panicle width, fruit length and seed length. Fruit length had highly negative direct effect (-0.326) on yield and this trait exerted positive indirect effect via tree volume, petiole length, length of leaflet, number of fruits per cluster, fruit diameter, seed breadth, seed weight, chlorophyll B and negative indirect effect via plant height, rachis length, fruit weight and seed length.

Fruit diameter had highly positive direct effect (0.332) on yield and this trait exerted positive indirect effect via rachis length, chlorophyll B and negative indirect effect via length of leaflet, fruit length, fruit weight and seed weight. Fruit weight had highly negative direct effect (-0.279) on yield per plant and this trait exerted positive indirect effect via tree volume, length of leaflet, number of fruits per cluster, fruit diameter, seed breadth, seed weight and negative indirect effect via plant height, rachis length and fruit length. Ascorbic acid had high positive direct effect (0.258) and total sugar had high negative direct effect (-0.221) on yield. Aril weight had low positive direct effect (0.061) on yield and this trait exerted positive indirect effect via fruit diameter and negative indirect effect via fruit length and fruit weight.

Seed length had high negative direct effect (-0.238) on yield and this trait exerted positive indirect effect via tree volume, petiole length, leaflet length, duration of flowering, panicle length, number of fruits per cluster, seed breadth, seed weight and negative indirect effect via plant height, number of leaflet, rachis length, panicle width, fruit weight, ascorbic acid and total sugar. Seed breadth had high positive direct effect (0.371) and indirect positive effect via tree volume, petiole length, leaflet length, duration of flowering panicle length, number of fruits per cluster and seed weight. Seed weight had high positive direct effect (0.393) and positive indirect effect via petiole length, leaflet length, duration of flowering, panicle length, number of fruits per cluster, seed breadth and negative indirect effect via plant height, number of leaflet, rachis length,

panicle width, fruit length and seed length. Chlorophyll A, B and total had positive effect (0.055, 0.210 and 0.178, respectively) on yield per plant.

4.9 Diversity analysis

4.9.1 Clustering

Cluster analysis based on 44 qualitative and 39 quantitative traits divided 30 genotypes of litchi into two main lineages that was further categorized into different clusters. Basic statistics *i.e.* range, mean, standard deviation (SD) and coefficient of variation (CV %) of the variables is given in table 4.9.1. Means and standard deviations for each cluster were computed and average of the cluster means was taken as the reference for traits comparison between clusters. These groups and their clusters, as shown in the respective dendrogram can be considered as distinct germplasm pools. Based on UPGMA method, grouping of genotypes were done separately based on 44 qualitative traits (Figure 4.21) and 39 quanitative traits (Figure 4.22) but results were not much accurate. So, clustering was done with combined 39 quantitative and 44 qualitative traits and 30 genotypes of litchi was separated into 2 main clusters (Table 4.9.2, 4.9.3 and Figure 4.23). Cluster-I is again divided into two sub-cluster-I and sub-cluster-II. Sub cluster-1 consisting of three genotypes *i.e.*, IC-0615593, IC-0615596 and IC-0615604.

They were characterized as broadly pyramid canopy shape, drooping tree growth habit, high branching density, dark green colour of mature leaf, opposite arrangement of leaflet, cuneate leaf base shape, leaflet curved upward from the middle, yellow flower disc colour, terminal and axillary position of inflorescence, profuse flower, late ripening, medium fruit bearing intensity, cordate fruit shape, protruding fruit shoulder, obtuse fruit tip, swelling fruit segment, crimson red fruit colour, uniforn distribution of colour on skin, obtuse fruit shape, prominent suture on skin, sparse tubercles density, excellent attractive fruit, leathery aril texture, bitter quality, juicy, dull

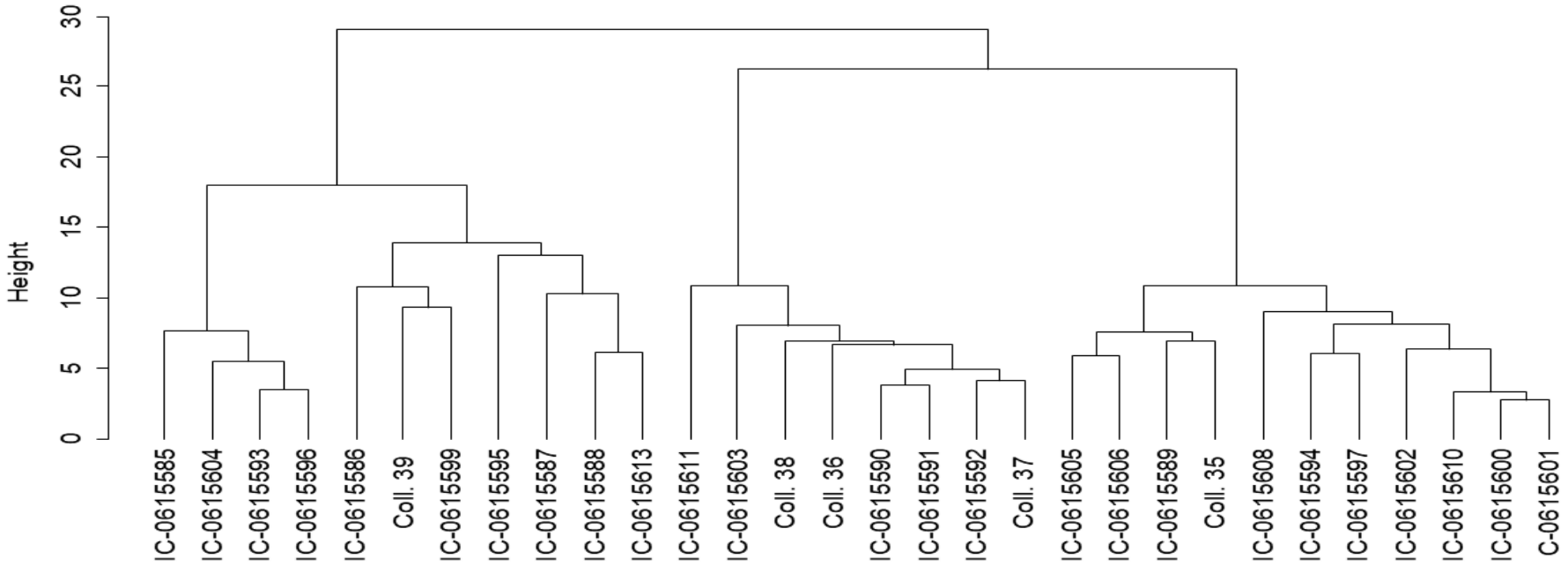


Figure 4. 21. Dendrogram showing the clustering of 30 litchi genotypes based on 44 qualitative traits using UPGMA clustering

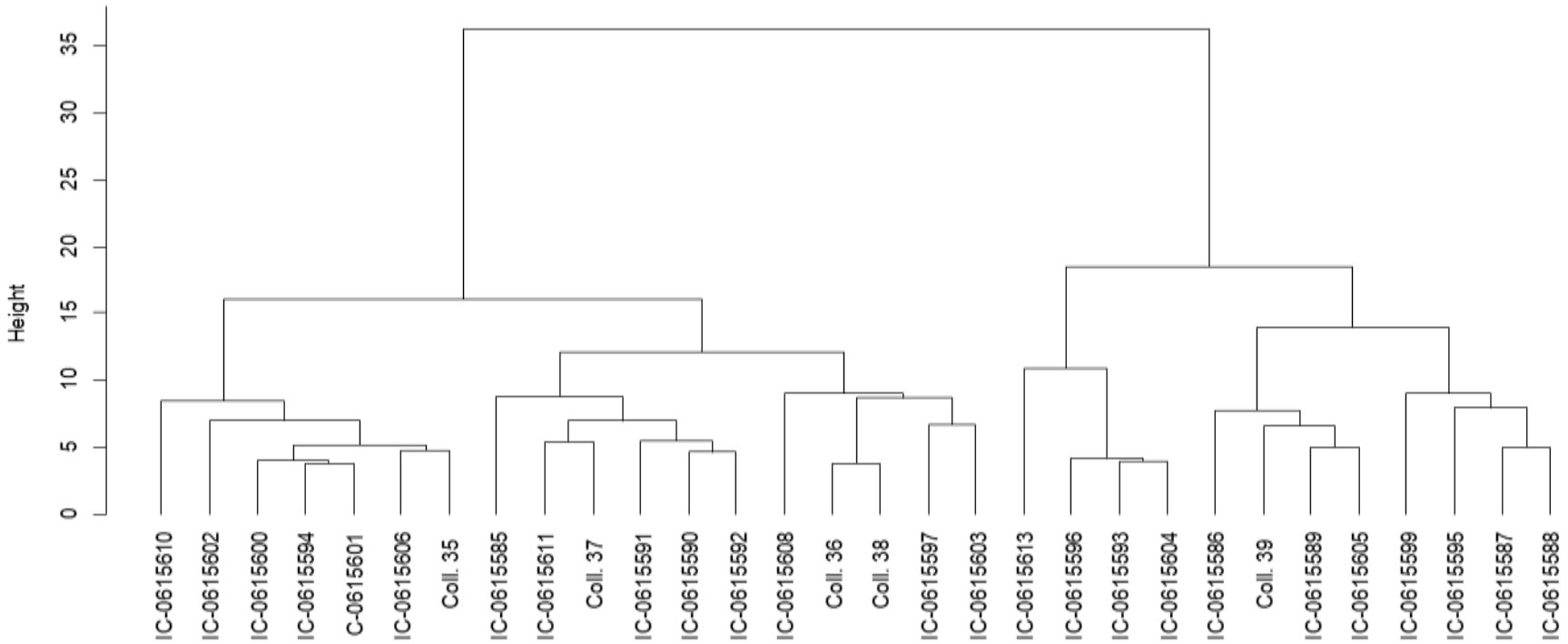


Figure 4. 22. Dendrogram showing the clustering of 30 litchi genotypes based on 39 quantitative traits using UPGMA clustering

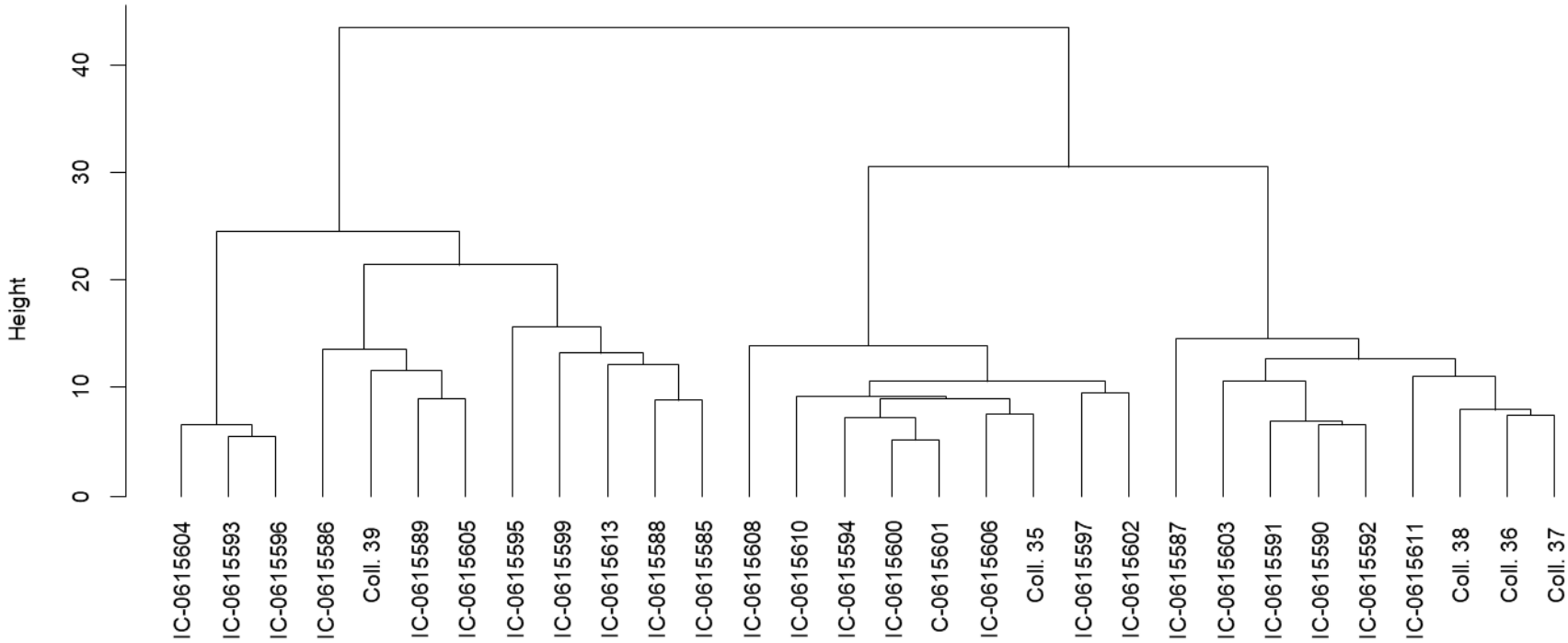


Figure 4. 23. Dendrogram showing the clustering of 30 litchi genotypes based on combined 83 quantitative and qualitative traits using UPGMA clustering

white aril colour and irregular seed shape was registered by genotypes under this cluster. On the basis of these traits, IC-0615593, IC-0615596 and IC-0615604 showed maximum similarity.These genotypes were poorest in performance with respect to rachis length (7.44 cm), petiole length (2.81 cm), length of leaflet (11.27 cm), length of panicle (25.93 cm), width of panicle (14.38 cm), per cent of female flower (16.60%), number of fruits per cluster (4.54), TSS/acidity ratio (46.12), seed breadth (9.96 mm), seed weight (1.95 g) and flavonoids in pericarp (7.87 mg/g) but better performance with respect to phenol content in pulp (8.04).

Sub-cluster II was further divided into two minor sub-cluster-I and minor sub-cluster-II. The minor sub-cluster-I composed of 4 genotypes *viz.,* IC-0615586, IC-0615589, Coll. 39 and IC-06155605. This cluster was characterized as medium branching density, acute apex shape of leaflet, yellow flower disc colour, terminal inflorescence, regular fruit bearing habit, cluster fruiting, obtuse fruit tip, greenish red fruit colour, sharp pointed tubercles shape and dull white aril colour. As regards to quantitative traits, table 4.9.2 showed that minor sub-cluster I was characterized by lower performance for length of panicle (31..37 cm), per cent of female flower (16.13 %), fruit length (31.15 mm), fruit diameter (28.65 mm), aril weight (10.40 g), yield per plant (14.50 kg), TSS/acidity ratio (37.88), flavonoids in pericarp (20.68) and anthocyanin in pericarp (33.72 mg/100 g).

Minor Sub-cluster II constituted five genotypes and comprised IC-0615587, IC-0615588, IC-0615595, IC-06155599 and IC-0615613. This cluster was generally represented as elliptic leaflet shape, yellow flower disc colour, regular fruit bearing habit, spreading tree growth habit (80%), poor fruit bearing intensity (80%), round fruit tip (80%), swelling fruit segment, free from cracking, obtuse fruit shape (80%), prominent suture (80%), sparse tubercles density, juicy, dull white aril colour, brown seed coat colour (80%). Genotypes of this cluster presented lower performance for trunk girth (44.10 cm), tree volume (20.55 m^3), length of leaflet (9.40 cm), length of panicle (23.81 cm), panicle width (12.88 cm), percent of

female flowers (9.25%), number of fruits per cluster (2.96), yield per plant (11.82 kg), seed length (17.90 mm), seed breadth (9.21 mm), chlorophyll A in leaf (5.34 mg/10 g), total chlorophyll (6.63 mg/100 g) and total phenol in seed (43.98 mg/g).

The cluster-II was divided into two sub-clusters: Sub-cluster-III and Sub-cluster-IV. The sub-cluster-III constituted nine genotypes and comprised genotypes IC-0615608, IC-0615610, IC-0615594, IC-0615600, IC-0615601, IC-0615606, Coll. 35, IC-0615597 and IC-0615602. This cluster was generally represented as rough trunk surface, semi-erect growth habit, yellowish green colour of young leaf, prominent midrib appearance, upward curvature of leaflet, terminal panicle, early maturing fruit, synchronous fruit ripening, regular bearer, heavy fruit bearing intensity, cluster habit, oval fruit shape (66.66 %) and elliptic fruit shape (33.33%), obtuse fruit tip (88.88 %), sharp pointed fruit segment, highly fruit cracking (44.44 %) and prone to cracking (44.44%), sharp pointed tubercles shape (88.88 %), presence of weak suture (66.66%), sparse density of tubercles (77.77%), sweet fruit quality, strong aril flavour (66.66%), juicy (88.88%), dull white aril colour (88.88%), oblong (55.55%) and oval (44.44%) seed shape and brown (88.88%) seed coat colour. These genotypes were best in performance with respect to plant height (3.92 m), tree volume (46.82 m^3), leaflet length (13.38 cm), duration of flowering (20.00 days), panicle length (40.77 cm), panicle width (26.17 cm), female flower (19.12 %), number of fruits per cluster (9.85), fruit length (34.49 mm), fruit weight (21.67 g), aril weight (13.45 g), yield per plant (19.34 kg), TSS (18.66 %), total sugar (12.30 %), reducing sugar (10.30 %), TSS/acidity (67.73), seed length (22.54 mm), seed breadth (13.22 mm), seed weight (3.80 g), total flavonoids in pulp (5.17 mg/g), flavonoids in seed (11.3 mg/g) and total anthocyanin (60.58 mg/100 g), and were poorest in performance with respect to ascorbic acid (25.99 mg/100 g), days from fruit set to maturity (62 days), titratable acidity (0.29 %), chlorophyll A (6.46 mg/100 g), chlorophyll B 91.52 mg/100 g), total chlorophyll (8.02 mg/100 g), total

Table 4.9.1: Basic statistics of quantitative traits of 30 litchi genotypes

Characters	Mean	SD	CV	Max	Min
PHT	3.78	0.43	11.23	4.60	2.50
TRG	56.39	8.61	15.27	68.00	35.50
CD	5.27	0.73	13.81	6.57	3.62
TV	40.73	15.77	38.73	76.37	10.44
NLF	6.51	0.48	7.39	7.29	5.05
RLG	9.42	1.87	19.83	15.40	6.45
PTLG	3.72	0.59	15.85	4.83	2.54
LLG	12.24	1.84	15.00	15.98	8.10
LWD	3.84	0.38	9.90	5.05	2.99
FRD	19.30	2.19	11.34	24.00	15.00
PNLG	33.40	7.68	22.99	47.50	16.20
PNWD	19.90	6.11	30.72	33.50	9.15
FMFP	19.06	10.11	53.01	43.32	3.96
DFFM	63.83	3.02	4.73	70.50	55.50
FTPC	8.25	3.70	44.79	13.51	1.00
FTLG	34.32	3.17	9.23	42.45	27.95
FTD	31.05	1.98	6.39	35.81	27.97
FTWT	20.65	2.32	11.22	25.76	15.55
AWT	12.67	2.03	16.07	17.66	7.27
YPP	18.01	4.36	24.20	25.64	8.70
TSS	18.60	0.89	4.77	19.98	17.04
AA	27.37	8.18	29.90	47.50	14.62
TS	11.38	0.91	7.95	13.54	10.05
TA	0.38	0.11	27.80	0.55	0.23
RS	9.28	0.91	9.79	10.78	7.69
TSS/A	52.31	15.06	28.80	82.42	32.69
SLG	20.95	2.24	10.71	23.82	16.63
SBRT	11.84	1.69	14.27	13.84	8.18
SWT	3.24	0.80	24.82	4.39	1.72
CHA	7.27	2.53	34.82	11.69	1.94
CHB	1.85	0.94	51.04	3.95	0.35
CHT	9.16	3.38	36.91	15.19	2.30
TPPL	2.20	2.50	113.91	8.41	0.20
TPPR	31.18	15.15	48.58	61.24	8.57
TPS	46.33	15.84	34.18	86.56	23.68
FPL	4.83	5.65	116.90	23.88	0.50
FPR	24.66	32.65	132.38	96.49	0.75
FS	9.91	5.51	55.59	27.50	2.41
ANTP	55.44	22.21	40.06	107.60	17.70

Table 4.9.2: Means and SD of quantitative variables

Traits	Sub-Cluster-I		Sub-Cluster III		Sub-Cluster IV		Minor Sub-Cluster I		Minor Sub-Cluster II	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
PHT	3.83	0.26	3.92	0.35	3.82	0.26	4.12	0.38	3.17	0.39
TRG	62.28	4.38	59.76	8.00	57.19	6.45	57.97	4.71	44.10	7.46
CD	6.23	0.36	5.54	0.71	5.21	0.50	5.15	0.27	4.41	0.65
TV	46.53	11.81	46.82	15.14	39.21	10.24	51.30	19.6	20.55	6.56
NLF	6.31	0.33	6.75	0.35	6.62	0.34	6.71	0.17	5.81	0.53
RLG	7.44	0.39	10.95	1.91	9.80	0.69	9.69	0.66	6.95	0.63
PTLG	2.81	0.11	4.13	0.42	3.96	0.28	3.83	0.38	3.01	0.34
LLG	11.27	1.82	13.38	1.24	12.73	1.04	12.82	1.36	9.40	1.26
LWD	3.99	0.16	3.95	0.24	3.95	0.49	3.54	0.08	3.59	0.45
FRD	18.83	1.26	20.00	2.50	20.00	1.80	18.12	2.59	18.00	2.00
PNLG	25.93	5.92	40.77	4.60	34.75	4.58	31.37	4.88	23.81	4.54
PNWD	14.38	3.78	26.17	5.23	19.89	2.85	18.75	3.70	12.88	2.88
FMFP	16.60	2.58	19.12	5.83	26.58	13.47	16.13	6.71	9.25	3.45
DFFM	64.00	0.87	62.00	2.69	65.67	3.13	62.37	2.46	64.90	2.90
FTPC	4.54	0.17	9.85	1.64	11.36	2.82	7.038	1.61	2.96	1.20
FTLG	33.94	1.07	34.49	1.07	37.47	2.42	31.15	0.75	31.10	3.51
FTD	33.09	0.18	30.38	1.27	31.82	1.63	28.65	0.54	31.59	2.86
FTWT	20.73	0.66	21.67	0.98	21.43	2.31	18.82	0.30	18.81	3.84
AWT	14.40	0.20	13.45	0.87	12.41	1.67	10.40	0.74	12.48	3.67
YPP	18.37	1.27	19.34	2.76	21.55	3.28	14.50	1.44	11.82	2.48
TSS	19.83	0.09	18.66	0.73	18.81	0.57	17.40	0.34	18.33	1.06
AA	37.76	4.03	25.99	7.68	22.78	3.83	30.60	7.42	29.28	11.88
TS	10.53	0.07	12.30	0.74	11.43	0.57	10.45	0.42	10.90	0.68
TA	0.43	0.00	0.29	0.09	0.41	0.10	0.47	0.09	0.41	0.08
RS	9.12	0.06	10.30	0.38	9.29	0.62	8.005	0.21	8.55	0.52
TSS/A	46.12	0.21	67.73	13.80	48.83	12.60	37.88	9.18	46.08	6.01

SLG	17.64	0.46	22.54	0.74	22.20	1.12	20.82	1.44	17.90	1.47
SBRT	9.96	0.20	13.22	0.43	12.43	0.52	12.11	1.44	9.21	1.33
SWT	1.95	0.08	3.80	0.22	3.71	0.42	2.987	0.22	2.38	0.89
CHA	9.39	2.40	6.46	1.00	9.50	1.92	4.913	2.21	5.34	2.07
CHB	2.81	1.06	1.52	0.42	2.54	0.93	1.038	0.46	1.25	0.74
CHT	12.25	2.59	8.02	1.39	12.10	2.75	5.978	2.67	6.63	2.74
TPPL	8.04	0.33	0.61	0.44	1.72	1.56	3.213	2.63	1.59	1.26
TPPR	40.10	0.27	12.63	2.60	35.06	9.56	36.91	6.70	47.61	13.97
TPS	61.15	0.49	38.78	20.65	48.53	13.71	50.19	12.80	43.98	11.86
FPL	2.67	0.08	5.17	4.44	1.98	1.20	8.780	8.58	7.48	9.35
FPR	7.87	9.76	1.27	0.54	44.58	32.37	20.68	25.94	44.17	47.48
FS	8.98	0.16	11.43	5.96	6.57	3.45	14.26	8.85	10.26	4.05
ANT	51.90	0.26	60.58	28.64	69.38	13.78	33.72	9.55	40.62	15.37

PHT= Plant height, TRG=Trunk girth, CD= Crown diameter, TV=Tree volume, NLF= No of leaflet, RLG= Rachis length, PTLG= Petiole length, LLG= Length of leaflet, LWD= Width of leaflet, FRD= Duration of flowering, PNLG=Panicle length, PNWD=Panicle width, FMFP= Per cent of female flower, DFFM= Days from fruit set to maturity, FTPC= No of fruit/cluster, FTLG= Fruit length, FTD= Fruit diameter, FTWT= Fruit weight, AWT= Aril weight, YPP= Yield per plant, TSS=Total soluble solids, AA=Ascorbic acid, TS=Total sugar, TA=Titratable acidity, RS=Reducing sugar, TSS/A=Total soluble solids/titratable acidity, SLG= Seed length, SBRT=Seed breadth, SWT=Seed weight, CHA= Chlorophyll A, CHB= Chlorophyll B, CHT=Total chlorophyll, TPPL=Total phenol in pulp, TPPR= Total phenol in pericarp, TPS=Total phenol in seed, FPL= Flavonoids in pulp, FPR= Flavonoids in pericarp, FS= Flavonoids in seed, ANTP= Anthocyanin in pericarp

phenol in pulp (0.61 mg/g), pericarp (12.36 mg/g) and seed (38.78 mg/g), and total flavonoids in pericarp (1.27 mg/g)

Sub-cluster-IV constituted nine genotypes and comprised genotypes IC-0615603, IC-0615591, IC-0615590, IC-0615592, IC-0615611, Coll. 36, Coll. 37 and Coll. 38. This cluster was generally represented as broadly pyramid crown shape (77.77%), medium branching density, irregular branching pattern (77.77%), pink (55.55%) and bright pink (33.33%) young leaf colour, dark green (88.88%) of

mature leaf, elliptic leaflet shape, downward curvature (88.88%), yellow flower disc colour (77.77%), terminal panicle, profuse flowering (88.88 %), late maturing fruit, regular bearer (88.88%), heavy fruit bearing intensity (88.88%), conical fruit shape (88.88%), protruding fruit shoulder, nipple shaped fruit segment, not prone to cracking, uniform distribution of colour on skin, slightly pointed (77.77%) tubercles shape, dense (88.88%) tubercles density, excellent fruit attractiveness (88.88%), sweet aril quality. Significant (77.77%) aril flavour, dull white aril colour (77.77%), oblong seed shape and brown (66.66%) seed coat colour. These genotypes were best in performance with respect to plant height 93.82 m), duration of flowering (20.00 days), panicle length (34.75 cm), female flower (26.58 %), number of fruit per cluster (11.36), fruit length (37.47 mm), fruit weight (21.43 g), yied per lant (21.55 kg), TSS (18.81 %), total sugar (11.43 %), titratable acidity (0.41 %), seed length (22.20 mm), seed breadth (12.43 mm), seed weight (3.71 g), chlorophyll A (9.50 mg/100 g), chlorophyll B (2.54 mg/100 g), total chlorophyll (12.10 mg/100 g), total phenol in pericarp (35.06 mg/g) and seed (48.5 mg/g), total flavonoids in pericarp (44.58 mg/g) and total anthocyanin (69.38 mg/100 g).

Table 4.9.3: Proportion (%) of cluster based on 44 qualitative traits of 30 litchi germplasm

Traits	Sub-Cluster-I	Sub-Cluster III	Sub-Cluster IV	Minor Sub-Cluster I	Minor Sub-Cluster II
TSF	Smooth (66.66%)	Rough	Rough (55.55%) Smooth (22.22%), Very rough (22.22%)	Rough (75%)	Rough (60%)
CSH	Broadly pyramid	Broadly pyramid (77.77%)	Broadly pyramid (77.77%), spherical (22.22%)	Broadly pyramid (75%)	Broadly pyramid (60%)
TGH	Drooping	Semi erect	Semi-erect (88.88%)	Semi-erect (75%)	Spreading (80%)
BRD	High	Medium (66.66%)	Medium	Medium	Medium (60%)
BRP	Verticillate (666.66%)	Irregular (77.77%)	Irregular (77.77%)	Verticillate (50%), Irregular (50%)	irregular (60%)
YSP	Pubescent (66.66%)	Glabrous	Glabrous	Glabrous	Glabrous (80%)
YLC	Deep Pink (66.66%)	Yellowish Green	Pink (55.55%), Bright pink (33.33%)	Yellowish green (75%)	Bright Pink (40%), Pink (40%)
MLC	Dark green	Green (66.66%)	Dark Green (88.88%)	Green (75%)	Dark Green (60%)
ALF	Opposite	Opposite (55.55%), Both (44.44%)	Opposite (66.66%) Both (33.33%)	Opposite (50%), Both (50%)	Opposite
LFSH	Elliptic	Elliptic	Elliptic	Elliptic (75%)	Elliptic
LFASH	Acute	Acute	Acute	Acute	Acute
LFBSH	Cuneate	Cuneate (88.88%)	Cuneate(77.77%)	Attenuate (50%)	Cuneate (60%)
LFUSP	Glabrous	Glabrous	Glabrous	Glabrous	Glabrous
LFLSP	Non-glabrous	Non-glabrous	Non-glabrous	Non-glabrous	Non-glabrous
LFMA	Prominent	Prominent	Prominent	Prominent	Prominent
LFVA	Slightly Prominent (66.66%)	Slightly Prominent (77.77%)	Slightly prominent (77.77%)	Prominent (50%), Slightly Prominent (5%)	Slightly Prominent (80%)
LFC	Curve upward from the middle	Curve upward from the middle	Curve downward along the margin (88.88%)	Curve upward from the middle (75%)	Curve upward from the middle
PRO	Present	Present	Present	Present	Present

FLDC	Yellow	Yellow (66.66%), pink (33.33%)	Yellow (77.77%)	Yellow	Yellow
POI	Both	Terminal	Terminal	Terminal	Both (60%)
AOF	Profuse	Profuse (88.88%)	Profuse (88.88%)	Profuse (75%)	Sparse (40%), Profuse (40%)
FTMG	Late	Early	Late	Mid (50%)	Late (6%)
FTR	Synchronous	Synchronous	Synchronous	Synchronous (50%), Non-Synchronous (50%)	Synchronous (60%)
FTBH	Regular	Regular	Regular (88.88%)	Regular	Regular
FTBI	Medium	Heavy	Heavy (88.88%)	Medium (75%)	Poor (80%)
FTCH	Cluster	Cluster	Cluster	Cluster	Cluster (80%)
FTSH	Cordate	Oval (66.66%), Elliptic (33.33%)	Conical (88.88%)	Oval (50%), Elliptic (50%)	Round (60%)
FTSHO	Protruding	Smooth (77.77%)	Protruding	Smooth (50%), Protruding (50%)	Smooth
FTTP	obtuse	Obtuse (88.88%)	Obtuse (55.55%), acute (44.44%)	Obtuse	Round (80%)
FTSG	Swelling	Sharp pointed	Nipple Shaped	Sharp pointed (75%)	Swelling type
CRK	Not prone to cracking	Highly (44.44%), Prone to cracking (44.44%)	Not prone to cracking	Prone to crack (75%)	Not prone to cracking
FTCM	Crimson Red	Reddish Yellow (44.44%), Red (33.33%)	Rosy Red (55.55), Crimson Red (33.33%)	Greenish red	Reddish Yellow (40%), Deep Pink (40%)
DOC	Uniform	Uniform (88.88%)	Uniform	Partial (50%), Uniform (50%)	Partial (60%), Uniform (40%)
TSH	Obtuse	Sharp pointed (88.88%)	Slightly pointed (77.77%)	Sharp Pointed	Obtuse (80%)
POS	Prominent	Weak (66.66%)	Prominent (44.44%), Weak (44.44%)	Weak (75%)	Prominent (88.88%)
TDN	Sparse	Sparse (77.77%)	Dense (88.88%)	Sparse (50%), Medium (50%)	Sparse
FTAT	Excellent	Good (55.55%), Excellent	Excellent (88.88%)	Intermediate (50%), Good (50%)	Intermediate

		(22.22%)			(60%)
ATEX	Leathery	Soft (55.55%)	Leathery (66.66%)	Soft (50%)	Soft (40%), Leathery (40%)
AQTY	Bitter	Sweet	Sweet	Acidic (50%), Sweat (50%)	Sweat (60%)
AFLV	Intermediate (66.66%)	Significant (66.66%)	Significant (77.77%)	Week (50%), Intermediate (50%)	Significant (40%), Weak (40%)
AJCY	Juicy	Juicy (88.88%)	Juicy (77.77%), very juicy (22.22%)	Juicy (75%)	Juicy
ACLR	Dull White	Dull white (88.88%)	Dull white (77.77%)	Dull white	Dull White
SSH	Irregular	Oblong (55.55%), Oval (44.44%)	Oblong	Oval (75%)	Irregular (60%)
SCC	Brown (66.66%)	Brown (88.88%)	Brown (66.66%)	Brown (50%)	Brown (80%)

TSF= Trunk surface, CSH= Crown shape, TGH= Tree growth habit, BRD= Branching density, BRP= Branching pattern, YSP= Young shoot pubescence, YLC= Young leaf colour, MLC= Mature leaf colour, ALF= Arrangement of leaflet, LFSH= Leaflet shape, LFASH= Leaflet apex shape, LFBSH= Leaflet base shape, LFUSP= Leaflet upper surface pubescence, LFLSP= Leaflet lower surface pubescence, LFMA= Leaflet midrib appearance, LFVA= Leaflet venation appearance, LFC= Leaflet curvature, PRO= Protuberance on panicle, FLDC= Flower disc colour, POI= Position of inflorescence, AOF= Abundance of flower, FTMG= Fruit maturity group, FTR= Fruit ripening, FTBH= Fruit bearing habit, FTBI= Fruit bearing intensity, FTCH= Fruit clustering habit, FTSH= Fruit shape, FTSHO=Fruit shoulder, FTTP= Fruit tip, FTSG= Fruit segment, CRK= Cracking of fruit, FTCM= Fruit colour at maturity, DOC= Distribution of colour on fruit surface, TSH= Tubercles shape, POS= Presence of suture, TDN= Tubercle density, FTAT= Fruit attractiveness, ATEX= Aril texture, AQTY= Aril quality, AFLV= Aril flavor, AJCY= Aril juiciness, ACLR= Aril colour, SSH= Seed shape, SCC= Seed coat colour

CHAPTER V
DISCUSSION

DISCUSSION

The improvement of litchi has been a challenge for many years and success primarily depends on the nature and magnitude of variation present within the population. The need for proper selection criteria has always been felt. Moreover, assessment of genetic variability, employing universal descriptors are of immense value for selection of superior genotype from the existing population. Research efforts on characterization of litchi germplasm are scanty, which could have contributed a lot to litchi breeding programmes worldwide. Phenotypic characterization of litchi germplasm is essential for the identification of potential genotypes and deciphering their genetic relationship. In the present study, 30 litchi germplasm were characterized and grouped on the basis of vegetative growth, flower, fruit morphology and physio-biochemical analysis.

5.1. Tree Characters

5.1.1. Qualitative characters

Litchi genotypes showed significant variations for different morphological characters. All the genotypes could not produce uniform values for any single character. The data regarding tree qualitative characters are presented in table 4.1.1. A marked variation was noted in trunk surface among the studied genotypes. The trunk surface of the trees was recorded on the basis of visual observation for two successive years (2017 and 2018). In the 30 studied genotypes, rough surface was observed as the dominant habit (70.0%) that includes 21 genotypes while 7 genotypes (23.33.0%) had smooth surface and two genotypes (6.66%), namely Coll. 36 and Coll. 38 had very rough surface (Plate 1).

Crown shape is one of the most important characters to identify litchi germplasm if properly managed in the field. Though, wide variations have been reported with respect to crown shape in litchi, however, in our study, only two forms of crown shapes was observed, with broadly pyramid as the most frequent (76.66%) and

represented by 23 genotypes and spherical type of crown shape as quite frequent (23.33%) and consists of 7 genotypes. Crown shapes, owing to its inherent nature have been used as a key taxonomic character in classifying genotypes, species identification or cultivar classification. The crown structure of a tree solely depends on branching pattern and crotch angles. The difference in shape is also due to the genotypes and their interaction with the prevailing climatic conditions of the area. Crown shape and canopy size are important factors that influence productivity and quality production of various fruit crops which helps in net assimilation rate and flowering (Nath *et al.,* 2014). Tree crown shape also influence light penetration (Kellomaki *et al.,* 1985) and canopy microclimate including temperature, vapour pressure deficit and wind speed (Gary 1974). Chavaradar (2016) found most prominent crown shape as semicircular (34.37 %) followed by oblong (31.25 %), spherical (25.12 per cent), irregular (3.12 %) and broadly pyramidal shape (3.12 %) in litchi.

With respect to tree growth habit, a wide variability was observed among genotypes. Tree growth habit is an important factor for characterizing the genotypes. However, tree growth habit is greatly influenced by location, soil and climatic factors. According to Palmer (1981), the tree shape and size depend upon light penetration into the tree. In the present study, three types of growth habit (Plate 2) was observed within the 30 studied genotypes, with semi-erect as the most frequent (70.00%) and represented by 21 genotypes, a quite frequent type of growth habit was spreading (20.00%) and consists of 6 genotypes while drooping habit had a lower representation (10.00%) and includes three genotypes *viz.,* IC-0615593, IC-0615596 and IC-0615604.

Branching density is an important factor for characterizing the genotypes. However, branching density is also influenced by location, soil and climatic factors. The amount of light intercepted and penetrated into the tree strongly influences the amount and arrangement of branches (Palmer 1981). In the present study, the

genotypes showed variability in their growth behaviour and these were divided into three branching density types *i.e.* high, medium and low. The branching density was mostly medium (73.33%) and high (16.66%) comprising of 22 and 5 genotypes respectively whereas, low branching density was quite frequent in 3 genotypes (10.00%) namely, IC-0615599, IC-0615600 and IC-0615602. Branches are the skeletal structures of the tree. The nature of branching is an important factor which decides the population density for utilizing the horizontal as well as vertical space. Different branching patterns *viz.,* erect, opposite, verticillate, horizontal, and irregular have been reported in litchi, but in the present study, only two branching forms, *viz.,* irregular branching pattern which was dominant (66.66%) and represented by 20 genotypes and verticillate branching pattern (33.33%) consisting of 10 genotypes were observed. Chavaradar (2016) noted verticillate branching pattern dominated by 65.62 per cent followed by horizontal (15.62%), irregular (15.62%) and erect type (3.12%). Predominantly, young shoot was glabrous (90.00%) and represented by 27 genotypes as dominant characters in litchi germplasm and 10% genotypes namely, IC-0615587, IC-0615593 and IC-0615596 showed pubescent young shoot.

5.1.2. Quantitative characters

5.1.2.1. Tree height (m)

A significant variation in tree height among the selected genotypes was observed ranging from 2.50 m to 4.60 m and maximum height was recorded in genotype Coll. 39 (4.60 m) and lowest height in IC-0615599 (2.50 m). During the period under study, the highest percentage of increases in tree height was recorded in IC-0615599 (27.27%) and lowest in IC-0615604 (1.32%).The result indicated that genotype IC-0615599 is fast growing vertically while IC-0615604 showed slow vertical growth and this nature of growth make it perfect for high density planting as well as make convenient to perform all the cultural practices in the tree. The nature of tree growth is purely genetical and its nature remains unaffected though, agronomical practices make slightly affect the rate of growth.

Chavaradar (2016) reported that tree height among genotypes ranged from 3.00 m to 19.00 m which accounted for 57.87 per cent of CV. Similarly, Pereira (2002) also found tree height ranged from 3.57 m to 7.54 m among the litchi cultivars. The height as well as girth of the tree is positively influenced by the age of the plant. Litchi is an evergreen fruit tree that grows up to the height of 15 m if left unpruned and up to 30 m under favourable conditions (Cronje 2010). According to Singh *et al.* (2012), a well-managed orchard will be commercially productive for a period of up to 50 years.

5.1.2.2. Trunk girth (cm)

Trunk girth differed significantly among the studied genotypes which ranged from 35.50 to 68.00 cm. The maximum girth was found in genotype IC-0615597 (68 cm) while lowest girth was recorded in IC-0615587 (35.50 cm).The highest increase in trunk girth during the study period (2017-18) was recorded in IC-0615599 (21.21%) and lowest in IC-0615590 (3.33 %).The highest increase in trunk girth of IC-0615599 is attributed to maximum increases in tree height which is positively influenced by tree age. Chavaradar (2016) observed a very high coefficient of variation (74.1 %) in tree trunk girth which range from 28.00 cm to 540 cm.

5.1.2.3. Crown diameter (m)

The crown diameter varied significantly among the studied genotypes and was noted maximum in IC-0615593 (6.56 m) and minimum in IC-0615599 (3.61 m). The highest increases in crown diameter were recorded in IC-0615592 (24.71%) and lowest in IC-0615605 (2.83%). It seems that the horizontal growth of genotype IC-0615592 is faster and more vigorous in nature. Sahay (2001) observed maximum spread of the plant, in North-South and East-West direction in Kasba (9.20 m and 9.28 m) and minimum in Bedana (7.10 m and 7.18 m). The variations in crown diameter were also reported by Kanwar and Nijjar (1975), Singh (1984), Singh and Singh (1954) and Sang (1979).The plausible cause of variation might be due to genetic make up of the crop.

5.1.2.4. Tree Volume (m^3)

The variation in tree volume ranged from 6.43 m^3 in IC-0615599 to 39.09 m^3 in IC-0615593. The highest increases in tree volume were recorded in genotypes IC-0615599 (27.21 %) and lowest in genotypes IC-0615603 (1.34 %). The result indicated that IC-0615599 exhibited vigorous growth both vertically and horizontally and recorded highest tree volume among the studied germplasm. The lowest tree volume was associated with lowest height and lowest crown diameter. The variation in tree volume was also reported by Yadav *et al.* (2010), and Chandola and Mishra (2015).

5.2. Leaf characters

5.2.1. Qualitative characters

5.2.1.1. Young leaf colour

A wide variability in leaf qualitative characters was observed within genotypes**.** Among the 30 studied genotypes, four young leaf colour was observed, with yellowish green colour as the most frequent (40.00%) and represented by 12 genotypes, a quite frequent type of leaf colour was pink (30.00%) and consists of 9 genotypes, bright pink colour had a lower representation (20.00%) while deep pink had the lowest representation (10.00%) shown by IC-0615585, IC-0615593 and IC-0615604 (Table 4.2.1 and Plate 3 & 7). The colour of newly emerging leaf is ranked as genetic properties of each genotype and is useful for identification of varieties. Chavaradar (2016) observed that leaf colour of young flushes varies from pinkish green (78.12%), greenish yellow (12.5%) and light green (9.37%). Nakasone and Paull (1998) reported that colour of young emerging flushes ranged from pale green to pinkish to a copperish red in colour. The foliage colour is a genetic trait that may be used for identification of cultivars. The litchi cultivars can be distinguished on the basis of colour of flush and season of flushing (Singh *et al*., 1999). Khurshid *et al*. (2004) also reported reddish brown flush colour in Gola and Bombay, brownish red in Calcuttia and dark pink flush colour in Bedana cultivar. The slight variation could also be due to prevailing environmental conditions *i.e.* sunlight, temperature, humidity, rainfall

etc. The colour of the newly emerged leaf was deep golden in Nafarpal. Ellaichi and Mclean showed copper red to light golden coloured new flush. The new flush in other cultivars varied from light to deep copper colour (Pereira 2002).

5.2.1.2. Mature leaf colour

Among the evaluated morphological leaf descriptors, mature leaf colour was also found to be highly variable (Plate 4). Results for mature leaf colour indicated that dark green in the evaluated genotypes was most frequent (46.66%) that include 14 genotypes while it was green (36.66%) in 11 genotypes. On the basis of morphological and phenotypic evaluations of litchi germplasm, mature leaf colour was morphologically variable. Chavaradar (2016) also observed matured leaf colour as green, light green and dark green. The colour of the mature leaves were deep green in Bedana, Bombai, Early Large Red, Nafarpal, Piazi, Rose Scented and Seedless Late while the other cultivars showed comparatively light green leaves (Pereira 2002). Significant variation in leaf morphology was also confirmed by Dass *et al.* (1998) and Jaskani *et al.* (2006) on citrus rootstock breeding.

5.2.1.3. Arrangement of leaflet

With respect to the arrangement of leaflet, a considerable variability was observed among genotypes. In the evaluated genotypes, opposite arrangement of leaflet was most frequent (70.00%) that include 21 genotypes while the remaining 9 genotypes (30.00%) had opposite and alternately arranged leaflets. Growth habit is an important factor in characterizing genotypes. However, growth habit is greatly influenced by location, soil and the amount of intercepted light (Palmer 1981).

5.2.1.4. Leaflet blade shape

All genotypes exhibited considerable variability with respect to the shape of leaflets. In the present study, two shapes of leaf blade was observed, with elliptic shape as most frequent (96.66%) and represented by 29 genotypes whereas lanceolate shape was noted

only in IC-0615586. Pereira (2002) observed elliptie-lanceolate shape of the leaflets in cvs. China, Deshi, Early Large Red, Ellaichi. Purbi and Rose Scented while others showed oval-lanceolate shaped leatlets. The leaf size and shape are important varietal characters and is also used for cultivar identification (Singh *et al.,* 1999). Khurshid *et al.* (2004) reported significant difference in characteristics of leaf length and leaf width of litchi cultivars. Madhou *et al.* (2010) also noticed major morphological differences in leaflet size and number of leaflets among 34 litchi accessions in Mauritius. A marked variability in leaf characters of pummelo accessions was also reported by Susandarini *et al.* (2013).

5.2.1.5. Shape of leaflet apex and leaflet base

Acute leaflet apex shape was universally noticed in all germplasm. However, three categories of leaflet base were observed within the studied genotypes which were most frequented by cuneate shape (73.33%) and represented by 22 genotypes. Six genotypes possessed attenuate base shape (20.00%) while oblique shape (6.66%) was noted only in IC-0615586 and IC-0615603. This was in contrast with the findings of Pereira (2002) who reported acuminate leaflet apex and attenuate leaflet base shape in all the cultivars studied except in cv. China which showed slightly oblique to attenuate leaflet base. The significance of leaf shape in distinguishing one species from the other was also previously described by Walter and Sam (2002) and Altaf and Khan (2008).

5.2.1.6. Leaflet surface pubescence and leaflet midrib appearance

The pubescence on upper as well as on lower surface of leaflet was absent in all germplasm, however, leaflet midrib appearance was prominent in all germplasm which agrees to the finding of Pereira (2002).

5.2.1.7. Leaflet venation appearance and protuberance on petiole

Among the 30 studied genotypes, the leaflet venation appearance was observed to be predominantly slightly prominent (73.33%) which include 22 genotypes while 20.00% and 6.66% of the genotypes had their leaflet marked by prominent venation and without venation respectively. Pereira (2002) observed the leaflet venation was comparatively less prominent in all the cultivars except in cultivars Kasba, Nafarpal and Rose Scented in which the venation was not very prominent. Protuberance on petiole was present in all germplasm.

5.2.1.8. Leaflet curvature

Results for leaflet curvature indicated that three types of curvature was observed within the 30 studied genotypes (Plate 5), with upward curve as the most frequent (70.00%) and represented by 21 genotypes, a quite frequent type of curvature was downward curve (26.66%) and consists of 8 genotypes and flat leaflet had a lower representation (3.33%) and include IC-0615605.

5.2.2. Quantitative characters

5.2.2.1. Number of leaflet

The observation of number of leaflets per compound leaf showed that maximum leaflets were recorded in Coll. 35 (7.29) and the minimum was in IC-0615587 (5.05). Other genotypes had intermediate number of leaflets under our study. Although, leaflets play an important role in the manufacturing of food material, but excessive leaflet with more number of shoot can cause shade to other leaflet and thus reduces yield potential. On the other hand, IC-0615587 showed minimum number of leaflet which is one of the main reasons of small fruit size and weight, and low yield. Although, the number of leaflets played an important role in yield potential but other characters are also associated with yield. The possible variation in number of leaflet is due to inherent characters of the germplasm. Brahmachari (1990) found maximum number of leaflets per shoot in Purbi under Sabour conditions and more or less similar observation was also reported by Jha (1972).The average number of leaflets

varied between 5.9/leaf in Bedana and 7.5/leaf in Early Muzaffarpur (Pereira, 2002).

5.2.2.2. Length of rachis (cm) and petiole (cm)

During the study, significant variation was observed in rachis length ranging from the highest in IC-0615608 (15.40 cm) to the lowest in IC-0615588 (6.45 cm). The variation in length of petiole varied from 2.54 cm to 4.83 cm. The maximum length of petiole was recorded in genotype IC-0615597 and minimum in IC-0615595. Similar finding was also by Wu *et al.* (2016). The genotype which has smallest petiole is also responsible for small size of leaf.

5.2.2.3. Leaflet blade length (cm)

A significant variation in leaflet length among genotypes was observed ranging from 8.10 cm (IC-0615595) to15.98 cm (IC-0615608). Pereira (2002) observed maximum leaflet length in cv. Seedless Late (15.5 cm) and minimum length in cultivar Early Muzaffarpur (12.1 cm). Chavaradar (2016) also reported a significant amount of variation in leaf length ranging from 12.0-16.8 cm. Tremendous variations in leaf size were also reported by Dorji and Yapwattanphun (2011), Kahn *et al.* (2001) and Marboh *et al.* (2015) in mandarin (*Citrus reticulate* Blanco).

5.2.2.4. Leaflet blade width (cm)

The variation in width of leaflet varied from 2.99 to 5.05 cm. The maximum width was in genotype IC-0615603 (5.05 cm) and lowest in IC-0615599 (2.99 cm). Pereira (2002) observed maximum width in cv. Seedless Late (4.8 cm) and minimum in Early Muzaffarpur (3.6 cm) while Chavaradar (2016) reported that leaflet width of the litchi ranged from 1.8 cm to 5.2 cm. The leaf size and shape are important varietal characters and is also used for cultivar identification (Singh *et al.,* 1999). Khurshid *et al.* (2004) reported significant difference in characteristics of leaf length and leaf width among litchi cultivars. Madhou *et al.* (2010) also noticed major morphological

differences in leaflet size and number of leaflets among 34 litchi accessions in Mauritius.

5.3. Flowering characters

5.3.1. Qualitative characters

5.3.1.1. Date of first and last panicle initiation

The emergence of the panicle is the first obvious sign of flowering in litchi. This character shows a similar trend in germplasm in both the years. In the present study, it is very much evident that date of panicle emergence differed among the litchi germplasm. Panicle emergence in genotypes IC-0615602, IC-0615610 and IC-0615613 was early while IC-0615586 and IC-06015599 is late in this respect. Minimum duration of panicle emergence (13 days) was recorded in genotype Coll. 39 and maximum (21 days) in genotype IC-0615603 during the first years whereas, in second year, minimum duration of panicle emergence (14 days) was found in genotype IC-0615586 and maximum (26 days) in IC-0615599. It is clear from these data that when panicles initiated early in the season, longer duration was needed to complete their emergence, while, genotypes that started panicle initiation late in the season, took shorter time. This is due to low temperatures prevalent during the early phase of panicle initiation and with increase in temperature, duration of panicle initiation shortened. Singh *et al.* (2012) reported that in the northern hemisphere the emergence of flower panicle starts in January and is continued up to the end of February. However, Singh *et al*. (2010) reported that the emergence of flower panicles in different litchi cultivars grown in Bihar condition started during second week of March and continued for a month. The duration of panicle emergence of more than one month from first week of January has been reported under Gurdaspur (Punjab) conditions by Chadha and Rajpoot (1969).The cause of variation might be due to environmental conditions.

The variation observed in terms of panicle initiation might be due to the differences in genetic composition of different litchi genotypes. The process of panicle development is a genetically fixed

property of the respective genotype, but the environment of the growing site may cause significant changes in the manifestation of the inherited character. Other factors also play significant role in determining the rate of panicle development such as age, health and vigor of the tree (Das *et al*., 2002) and site of the plants in the field. The variations in emergence of panicle were also reported by Sharma and Ray (1987); Sarkar and Bandyopadhyay (1989); Pathak *et al*. (2013) and Kumar *et al*. (2015).

5.3.1.2. Date of opening of first and last male flower

Three basic types of flowers *viz.,* male or staminate flowers (Type 1, male), hermaphrodite female flower (Type 2, female) and hermaphrodite male flower (Type 3, male) were observed in all the genotypes (Plate 6). In all the genotypes, the sequence of opening of flower is succeeded as Type 1, male followed by Type 2, female and lastly Type 3, pseudo hermaphrodite flower. Data pertaining to the initiation of flowering in different litchi germplasm are also presented in table 4.3.1. It is evident from the data that date of opening of male flower in different germplasm of litchi under study varied from 2nd March to 22nd March for both the years. The opening of male flower was firstly started in IC-0615602 (8th March, 2017 and 13th March, 2018) and opening of male flower was lastly ended in IC-0615599 (26th March, 2017 and 28th March, 2018).

The pattern and timing opening of flowers in litchi depends on many genetic and environmental factors. Litchi flowering is indeed promoted by cool and dry winters, but not by short day length. Litchi is a day-neutral plant, extremely short (8 hours) or long (16 hours) days do not affect its flowering (Nakata and Watanabe1966; Stern 1992). The litchi flowering season occurs in the spring. In warm tropical climates, flowering occurs in January to February (Das and Choudhury 1958; Subhadrabandhu 1990), whereas, in the cool subtropical climates of Northern Hemisphere it starts in April to early May (Goren *et al*., 1998). ‘San Yue Hong’ is the first cultivar to flower; whereas ‘Nuo Mi Ci’ and ‘Huai Zhi’ are late bloomers (Wang and Qiu 1997). The typical flowering period of a cultivar extends for about

three to five weeks (Chadha and Rajpoot 1969; Menzel, 1984; Goren *et al*., 1998). Sharma and Roy (1987) observed that flower opening in litchi under Bihar condition started from second week of March to third week of April. However, with milder summer and winter, litchi blooms twice a year under Bangalore conditions (Firminger 1947). February-March flowering is considered as erratic flowering in South India. The flowering period may vary with the genotype and environmental conditions. Whereas, Kumar *et al*. (2015) observed earliest flowering in the cultivars (Dehradun, Large Red, Rose Scented, Seedless Early, Saharanpur and Mclean), that started to flower in the third week of March, while the cultivar Seedless Late flowered later *i.e.* in the first week of April. However, cultivars Calcuttia and Muzaffarpur flowered in the last week of March.

5.3.1.3 Date of opening of first and last female flower

Data pertaining to the initiation of flowering in different litchi germplasm are also presented in table 4.3.2. It is evident from the data that date of opening of female flower in different germplasm of litchi under study varied from 9th March to 30th March for both the years. The first opening of female flower was noticed in genotype IC-0615602 (9th March, 2017) and IC-0615587 (9th March, 2017 and 14th March, 2018). The opening of female flower was firstly ended in genotype IC-0615587 (14th March, 2017) and IC-0615587, IC-0615588 and IC-0615602 (19th March, 2018) and lastly ended in IC-0615599 (30th March, 2017 and 1st April, 2018) followed by Coll. 36 (28th March, 2017 and 30th March, 2018). The earliest opening of female flowers in genotypes is attributed to earliest panicle initiation.

5.3.1.4 Date of opening of first and last hermaphrodite functional male

Data pertaining to opening of hermaphrodite functional male in different litchi germplasm are presented in table 4.3.2. The last phase, *i.e.,* hermaphrodite phase (M2), started one to two days, before or just after completion, of the second phase. Among the genotypes studied, hermaphrodite phase emerged earlier from 14th March to 1st April for

both the years. The first opening of hermaphrodite male flower was found in genotype IC-0615602 (14th March, 2017) and IC-0615587, IC-0615588 and IC-0615602 (20th March, 2018) and the opening of Hermaphrodite male flower was eventually recorded in genotype IC-0615599 (30th March, 2017 and 1st April, 2018). The opening of hermaphrodite male flower firstly terminated in IC-0615587 (21st March, 2017 and 26th March, 2018) and the opening of hermaphrodite male flower was finally ended in IC-0615599 (6th March, 2017 and 8th March, 2018). In the present study, the third phase of flowering was the longest of the three phases which was in contrary to the findings of Pathak *et al*. (2013); Chadha and Rajput (1969) and Stern and Gazit (1996) who found first phase (Male flower) as longest phase.

5.3.1.5 Flower disc colour

The colours of flower disc are ranked as genetic properties of litchi genotypes. The flower disc colour in 25 genotypes (83.33%) was light yellow while 3 genotypes (10.00%) namely, IC-0615997, IC-0615602 and IC-0615608 had pink flower disc colour (Plate 9). The colour of flower disc is purely genetical characters and it is used for identification of cultivars in litchi. The variations in flower disc colour were also reported by Khurshid *et al.* (2004). They observed that Gola had light yellow flower colour, while Bombay, Calcuttia and Bedana cultivars had yellowish flower colour. Similarly, Kumari (2016) also showed that variation in colour of flower varied from light cream to light yellow and greenish white.

5.3.1.6 Position of inflorescence

In all the studied genotypes, the position of inflorescence in 24 genotypes (80.00%) was terminal while 6 genotypes (20.00%) namely, IC-0615588, IC-0615593, IC-0615595, IC-0615596, IC-0615604 and IC-0615613 had both terminal and axillary inflorescence. The panicles are generally produce terminally in cluster of 10 or more but in some tree a high percentage of axillaries are produced. However, no varietal differences have been established

with respect to this characteristic (Das and Choudhury 1958). The similar observations were also noticed by Kumari (2016) who noted the terminal position of inflorescence as predominant in most genotypes though both terminal and axillary inflorescence was noticed. Chavaradar (2016) observed terminal position of the inflorescence in all collections studied. Khurshid *et al.* (2004) found terminal panicle in Gola and Bedana. Ray (2002) stated that the panicles were normally produced terminally in clusters of 10 or more but in some trees a high percentage may also be produced. Litchi inflorescence is compound recemose which is composed of several multiple branched terminal panicle where the flowers occur in cymes (Pandey and Sharma 1989).

5.3.1.7 Abundance of flower

The variations in abundance of flower have been seen in litchi. Sparse flowering was noticed in genotypes IC-0615595 and IC-0615599 while moderate flower was found in genotypes *viz*., IC-0615585, IC-0615588, IC-0615613 and IC-0615605 and rest genotypes showed profuse flowers in panicle. The genotype which produced late panicle showed minimum number of flower in panicle compared to genotype with early emergence of panicle owing to larger and significant panicle size. Biswas *et al.* (1994) found that Mandaraji had maximum flowering whereas, Bombai and Dinajpuri (local cultivar) had minimum flowering. The variations in number of flowers were also reported by many workers (Mustard *et al.,* 1953; Chaturvedi 1965; Chadha and Rajpoot 1969; Hoda and Syamal 1975; Gupta and Koul 2000; Das and Chaudhury 1958; Das and Roychaudhury 1958; Dabral and Misra 2007; Somnuk and Suavansri 2005).

5.3.2 Quantitative characters

5.3.1.1 Duration of flowering (Days)

The duration of flowering varied from 15 to 24 days in studied litchi germplasm. The maximum duration of flowering was found in IC-0615610 (24 days) and minimum days were recorded in IC-0615586

(15 days). Results showed that cultivars which start flowering early in the season took longer to complete flowering cycle, whereas, those that start flowering later in the season, take a shorter time to complete flowering. This variation is due to increase in temperature during later part of the season. The variation among the different litchi genotypes with respect to flowering duration may be accorded to their genetic constitution and weather conditions which are responsible for increment in transpiration such as high temperature, low humidity and wind, which shortens the flowering duration. Chaddha and Rajput (1969) reported that duration of flowering in litchi usually ranges from 20-45 days, while Sarkar and Bandyopadhyay (1989) reported that duration of flowering in litchi varied from 24 days in Kasba to 14-15 days in Ellaichi cultivar. Saxena (2016) recorded maximum duration of flowering in Dehradoon (28 days) and minimum in Late Seedless (21.5 days). Sharma and Ray (1987) reported that cultivar China and Bedana had flowering duration of 27 and 38 days respectively under Bihar condition.

The variations in flowering characteristics might be due to genetic behaviour of the cultivars as floral characters are less affected by the environmental conditions. Variations in duration of flowering were also reported by Ray (2002) and Sahay (2001). Hence the variations in flowering to maturity may be due to the genetic makeup of the cultivars as well as environmental conditions prevailing in the region. Kumari (2016) reported that flowering duration ranged from 9.33 days to 19 days in different litchi genotypes. Chadha and Rajpoot (1969) reported that flowering duration ranged from 26 to 35 days in different varieties while Singh and Dhillon (1983) noted 11 to 17 days for anthesis. The flowering duration was 27.58 days under West Bengal condition as observed by Hasan and Chattopadhyay (1991). The duration of flowering within a planting is usually between 20 and 45 days, depending on seasonal conditions, but usually without much varietal response (Banerjee and Chaudhuri 1944; Mustard *et al.,* 1953; Pivovaro 1974).

5.3.1.2 Length of inflorescence (cm)

The length of inflorescence has been considered to be a good measure for identification of some varieties in litchi. A significant variation in the length of inflorescence among the 30 studied litchi genotypes (Plate 10) was observed which ranges from a maximum of 47.50 cm in genotype IC-0615610 to a minimum of 16.20 cm in genotype IC-0615613 (Table 4.1.7). Genotype IC-0615610 showed significant superiority over all the germplasm studied. These differences are due to the genetic makeup of the cultivars. However, panicle length also depends on the existing environmental conditions, time of panicle emergence and shoots maturity. The physiological mature shoot and early emergence of panicle is good indication of significant panicle. Chen and Cheng (1996) also found that largest inflorescences were produced early in the season under lower temperatures. High temperature accelerated panicle growth and flowering in Hawaii (Nakata and Watanable 1966) and China (Li and Li 1948). However, size of the inflorescence was small in late emerging panicle. In litchi, the temperature requirements for inflorescence induction, inflorescence development and anthesis are different (Chen *et al.,* 2016).The low temperature favours inflorescence induction (Menzel 1983) and inflorescence growth as compared to higher temperatures where inflorescences were shorter Chen *et al.* (2013).

5.3.1.3 Width of inflorescence (cm)

The genotype IC-0615602 produced maximum width of inflorescence (33.50 cm) while minimum width was found in genotype IC-0615613 (9.15 cm).Trees with longer inflorescence resulted in increased width of inflorescence. A higher panicle width is produced under medium intensity of panicle production which leads considerably to lower competition among the emerged panicle as food material is diverted from leaf to promoted the length and width of panicle. The variation in length and width of panicles is genetic character of litchi genotypes and more specifically the physiological condition of the shoot on which panicle is raised. Similar observations

were also made by Sauco (1989), Sahay (2001), Khurshid *et al*. (2004), Dabral and Misra (2007) in litchi varieties.

5.3.1.4 Per cent of functional female flower

The per cent of female flowers in inflorescence play a significant role in regulation of fruit set, growth and yield. The genotype Coll. 36 produced maximum per cent of female flowers (43.32%) and minimum in genotype IC-0615585 (3.96%).The proportion of female flowers was higher in larger panicle which corroborates with the report of Menzel and Simpson (1991). Pereira (2002) showed that cultivar Bombai had highest percentage of female flowers (53.77%) and a low sex ratio of 0.85:1compared to Seedless Late which showed the lowest percentage of female flowers (7.10%) and highest sex ratio (13.08:1). Thus, the cultivars with a comparatively lower sex ratio (male: female) suggest that the number of female flowers in those cultivars is more, which in turn indicate the potentiality of the cultivars to produce more fruits compared with other cultivars with a higher sex ratio. Saxena (2016) found highest percentage of functionally female flowers in Calcuttia (48.7%) followed by Seedless No. 2 (38.2 %), while Dehardoon had the least number of functionally female flowers per panicle. Datt (1998) also reported that functional female flowers varied greatly among the cultivars. The proportion of functional female flowers depends on cultivars and years, from less than 10% to more than 60% (Khan 1929; Mustard *et al*., 1953; Cobin 1954; Das and Choudhury 1958; Chaturvedi and Saxena 1965; Chadha and Rajpoot 1969; Hoda and Syamal 1975). The production of female flowers depends on cool temperature during floral bud differentiation in litchi. Chakraborty *et al.* (1981) also noted that the maximum number of hermaphrodite flowers on cashew in India developed on panicle which emerged during the first week of January when daily maximum and minimum temperatures were lowest.

5.4 Fruit characters:

5.4.1 Qualitative characters

5.4.1.1 Date of initiation and end of fruit set

Double fertilization takes place 2-3 days after pollination followed by division of the nucleus of the primary endosperm (Lu *et al*., 1985). The zygote then begins to divide after 3-7 days (Joubert 1986). Fruit-set in different germplasm of litchi under study varied from 17th March to 7th April and 20th March to 10 April during 2017 and 2018, respectively. The initiation of fruit-set was earliest in genotype IC-0615602 in both the years (17th March 2017 and 23rd March 2018) while it was late in genotype IC-0615599 (5th April 2017 and 7th April 2018). Fruit set terminates firstly on 20th March in IC-0615601 and IC-0615602 during 2017 and IC-0615602 (26th March) in 2018 while it eventually ended on 7th April in genotype IC-0615599 during 2017 and on 10th April in genotype IC-0615599 during 2018. Thus, from the data it is very much evident that date of fruit-set differed among the litchi cultivars. The early fruit set in genotype IC-0615602 is due to earliest panicle emergence and opening of female flowers. The reserve of tree also plays an important role on fruit set initiation. Early fruit set in some of the genotypes are probably due to early panicle emergence, early anthesis and subsequently early fruit set in these genotypes. Sharma and Ray (1987) reported that fruit set occurred within 7-18 days of flowering. The variation observed in terms of fruit set might be due to the differences in genetic composition of different litchi genotypes. The seasonal cyclic change of growth, flower, fruit and their development differ between genotypes and location. The age, health and vigour of the tree have significant role in determining fruit set (Das *et al*., 2002). Variation in time of panicle emergence, panicle development and anthesis among the cultivars in relation to seasonal progression of temperature affected the number of fruit set. Such marked differences in fruit set have also been reported by Chadha and Rajpoot (1969); Pereira (2002); Hoda and Syamal (1975) and Sanyal *et al.* (1996).

5.4.1.2 Fruit maturity group

A wide variation in maturity of fruit among various litchi genotypes has been observed. As presented in table 4.4.1, maturity of fruits was grouped into three classes. Mid ripening group was most

frequent (53.33%) that consists of 16 genotypes, while early ripening group was quite frequent (33.33%) and include 10 genotypes. The late ripening group (13.33%) was represented by only four genotypes *viz.,* IC-0615585, IC-0615595, IC-0615599 and IC-0615603. The variation in maturity is due to variation in panicle emergence and opening of flowers. The variation in maturity was also reported by Rani *et al.* (2007).

5.4.1.3 Fruit ripening and bearing habit

Results for fruit ripening indicated that synchronous ripening in the evaluated genotypes was most frequent (90.00%) that include 27 genotypes while it was non- synchronous ripening (10.00%) in 3 genotypes. Though fruit ripening is a genetic character of litchi, the amount of prevailing sun light also exerts an important role in determining colour of fruits as exposed side of fruits develops more colour as compare to other rear side.

Fruit bearing habit also markedly varied among the 30 studied genotypes. Predominantly, completely regular bearing was noted in 29 genotypes (96.66%) while only 3.33% of the genotypes had partially regular bearer. The partially regular bearer genotype become exhausted totally in the first year and produced limited number of fruits in the next year.

5.4.1.4 Fruit bearing intensity and clustering habit

Results indicated heavy fruit bearing intensity was most frequent (56.66%) that comprise of 17 genotypes while it was medium (23.33%) in 7 genotypes and poor (20.22%) in 6 genotypes which includes IC-0615585, IC-0615587, IC-0615588, IC-0615595, IC-0615599 and IC-0615605. All the germplasm produced fruits in cluster except in genotype IC-0615595 which produced single fruit. However, many flowers were produced in bunch but only one fruit retained at the time of harvest due to low retention capacity in genotype.

5.4.1.5 Fruit shape

Fruit shape is a very important genetic marker in identification of litchi cultivars as it does not influence by location and climatic condition. Data pertaining to fruit shape among the 30 studied genotypes reveals that elliptic, oblong, round, oval, conical and cordate shapes were observable and detectable in fruits. The result also indicated that among all kinds of fruit shape, the number of genotypes possessing oval shape was the highest and comprised 9 genotypes. Conical fruit shape was detectable in 8 genotypes while the number of elliptic fruit shape was recorded in five genotypes *viz*., IC-0615586, Coll. 39, IC-0615606, IC-0615608 and Coll. 35. Cordate fruit shape was observed in four genotypes *viz.,* IC-0615593, IC-0615588, IC-0615596 and IC-0615604. Pereira (2002) observed that fruits of Bedana were globose in shape while China and Seedless Late were heart shaped. Cultivars Nafarpal and Piazi produced egg round fruits and the fruit of Bombai, Ellaichi and Kasba were long egg round in shape. Fruits of other cultivars were ellipse shaped. Khurasid *et al.* (2014) observed that variation in fruit shape in litchi may be due to the genetic makeup of cultivar.

5.4.1.6 Fruit shoulder

The nature of fruit shoulder was mostly protruding (56.66%) that comprise of 17 genotypes and while it was smooth (43.33%) in 13 genotypes. Pereira (2002) found uneven fruit shoulders in cultivars Bombai, China, Ellaichi, Kasba, Piazi and Seedless Late while other cultivars had smooth shoulders. Fruit shoulder is a genetic character inherited from generation to generation.

5.4.1.7 Fruit tip

With respect to shape of fruit tip, a wide variability was observed among genotypes. Three types of fruit tip were observed within the 30 studied genotypes, with obtuse fruit tip as the most frequent (70.00%) and represented by 21 genotypes, a quite frequent type of fruit tip was round (16.66%) and consists of 5 genotypes, acute fruit tip had a lowest representation (13.33%) by four

genotypes. This genetic character is not affected by environment and location. Pereira (2002) observed obtuse shaped fruit apex in cultivars Bombai, China, Ellaichi, Kasba, Nafarpal, Piazi and Seedless Late while rest of the cultivars showed a round fruit apex.

5.4.1.8 Segmentation on fruit skin

Four types of segment on fruit skin was observed within the studied genotypes, with sharp pointed as the most frequent (43.33%) and represented by 13 genotypes, a quite frequent type of segment was nipple shaped (30.00%) and consists of 9 genotypes, swelling type segment had a lower representation (23.33%) by 7 genotypes while smooth segment had the lowest representation (3.33%) shown by genotype IC-0615587.

5.4.1.9 Cracking of fruit skin

The results on fruit cracking indicated that 18 genotypes (60.00%) were free from cracking of skin while 7 genotypes (23.33%) were prone to cracking and 5 genotypes (16.66%) were highly prone to cracking. The skin-cracking of developing fruit is a serious problem in litchi and are promoted by high temperatures, low humidity and low soil moisture. Inadequate moisture during the early period of fruit growth results in the hard skin and it may then crack when it is subject to increased internal pressure as a result of rapid aril growth following irrigation or rainfall. The genotypes free from cracking were characterized by a thicker peel and spongy layer, and compact of tubercles on skin whereas cracking susceptible genotypes possessed thin peel and spongy layer, and tubercles are sparsely located on skin. The variation in fruit cracking was also reported by other workers (Chadha and Rajpoot 1969; Sanya *et al*., 1990; Kanwar and Nijjar 1975; Rani *et al.,* 2007).

5.4.1.10 Mature fruit colour

With respect to fruit colour at maturity, a wide variability was observed among genotypes. Eight types of fruit colours were observed within the studied genotypes, with reddish yellow and crimson red as most frequent, each of which was represented by 7

genotypes (23.33%), a quite frequent type of fruit colour was rosy red (16.66%) and consists of 5 genotypes; deep pink had a lower representation (10.00%) comprising of 4 genotypes while scarlet and greenish red had the lowest representation each (3.33%) shown by genotype IC-0615585 and IC-0615886, respectively. Pereira (2002) observed pink colour at maturity in cultivars Early Large Red, Mclean, Piazi and Seedless while Kasba and Purbi produced scarlet coloured fruits. Variations in fruit colourwere also reported by Chavaradar (2016), Froneman (1999), Wong (1999), Yuan and Zhu (2001) and Chandola and Mishra (2015) in litchi. The dark red colour or scarlet colour is attributed to high content of anthocyanin in pericarp per unit area.

5.4.1.11 Distribution of colour on fruit surface

The distribution of colour on fruit surface was found uniform in 23 genotypes (76.66%) while 7 genotypes (23.33%) showed partial distribution of colour on fruit surface. Besides genetic factors, the role of light has been assigned as equally contributory on distribution of colour on fruit skin because side of fruit exposed to sun light develops more red coloured as compared to other sides of fruit. Under direct sunlight, the shaded part of the fruit received almost no light and the synthesis of anthocyanins was inhibited, resulting in uneven colouring on the fruit.

5.4.1.12 Shape of tubercles

With respect to shape of tubercles, a wide variability was observed among genotypes. Four shapes of tubercles were observed within the studied genotypes, with sharp pointed shape as the most frequent (43.33%) and represented by 13 genotypes, a quite frequent type of tubercle shape was slightly pointed (30.00%) and consists of 9 genotypes; obtuse shape had a lower representation (23.33%) while smooth shape had the lowest representation (3.33%) shown by IC-0615887. Pereira (2002) found that fruits of cultivars Bedana, China and Nafarpal had smooth tubercles on their surface. The cultivar

Ellaichi possessed obtuse shaped tubercles. The fruits of cultivars Bombai, Deshi, Kasba, Piazi and Purbi had sharp pointed tubercles.

5.4.1.13 Tubercles density and presence of suture

The tubercles density was sparse in 17 genotypes (56.66%) among the studied germplasm while 8 genotypes (26.66%) showed dense tubercles and 5 genotypes (16.66%) had medium density of tubercles. All the early maturing genotypes showed less number of tubercles per unit area as well as genotypes belonging to Bedana group also showed less number of tubercles but closely located with flat or obtuse types of shape. The presence of suture was most prominent which comprise 14 genotypes (46.66%) while 43.33% of the genotypes had weak suture and 10.00% of the genotypes had no suture and include IC-0615595, IC-0615603 and IC-0615608.

5.4.1.14 Fruit attractiveness

Fruit colour in litchi plays an appealing role in determining its attractiveness, marketability and consumer preferences. The colour of the pericarp is produced by a combination of chlorophyll, carotenoids, flavones and anthocyanins. Chloroplasts are distributed in the outer mesocarp, particularly between the protuberances (Underhill and Critchley 1992). Anthocyanins are responsible for the red colour and are found in the outer mesocarp and exocarp (Underhill and Critchley 1994). Excellent fruit appearance was dominantly found in 14 genotypes (46.66%) while it was good in 9 genotypes (30.00%); six genotypes had intermediate fruit appearance and poor attractiveness was noted only in IC-0615599. Pereira (2002) observed that fruits of Bombai, Early Large Red, Ellaichi, Mclean, Muzaffarpur, Purbi and Rose Scented had a good appearance. The fruits of Bedana, China and Early Muzaffarpur were excellently attractive. Cultivars Nafarpal and Piazi had a poor attractiveness whereas Seedless Late and Deshi were intermediate in appearance.

5.4.1.15 Aril texture

Aril texture was categorized into four classes and leathery aril texture was most frequently observed in 14 genotypes (46.66%),

whereas soft aril texture (33.33%) that comprise of 10 genotypes and firm aril texture (10.00%) represented by IC-0615594, IC-0615608 and IC-0615599 as well as melting aril texture (10.00%) represented by IC-0615590, Coll. 39 and IC-0615603 was observed to be quite frequent.

5.4.1.16 Aril quality

Sweet aril quality (76.66%) of different litchi fruits as well as bitter (13.33%) and acidic (10.00%) aril was observed to be the dominant characters in the evaluated genotypes.

5.4.1.17 Aril colour, flavour and juiciness

The variation in aril colour varied from creamy white, white to dull white. In the present study, dull white aril colour (90.00%) was observed to be the dominant character. Kumari (2016) also noticed that colour of aril varied from creamy white to white and pinkish white. Four classes of aril flavour was observed and significant strong flavour was most frequently observed in 14 genotypes (46.66%), whereas intermediate flavor was recorded in nine genotypes (30.00%); weak flavour in five genotypes (16.66%) while good flavor was noted only in two genotypes (6.66%). Kumari (2016) found significant flavour in H-71, H-73, H-104, H-245, H-510, H-518, H-566, H-573, H-588, H-591, China, Kasba, Late Bedana and Dehra Rose had intermediate flavour. The flavour of aril was weak in H-72, H-98, H-503, H- 517, H-526, H-580 and Ajhauli. Juicy aril was observed to be the dominant characters (86.66%) in the evaluated genotypes.

5.4.2 Quantitative characters

5.4.2.1 Number of days from fruit set to maturity

In the present investigation, it was observed that genotype IC-0615585 has taken maximum days (70.5) to mature from fruit set and genotype IC-0615608, a very late ripening genotype has taken minimum (55.5) days to mature. This genotype was also late in panicle emergence and anthesis. Sahay (2001) noticed that Late Bedana, a late maturing cultivars took 68.67 and 66.83 days

respectively to mature in both the years. Deshi and Green proved early as they took 56.17 and 56.50 days. Purbi and China were intermediate in this respect taking 62.17 and 63.67 days, respectively. This variation in maturity of fruits among genotypes is attributed to genetic makeup of the plant which may mature few days earlier or later. All the germplasm which took maximum days to mature have more thickness of peel which resist the conversion of acid to sugar by lowering the fruit surface temperature necessary for metabolic activities. Similar views were expressed by Kanwar and Kahlon (1985), Singh and Abidi (1986) and Badiyala (1991). Rashmi (2016) also found that the maximum number of days taken from fruit set to maturity was 68.67 days in H-591 while a minimum of 55 days was recorded in Ajhauli. Menzel and Simpson (1992) and Gaur and Bajpai (1990) also enunciated variation in maturity period in different litchi cultivars.

5.4.2.2 Number of fruit per cluster

The maximum number of fruit per cluster (Plate 11) was observed in genotype IC-0615590 (13.51) whereas, the lowest number of fruits per cluster was found in genotype IC-0615595 (1) followed by IC-0615613 (2.97). Pereira (2002) observed maximum number of fruits per panicle at harvest in the cultivars McLean (5.49), Piazi (5.48), Early Large Red (5.33) and Rose Scented (532) whereas the lowest fruit retention was observed in cultivar Bedana (2.62). The variation among varieties in the number of fruits retained at harvest maturity may be a varietal character showing differential capacities to take crop load.

The number of fruits set per panicle increased as the number of female flowers per panicle increased (Menzel and Simpson 1992). Chadha and Rajpoot (1969) demonstrated a relationship between fruit set and female flowering, Calcuttia Late had 48.7% of female flowers and 23.2% of flowers setting fruit, while Dehradoon had 19.8% of female flowers and 8% fruit set. When the difference in the proportion of female flowers was taken into account, there was only a slight effect of cultivar on fruit set (47.6 % and 40.3 % for Calcuttia Late and

Dehradun, respectively). McConchie and Batten (1989) suggested that the most appropriate time for fruit to be considered set is when most fruitlets on a panicle reach maturity. When they pollinated all of the female flowers on panicles of Bengal litchi, 9% of flowers produced mature fruit. Chen (1991) observed 3.4 - 6.3% fruit set in Taiwan. Chavaradar (2016) also found the number of fruits per cluster/inflorescence ranges from 6 to 18. Maximum number of fruits/cluster (18) was observed in Coll. 2 and Coll. 13, followed by Coll. 9 (17) and Coll. 10 (16). The variation in number of fruits/cluster was also reported Kumar *et al.* (1981) in litchi.

5.4.2.3 Fruit length (mm)

The maximum fruit length was recorded in IC-0615585 (42.45 mm) while minimum was found in IC-0615587 (27.94 mm). The variation in fruit size is attributed to cultivar differences and environmental conditions as reported by Chadha and Rajpoot (1969), Pivovaro (1974) and Singh and Lal (1980). Arora (1998) reported variability in litchi genotypes with respect to fruit size, seed size and aril characters. Highest fruit length in genotype IC-0615585 is due to maximum length of seed which consequently increases the length and diameter of fruit. The cell division of pericarp starts 14 days after anthesis and division ceases in various parts of the pericarp at different times. A longer duration of cell division leads to larger pericarp and a larger fruit and differences in fruit length among genotypes was correlated to variation in the number of cells rather than to their final size (Wang *et al.,* 2000; Li *et al.,* 2002).

5.4.2.4 Fruit diameter (mm)

The maximum fruit diameter was observed in genotype IC-0615613 (35.81 mm) and lowest diameter in IC-0615595 (27.97 mm). Ghosh *et al.* (1988) reported that the length of fruit was maximum in Bombai (4 cm) while it was 3.8 and 3.7 cm in Ellaichi and Purbi, respectively compared to Early Large Red and the maximum fruit width was found in Bedana (3.5 cm) followed by 3.2 cm in Muzaffarpur Early and 3.1 cm in Purbi and Early Large Red. The

smallest width of fruit (2.8 cm) was noted in cultivars Bombai and McLean. Dabral and Misra (2007) reported that the fruit length was found significantly high in Calcuttia followed by Rose Scented, Mandraji and Dehra Dun, while minimum fruit length was noted with Longia. Singh *et al.* (2010) also obtained the mean maximum fruit length and diameter in cultivar Kasba (3.78 and 3.37 cm) while the minimum was recorded for cv. Dehradun (2.82 and 2.41 cm). The fruit breadth was maximum in Rose Scented (3.17 cm) and Early Seedless (3.17 cm) and minimum was found with Longia (2.70 cm). The differences in different physical characters between varieties might be due to their genetic varietal characteristics. Similar results were obtained by Badiyal and Awasthi (1991).

5.4.2.5 Fruit weight (g)

The observations in relation to fruit weight were recorded and presented in table 4.3.1.4 and figure 4.10. A glance of the data indicated that fruit weight was found maximum in genotype IC-0615585 (25.76 g) followed by IC-0615613 (24.77 g) and IC-0615601 (23.8 g) whereas it was lowest in IC-0615595 (15.55 g) followed by IC-0615587 (16.19 g) and IC-0615588 (17.26 g). Dabral and Misra (2007) reported that mean fruit weight differed significantly among cultivars. Rose Scented (20.93 g) gave the maximum mean fruit weight which was *at par* with Dehradun (20.9 g), Mandraji (20.00 g), Kasba (19.93 g) and McLean (19.33 g). The minimum mean weight of fruit was found in Longia (13.24 g). Yen (1984) reported that the weight of seeded fruit was heavier than seedless fruit, but the aril weight between seeded and seedless fruit was not significantly different. Singh *et al.* (2013) reported that the fruit weight showed an increasing trend with increasing developmental period. The increase in weight of the litchi fruit appears to be due to occurrence of cell division in the early stages and cell enlargement in later stage of fruit growth. The starch reserve in litchi plant is an important factor which controls the productivity of plant. The variation in physical attributes of fruits show the presence of genetic variability which might be effective in selection of mother tree. Maximum fruit weight was observed in cv.

Late Seedless followed by cv. Rose Scented whereas minimum fruit weight was observed in cv. Longia (Rani 2006). Singh *et al.* (2010) recorded the highest fruit weight for cultivar Kasba (28.19 g/fruit) while the lowest was for Longia (13.96 g/fruit). The differences in different physical characters between varieties might be due to their genetic varietal characteristics. Similar results were obtained by Ghosh *et al.* (1988.) and Badiyal and Awasthi (1991).Total fruit weight also differs among different cultivars of litchi. The fruit and pulp weight in litchi cultivar depend on genetic factors (Khurshid *et al*., 2004), nutrition (Cronje *et al.,* 2009), plant water balance and fruit orientation (Waseem *et al.*, 2002). The fruit weight was found highest in Rose Scented followed by Dehradoon, while minimum fruit weight was recorded in Longia followed by Late Seedless (Chandola and Mishra 2015).The fruit weight in litchi cultivars depends on genetic factors (Khurshid *et al*., 2004). Similar variations were noticed in the earlier findings of Haq and Rab (2012). Large fruit weight of 20.1g in cultivar Yook Ho Pow was reported by Luchooman and Ramburn (2016) under Mauritius conditions. Singh (1990) suggested the possible cause of differentiation in fruit size was either due to the variation in characters of the pericarp like cell size, laticiferous canals intercellular space in different tissues of the fruits which contribute to increase in length, breadth and thickness of the fruits (Baker and Davis1951) or due to accumulation of carbohydrates (Crane and Brown 1950). Coombe (1960) elucidated that the growth of fruit in the later stage was due to osmotic accumulation of food substances and water.

5.4.2.6 Aril weight (g)

The quantity of aril is an important factor for the evaluation of a cultivar because this is the part of the fruit which is finally utilized. Observations in relation to aril weight were recorded and presented in table 4.3.1.8 and figure 4.12. A glance of the data indicated that aril weight was found maximum in IC-0615613 (17.66 g) followed by IC-0615611 (14.73 g) which was *at par* with IC-0615585 (14.64 g) whereas, the lowest aril weight was recorded in IC-0615595 (7.27 g)

followed by IC-0615603 (9.85 g) which was *at par* with IC-0615605 (9.88 g).

Dabral and Misra (2007) reported that maximum fresh weight of aril was observed in Late Seedless (14.60 g) followed by Early Seedless (13.16 g) and minimum was recorded in Mandraji (8.83 g).The pulp weight of litchi fruit was comparable to the fruit weight with the maximum in cultivars Gola (16.58 g) followed by cultivars China and Surahi with 16.27 and 15.90 g pulp weight respectively while cultivar Bedana had the lowest pulp weight (11.19 g). The pulp weight of litchi fruit in cultivar Gola was 34.14%, 10.35% and 4.59% higher than cultivar Bedana, Surahi and China respectively (Haq and Rab 2012). The fruit and pulp weight in litchi cultivar depend on genetic factors (Khurshid *et al*., 2004), nutrition (Cronje *et al.*, 2009) and fruit orientation (Waseem *et al*., 2002), thus, it is likely to observe variations in fruit and pulp weight among different cultivars. The differences in different physical characters between varieties might be due to their genetic varietal characteristics.

Fresh weight of aril was found maximum in Late Seedless followed by Early Seedless while minimum fresh weight of aril was recorded in Mandraji followed by Longia (Chandola and Mishra 2015). Since the crop is highly heterozygous this difference can be seen. Ghosh *et al.* (1988) observed 15.3 g weight of aril in Bedana under West Bengal conditions. Chadha and Rajpoot (1969) and Syamal *et al*. (1983) also observed variation in pulp content of different varieties. The fruit and pulp weight in litchi cultivar depend on genetic factors (Khurshid *et al*., 2004), nutrition (Cronje *et al*., 2009), plant water balance (Batten *et al*., 1994) and fruit orientation (Waseem *et al.,* 2002), thus it is likely to observe variations in fruit and pulp weight among different cultivars. Variations in peel weight were also recorded by Chadha and Rajpoot (1969) and Syamal *et al.* (1983).The variation in pulp percentage might be due to genetic makeup of the cultivars. Similar variations with respect to pulp percentage were recorded by Rai *et al.* (2002).The differences in skin, stone and pulp percentage are varietal characters which depend upon

the nature of the variety in utilizing food material (carbohydrates) manufactured during the process of photosynthesis. Some varieties have the tendency to divert its manufactured food material towards mesocarp resulting in increased percentage of pulp. On the contrary, if the more food is diverted towards the endocarp the stone percentage is increased.

5.4.2.7 Aril thickness (mm)

The aril thickness is also an important character for the evaluation of cultivars because thickness of peel directly correlated to size of fruit. A perusal of analysis of variance indicated significant differences in aril thickness of fruit among 30 genotypes. The maximum aril thickness was found in genotype IC-0615593 (11.00 mm) followed by IC-0615604 (9.49 mm) whereas, the lowest aril thickness was recorded in genotype Coll. 39 (4.25 mm) followed by IC-0615586 (4.66 mm). Kumari (2016)also found wide variation in pulp thickness ranging from 4.1 mm in H-588 to 9.1 mm in Bedana. The genotype IC-0615593 had highest pulp thickness because of larger fruit and small seed size while low pulp thickness is associated with comparatively small size of fruit and larger size of seed. Kumari (2016) recorded highest aril thickness in Bedana (0.91 cm) which was followed by H-141, Purbi and H-73 while minimum aril thickness was recorded in H-588.

5.4.2.8 Yield (kg/plant)

In the present study it was observed that yield per plant differed significantly among 30 genotypes under study. The maximum fruit yield was found in genotype IC-0615611(25.64 kg/plant) whereas, minimum yield was recorded in IC-0615595 (8.70 kg/plant). The wide variation in fruit yield was also reported by Rani (2006) who observed that the fruit yield per tree was highest in Rose Scented (40.00 kg/ tree) followed by Shahi (39.16 kg/ tree) and minimum yield per tree was observed in Longia (29.00 kg/ tree). Fruit yield per tree was highest in Rose Scented followed by Dehradun and Calcuttia while minimum yield was recorded with Longia followed by Kasba

(Dabral and Misra 2007). Singh *et al.* (2010) also reported that the differences in yield due to cultivars were highly significant and highest yield was recorded in cultivar Shahi (100.30 kg/ tree) followed by China (95.33 kg/tree) while lowest yield was recorded by the cultivar Bedana (32.75 kg/ tree). The differences in different physical characters between genotypes are due to their varietal characteristics. Mishra *et al.* (2014) reported that the yield of cultivars varies from 60-120 kg tree^{-1} with highest yield reported in PLS-1 (120 kg tree^{-1}) followed by PLS-2 (110 kg tree^{-1}). Fruit yield per tree was found highest in Rose Scented followed by Calcuttia and Dehradun while minimum yield was noted in Kasba followed by Longia (Chandola and Mishra, 2015).

Similar studies on variation in yield potential of different cultivars of litchi were carried out in different countries by various researchers (Popenoe 1920; Groff 1921a; Vyas 1938; Marloth 1947; Stephens 1955; Nijjar 1972; Jawanda and Singh 1977; Paxton and Chapman 1980; Roy *et al.,* 1984; Ray *et al.*, 1985; Menzel *et al.,* 1986; Sharma and Ray 1987b; Menzel and Simpson 1992a; Jawanda and Singh 1977; Menzel and Simpson1990; Senthilkumar *et al.,* 2015 and Chavaradar 2016). Fruit yield of tree depends on many factors that include nutritional factors (Singh *et al.,* 2012), management practices, climate and locality of tree (Roy and Mishra 1982; Syamala *et al.,* 1983 and Lal and Kumar 1997). These discrepancies are also due to differences in varieties, environment, agricultural practices and inadequate pollination.

5.4.2.9 Total Soluble Solid (°Brix)

Perusal of data revealed that the total soluble solids were significantly varied among the germplasm. The maximum total soluble solids were observed in genotypeIC-0615610 (19.98 °Brix) and lowest TSS was recorded in genotype IC-0615589 (17.04 °Brix). Rani (2006) also reported that total soluble solids differed significantly among various litchi cultivars. Maximum TSS was observed in cv. Rose Scented (19.66 °Brix) followed by cv. Late Seedless (19.33°Brix) and minimum TSS was observed Longia (16.13°Brix) followed by McLean

(16.23°Brix). Singh *et al.* (2010) reported highest TSS (°Brix) in cultivar Deshi (22.82) followed by Trikolia (22.43°Brix) while the lowest noted in Late Bedana (18.17 °Brix). The TSS of cultivar Gola (22.13 °Brix) was higher than Bedana, Surahi and China (Haq and Rab 2012). Increase in total soluble solids during the growth period may be possibly be accounted to breakdown of starch and polysaccharides into simple sugars and organic acids (Marboh *et al.,* 2012). The regular increase in sugars in the pulp of fruit may be associated with increased translocation of photosynthates from leaves to the fruits as mentioned by Leopold and Kriedman (1975) and the increase in total soluble solids during fruit development could possibly be attributed to the difference in *in vivo* activities of invertase (Chan *et al*., 1975). The variations in TSS was also reported by Gaur and Bajpai (1978); Huang and Xu (1983); Syamal (1986); Sharma *et al*. (1987); Javier *et al*. (1999); Neog and Saikia (2001); Mahajan (2002); Pereira and Mitra (2004); Ghosh *et al.* (1988); Badiyal and Awasthi (1991); Kumar *et al.* (2015); Waseem *et al*. (2002); Islam *et al.* (2003) and Dhillon and Gill (2010).

5.4.2.10 Ascorbic acid content (mg/100 g)

The perusal of data in table 4.3.2.4 reveals that the ascorbic acid significantly varied among the genotypes. The maximum ascorbic acid was observed in IC-0615613 (47.50 mg/100 g) succeeded by IC-0615602 (43.58 mg/100 g) and minimum in IC-0615595 (14.62 mg/100 g) followed by IC-0615597 (16.78 mg/100 g). Waseem *et al.* (2002) found that the fruit of Purbi cultivar contained maximum Vitamin C content (56.19 mg/100g) followed by Bombai (54.93 mg/100 g). Minimum vitamin C content was observed in Bedana (47.87 mg/100 gm). Rani (2006) observed significantly higher ascorbic acid in Dehrarose (23.66 mg/100gm) followed by Calcuttia (23.33 mg/100 g) and minimum in cv. Longia (16.33 mg/100gm). Singh *et al.* (2010) estimated that the ascorbic acid content (mg/100g) was recorded highest in Rose Scented (41.29) and lowest in Kasba (19.94).The differences in ascorbic acid content are due to genetic effect of the variety in inhibiting the effect on ascorbic acid oxidation

by both enzymatic and non enzymatic catalyst (Marboh *et al.,* 2010). Hussain (1985) also reported vitamin C content to vary from 45-64 mg vitamin C per 100 g pulp in litchi cultivars. The ascorbic acid content increased with the advancement of maturity in all the cultivars. The increase in ascorbic acid content is also associated with rapid increase in sugars at the same time as the fruits synthesize ascorbic acid from sugar. Gaur and Bajpai (1978) also confirmed that the synthesis of organic acid depends on an adequate supply of hexose sugars. The rapid decline in vitamin C may be attributed to prevailing high temperature during fruiting period which governs the enzymatic system involving biogenesis and catabolism of ascorbic acid.

5.4.2.11 Total sugar (%)

The content of total sugar significantly varied among the litchi germplasm. The maximum total sugars were observed in Coll. 35 (13.54 %) succeeded by IC-0615610 (13.01 %) and lowest in IC-0615586 (10.05 %) followed by IC-0615587 (10.12 %). Singh *et al.* (2010) reported that the total sugar (g/100 g) content was highest in cultivar Deshi (13.48) and lowest in cv. Bedana (10.20). Differences in sugar content might be due to maximum conversion of starch into sugar which might be related to inherent varietal character. The variation in total sugar was also reported by Tripathi *et al.* (1987); Ghosh *et al.* (1988) and Jain *et al.* (1988). The total sugar contents of different varieties spreads over a wide range of 6.74-20.6% (Singh and Singh 1995) and total sugar content of litchi fruit vary between different cultivar (Wang *et al*., 2006).The data regarding the total sugars revealed the highest total sugars 21.57% in cultivar Gola, followed by 19.67 and 18.50% in cultivars China and Surahi respectively, while cultivar Bedana had the lowest total sugars of 15.43%. The total sugar contents of the fruit depends on genetic factors (Khurshid *et al*., 2004), thus, may vary among different cultivars (Singh and Singh 1995; Haq and Rab 2012). Waseem *et al.* (2002) estimated highest total sugar percentage (10.95%) in Purbi followed by the Bombai (10.68%) and least in Bedana (8.70%). Rani (2006) estimated that total sugar content differed significantly among

cultivar and higher in Late Large Green (15.39 %) followed by Late Seedless (15.04 %). Lowest total sugar content was observed in Dehrarose (11.30 %). The variations in total sugar content in fruit were reported by Wang *et al*. (2006).

5.4.2.12 Titratable acidity (%)

A glance of the data indicated that titratable acidity was maximum in both IC-0615585 and IC- 0615599 (0.55 %) and lowest in IC-0615601 (0.23 %). Singh and Singh (1954) reported a range of 0.20 to 0.64 per cent acid for 12 Indian varieties. The variation in acidity was also reported by Ghosh *et al.* (1988) and Badiyal and Awasthi (1991). Rani (2006) also reported high acidity ranging from 0.61-0.66% in Longia, McLean, Calcuttia, Shahi and Late Large Green while Rose Scented had the lowest (0.30%) acidity of pulp. These differences are due to their inherent characters in different genotypes. The role of pyruvic acid in the process of respiration might be manifested and expressed in the form of titratable acidity. Singh *et al.* (2010) opined the possible role of pyruvic acid in the process of respiration which was expressed in the form of titratable acidity.

5.4.2.13 Reducing sugar (%)

The perusal of data in table 4.3.2.5 reveals that the reducing sugars (per cent) was significantly varied among the evaluated genotypes. The highest reducing sugars was observed in genotype IC-0615601 (10.78 %) succeeded by IC-0615594 (10.58 %) and lowest in IC-0615589 (7.69 %) followed by IC-0615592 (8.04 %). Waseem *et al.* (2002) showed that Purbi was at the top position with maximum percentage (6.58) of reducing sugars, followed by Bombai with reducing sugars of 6.13%. The least percent reducing sugars (4.85%) was recorded in Bedana. Singh *et al.* (2010) estimated that reducing sugar (g/100g) was recorded highest in cultivar Rose Scented (10.82) and the lowest for cultivar Bedana (8.67). Differences in sugar content might be due to maximum conversation of starch into sugar which might be related to inherent varietal character. The variation in reducing sugar content in fruit of litchi was also reported

by Haq and Rab (2012).Variations in sugar content is be due to maximum conversion of starch into sugar which might be related to inherent varietal character as also reported by (Singh *et al*., 2010).The total sugar contents of fruit depends on genetic factors (Khurshid *et al*., 2004) thus may vary among different cultivars (Singh and Singh1995).

5.4.2.14 TSS/acidity ratio

The TSS/acidity ratio of the fruit significantly varied among the genotypes under study. The highest TSS/acidity ratio of the fruit was observed in IC-0615602 (84.42) followed by IC-0615601 (80.65) and lowest TSS/acid ratio was found in genotype Coll. 39 (32.69). The TSS/acid ratio is the best maturity standard for litchi as it gives good correlation with eating quality. Rani (2006) observed maximum TSS: acid ratio in Late Seedless and Dehrarose and minimum in Longia. Highest TSS/acid ratio (67.64) was also reported by Kumari *et al.* (2017) in Bedana. Singh *et al.* (2010) reported that cultivar China recorded highest TSS and Acid ratio (71.18) followed by Purbi (70.57) while the lowest was recorded for cultivar Kasba (50.76). These differences in TSS and Acid ratio in different cultivars were accounted to different levels of TSS and acid in different cultivars. The increase in total soluble solids/acidity ratio was due to soluble solids accumulation and decrease in organic acid amount (Batten 1989; Singh *et al.,* 2013).TSS/acid ratio is highly correlated with the litchi taste than TSS and it is the best indices for litchi harvesting. The variation in TSS/acid ratio was also reported by many researchers (Paull *et al*., 1984; Ghosh *et al*., 1989; Chandola and Mishra 2015; Batten 1989; Underhill and Wong 1990; Finger *et al.,* 1997; Revathy and Narasimham 1997 and Pesis *et al.,* 2002).

5.5 Seed characters

5.5.1 Qualitative characters

Seed shape is an important genetic character in litchi. Two forms of seed shapes *viz.,* oblong (46.66%) and oval (30%) seed shape were observed in the studied genotypes. Generally early

ripening genotypes possessed oval, and mid and late ripening genotypes showed oblong seed shape. In 73.33% of the genotypes brown seed coat colour was noted while 20% genotypes showed light brown colour.The variation in seed characters of litchi ranging from oblong, oval and round and seed colour from brown to dark brown was also observed by Kumari (2016) which might be due to highly heterozygous nature of litchi. Singh (1992) also reported variation in seed size. Similarly, variation was reported in seed size and seed shape index of different litchi varieties by Rai *et al*. (2002). Similar variations in seed weight was reported by Kumar *et al*. (1981) and Sharma and Roy (1987).

5.5.2 Quantitative seed characters:

The data pertaining to seed length, seed width and seed weight has been depicted in table-4.5.2, 4.5.3 and 4.5.4. A critical examination of the data clearly showed a significant variation for seed length, seed width and seed weight among different genotypes.

5.5.2.1 Seed length (mm) and breadth (mm)

The maximum seed length of the fruit was observed in genotype IC-0615585 (23.82 mm) followed by IC-0615600 (23.34 mm) and minimum seed length was found in genotype IC-0615613 (16.63 mm). IC-0615585 possessed maximum length of seed because of maximum length of fruit and fruit weight. The seed reached its maximum size when fruit have normal growth along with normal seed. Similarly, the maximum seed breadth was observed in genotype IC-0615600 (13.84 mm) followed by IC-0615610 (13.59 mm) while, the minimum seed breadth was found in genotype IC-0615595 (8.18 mm) followed by IC-0615613 (8.30 mm) and IC-0615587 (8.92 mm). Abortion of seed at early phases of growth also accounted for the variation in seed size among genotypes. Paull *et al*. (1984) observed that in the fruits with normal seed, the seed reached maximum size at the same time as the whole fruit whereas in fruits with aborted seed growth rate ceased early in the logarithmic growth phase. The variation in seed size among the litchi cultivars was also

reported by Dabral and Misra (2007) and Saxena (2016) which might be due to the difference in genetic makeup. Similar results were obtained by Ghosh *et al.* (1988); Kumari (2016) and Badiyal and Awasthi (1991).

5.5.2.2 Seed weight (g)

The highest seed weight was found in genotype IC-0615585 and Coll. 38 whereas, lowest seed weight was recorded in IC-0615613 and IC-0615587. Dabral and Misra (2007) reported that weight of seed was maximum in Calcuttia (3.83 g) and Kasba (3.83 g), however, minimum weight of seed was found in Early Seedless (0.88 g) followed by Late Seedless (1.11 g). Rani (2006) also observed minimum seed content was in Late Seedless followed by Shahi and maximum seed content in Calcuttia. Pereira and Mitra (2004) revealed that seed weight increased during early growth period but became static or even declined as the fruits approached harvest maturity. The seed weight increase rapidly during first phase and gradual increase was noticed thereafter (Dhillon and Gill 2010).The reduction in seed weight at later stage is due to movement of water from seed to aril and skin. The differences in seed weight between varieties might be due to their varietal differences (Ghosh *et al.,* 1988; Badiyal and Awasthi, 1991; Chandola and Mishra 2015).

5.6 Physiological and Biochemical character

5.6.1 Chlorophyll content (mg/100 g)

The analysis of pooled data indicated that Coll. 36 registered the maximum chlorophyll A (11.69 mg/100 g) and IC-0615595 recorded the lowest chlorophyll A (1.94 mg/100 g) while maximum chlorophyll B was found in genotype IC-0615611 (3.95 mg/100 g) followed by IC-0615596 (3.47 mg/100 g) whereas, minimum was recorded in genotype IC-0615595 (0.35 mg/100 g) followed by IC-0615589(0.55 mg/100 g). The total Chlorophyll content was found maximum in genotype IC-0615596 (15.19 mg/100 g) followed by Coll. 36 (14.82 mg/100 g) whereas, lowest was observed in genotype IC-0615595 (2.30 mg/100 g) followed by IC-0615589 (3.49 mg/100

g).The chlorophyll concentration of the leaf determines the photosynthetic activity of the plant. In the present study, the chlorophyll content of mature leaves varied from 1.07 to 1.87 mg/g and displayed a CV of 13.88 per cent. Sukhvibul *et al.* (2014) reported that chlorophyll content varied from 2.0-2.8 mg/g in leaves and slight variation in chlorophyll content of leaves during annual growth and pre-flowering period does not affect the floral differentiation.

5.6.2 Total phenol (mg GAE/ g)

The total phenol content varies significantly among genotypes as well as in pericarp, aril and seed. Perusal of pooled data indicated that phenol content in pulp was maximum in genotype IC-0615593 (8.41 mg GAE/g) followed by IC-0615604 (7.90 mg GAE/g) and IC-0615596 (7.80 mg GAE/g) whereas, the lowest phenol was recorded in genotype IC-06155600 (0.20 mg GAE/g). However, the maximum pericarp phenol content was recorded in genotype IC-0615613 (61.24 mg/g) followed by IC-0615586 (56.44 mg/g) whereas, lowest pericarp phenol was found in IC-0615606 (8.57 mg/g) followed by Coll. 35 (9.30 mg/g).

Similarly, maximum seed phenol was found in genotype IC-0615597 (86.56 mg GAE/g) followed by IC-0615603 (74.41 mg GAE/g) whereas, the minimum seed phenol content was recorded in Coll. 35 (23.68 mg GAE/g) followed by IC-0615608 (24.12 mg GAE/g). Results showed that genotypes contain low phenol in pulp having high phenol content in pericarp and seed. The genotype IC-0615587 showed low phenol content in pulp (0.71 mg/g) but high phenol content in pericarp (54.90 mg/g) and seed (43.44 mg/g) while genotype IC-0615586 contains high phenol in pulp (6.68 mg/g) and comparatively low phenol in pericarp (41.82 mg/g) and seed (37.73 mg/g). The genotype which contains low phenol has diverted secondary metabolites like phenol to pericarp and seed. The partitioning of secondary metabolites during growth and development of fruits decides the phenol content in different parts of fruit and in general, genotypes in which panicle emerged early showed considerably low phenol content in pulp. There is scanty information

on total phenol content in Indian litchi cultivars. Previous studies showed a difference in phenolic content in LFP, as reported by Prasad *et al.* (2009) with 16 mg/g dry weight in Baila variety and by Ruenroengklin *et al.* (2008) with 100 mg/g dry weigh in Feizixiao variety. The total phenolic contents of tested litchi genotypes were comparable to that of the grape seed with 1.4–22.3 mg GAE/g (Guendez *et al.,* 2005) and skin with 4.9–13.8 mg GAE/g (Poudel *et al*., 2008). Therefore, litchi fruit pericarp is a good source for phenolic compounds. Reyes *et al.* (2016) found total phenol content of 16.5±0.91 and 121.3±3.2 mg GAE/L in fresh and dry pericarp respectively.

It has been reported that phenolic compounds exist in significant quantities in cell walls of plants. These compounds, called bound phenolics, are covalently conjugated to cell wall components such as cellulose, pectin and polysaccharides through ester bonds (Naczk and Shahidi 1989). Because of the conjugation with cell wall components, bound phenolics cannot be extracted through commonly used solvent extraction method, which results in under-estimation and to some extent, of total phenolic content. The variation in total phenol content in litchi was also observed by Feng *et al.* (2017), Wang *et al.* (2011) and Zhang *et al.* (2013).These varietal differences may be partly attributed to the different genotypes of these litchi cultivars and to different growing conditions. Phenolic content in plant depends on genetic, agronomic and environmental factors. These results indicated that the genotypes vary greatly in their capacity to synthesize phenolics. Furthermore, it was hypothesized that bound phenolics were able to provide a slow and continuous release of phenolics in the lower gastrointestinal tract *via* the simultaneous action of b-glucosidases and esterases of gut microflora (Vitaglione *et al.,* 2008).

It showed that phenolics mainly exist in free forms in litchi pulp. Luximon-Ramma *et al.* (2003) and Wang et al. (2011) also reported the variation in total phenol content in litchi. These varietal discrepancies may be partly attributed to the different genotypes of

these litchi cultivars and to different growing conditions. Phenolic content in plant depends on genetic, agronomic and environmental factors. These results indicated that the genotypes vary greatly in their capacity to synthesize phenolics.

5.6.3 Total flavonoids (mg CE/ g)

The maximum pulp flavonoid was noted in genotype IC-0615613 (23.88 mg CE g^{-1}) followed by IC-0615586 (21.02 mg CE g^{-1}) and minimum pulp flavonoid was found in genotype Coll. 36 (0.50 mg CE g^{-1}) followed by IC-0615602 (0.69 mg CE g^{-1}). Likewise, flavonoid content in pericarp differ significantly which was maximum in genotype Coll. 37 (96.49 mg CE g^{-1}) and minimum in IC-0615610 (0.75 mg CE g^{-1}). The flavonoid content in seed was observed maximum in IC-0615586 (27.50 mg CE g $^{-1}$) followed by IC-0615602 (20.79 mg CE g $^{-1}$) and minimum inIC-0615587 (2.41 mg CE g $^{-1}$) followed by IC-0615591 (2.92 mg CE g $^{-1}$). From the above, it is clear that flavonoids content in litchi varies greatly in fruits. Results showed that genotypes with late panicle emergence had minimum level of flavonoids in pulp except genotype IC-0615602 which showed earliest panicle emergence and contains low flavonoids in pulp. All genotypes in which panicle emergence was earlier showed high flavonoids content in pulp. Similar results have also been found in respect of flavonoid content in seed with some exception in IC-0615586, which contained high flavonoids both in pulp and seed even after late emergence of panicle, because these genotypes had completed the fruiting period from fruit set to maturity in a short period of time. However, flavonoids in pericarp did not show any definite relation between emergence of panicle and flavonoids content. The genotypes which contain low flavonoids have diverted to pericarp and seed. The partitioning of secondary metabolites during growth and development of fruits decides the phenol content in different parts of fruit and in general, genotypes in which panicle emerged early showed considerably low phenol content in pulp. Li *et al.* (2012) found that total flavonoids contents of nine varieties ranged from 7.12 to 23.46 mg CAE/g FW. Prasad *et al.* (2009) reported that the major

flavonoid compounds extracted from LFP were epicatechin and epicatechin gallate. Zhao *et al.* (2006) identified the major flavonoid chemicals extracted from LFP as procyanidin B2, procyanidin B4 and epicatechin.

5.6.4 Total anthocyanin (mg/100g)

In most fruits, red colour development is majorly attributed to presence of anthocyanin pigment, however, in litchi redness of fruit is not solely depend on anthocyanin content in pericarp. Fruit skin colour of litchi is a composite display of chlorophyll, carotenoids, flavones and anthocyanins. Chloroplasts distribute in the upper mesocarp, particularly in the inter-protuberance zones (Underhill and Chitchley 1992). The peel colour changes from green to pinkish or red about 38 to 50 days fruit set in the different cultivars studied. The degradation of chlorophyll accompanied by the synthesis of anthocyanins is considered responsible for change of peel colouration in litchi (Paull *et al.,* 1984; Jaiswal *et al.,* 1987; Underhill and Chitchley 1992; Singh and Singh 1995; Li *et al.,* 1999). It has been observed that the germplasm with scarlet red colour did not show highest content of anthocyanin because of high thickness of pericarp which contributed less area of pericarp in anthocyanin analysis whereas germplasm with thin pericarp showed high content of anthocyanin because of larger area of pericarp that carried more anthocyanin. In the present investigation, the maximum anthocyanin content in pericarp was observed in IC-0615610 (107.6 mg/100g) followed by Coll. 36 (102.4 mg/100 g) and Coll. 35 (88.8 mg/100 g) whereas, the minimum pericarp anthocyanin content was found in IC-0615613 (17.7 mg/100 g) followed by IC-0615587 (23.6 mg/100 g) and IC-0615602 (25.8 mg/100 g). Li *et al.* (2012) found that total anthocyanin contents of nine varieties ranged from 1.77 to 20.94 mg CGE/100 g FW. The anthocyanin contents of Heiye and Guiwei varieties were consistent with the level (18.6 mg/100 g FW) reported by Duan *et al.* (2007), but lower than the level (52.0 mg/100 g FW) reported by Rivera-Lopez *et al.* (1999). Clifford (2000), and Cekicand Ozgen (2010) also argued that the total anthocyanin contents of

tested litchi varieties were comparable to that of strawberry (15.0–35.0 mg/100 g) and red raspberry (6.56–29.60 mg/100 g) respectively.

The development of red pigment of litchi was found to be associated with anthocyanin pigments. The chlorophyll loss occurs with ripening along with active synthesis of flavonoids, particularly anthocyanins, and the concentration of anthocyanin increases upto fully ripe stage. Chlorophyll degradation and flavonoid production occurred simultaneously. The polyphenol oxidase activity decreased during fruit maturation with peak activity prior to anthocyanin production. Anthocyanin production is also influenced by hormone, nutrition and light. Hasan and Chattopadhyay (1997) found that Bedana and Purbi had highest anthocyanin contents. The variation in anthocyanin content in pericarp was also reported by Li *et al.* (1999) and Pereira (2002).The peel colour changes from green to pinkish or red while approaching maturity with gradual loss of chlorophyll. So, the degradation of chlorophyll accompanied by the synthesis of anthocyanins is considered responsible for change of peel colouration in litchi (Paull *et al.,* 1984; Underhill and Chitchley, 1992; Singh and Singh, 1995). Anthocyanins are red pigments and considered as a surface colour, existing in the upper mesocarp and exocarp of litchi (Underhill and Chitchley, 1994) and chlorophylls degradation marks the onset of anthocyanin development and expression of red colour in pericarp of litchi (Paull *et al.,* 1984; Thakur *et al.,* 1990).

5.7 Correlation coefficient

In selection process for crop improvement, knowledge of association of various characters is the most important tool (Desai *et al*., 1994). Correlation coefficient studies help in determining the mutual relationship between various characters. It suggests the advantage of a scheme of selection for more than one trait at a time. Thus, the degree of closeness between characters is determined by correlation coefficient between them. It also provides information on the nature and extent of association between any two traits and it will be possible to bring genetic upgradation in one trait by selection of

the other of a pair. Correlation coefficients pooled over two years were worked out among different traits in all possible combinations.

The plant height had highly significant positive correlation with trunk girth (0.70), crown diameter (0.62), tree volume (0.93), leaflet number (0.48) and significant positive correlation with length of leaflet (0.39), panicle length (0.41), width of panicle (0.39), number of fruits per cluster (0.37), yield per plant (0.38), length of seed (0.39) and seed breadth (0.41). Assefa *et al.* (2016) also found that plant height in papaya had significant and positive correlation with canopy diameter (0.82, 0.65), leaf number (0.65, 0.59), girth diameter (0.88, 0.83), while negative and significant correlation was observed with fruit length (0.56, 0.47) at both genotypic and phenotypic levels and similarly plant height showed significant positive genotypic correlation with leaf number and girth of plant (Karunakaran *et al*., 2010). Majumder *et al.* (2012) revealed that plant height had significant and positive correlation with percent flowering shoot, number of fruits per plant, length of fruit and yield in mango. However, Saha (2004) and Jahan (2004) found insignificant positive correlation of plant height and diameter of fruit.

Trunk girth had highly significant positive correlation with crown diameter (0.62), tree volume (0.64) and significant positive correlation with panicle length (0.44), panicle width (0.43), number of fruits per cluster (0.37), fruit weight (0.37), yield per plant (0.43) and seed breadth (0.37).The crown diameter had highly significant correlation with tree volume (0.70) and significant positive correlation with yield per plant (0.45) and TSS (0.39) and tree volume had highly significant positive correlation with number of leaflet (0.47) and significant positive correlation with panicle length (0.37), panicle width (0.36), yield per plant (0.37) and seed breadth (0.38) in our study. The similar reports with respect to positive correlation of trunk girth with yield were also found by many researchers (Shikhamany *et al.,* 1978; Thimmappaiah *et al.,* 1985; Marak and Mukunda 2007).

Similarly, Prasad (1987) also reported that the stock diameter was significantly correlated with plant spread and fruit yield in mango.

Canopy spread had significant positive correlation with shoot length, days to flowering, flowering duration, number of petals per flower, petal width, stamen length, number of stamens per flower, pistil length and fruit yield both at genotypic and phenotypic level and days to fruit maturity at genotypic level only. Mir *et al.* (2006) revealed positive and significant correlation between plant height, plant spread and rind thickness but a negative association with days to first flower opening in pomegranate. Plant spread exhibited positive and significant association with fruit weight, fruit diameter, fruit number of fruits/ plant and gross fruit yield only at the genotypic level. Positive association of plant height with spread was also noticed in earlier studies conducted by Ram Asrey and Shukhla (2003). Plant spread showed non-significant and negative association with T.S.S. and leaf width (Nagar *et al.,* 2015).

Number of leaflet had highly significant positive correlation with rachis length (0.67), petiole length (0.58), leaflet length (0.65), panicle length (0.51), number of fruits per cluster (0.59), yield per plant (0.54), seed length (0.56), seed breadth (0.63), seed weight (0.49) and significant positive correlation with duration of flowering (0.39). Assefa *et al.* (2016) found that leaf number per plant in papaya at first flowering had a significant positive association with plant height (0.65, 0.59), stem girth diameter (0.90, 0.81) and canopy width (0.94, 0.77) whereas a high significantly negative association was noted with fruit length (-0.91,-0.77) at both genetic and phenotypic levels. Roocha *et al.* (1994) also observed a positive correlation between the number of leaves, number of flowers and fruits, indicating a relationship between the number of leaves and fruit set in orange.

Rachis length had highly significant positive correlation with petiole length (0.76), leaflet length (0.66), panicle length (0.63), panicle width (0.53), number of fruits per cluster (0.59), seed length (0.72), seed breadth (0.74), seed weight (0.65) and significant positive correlation with yield (0.42), reducing sugar (0.39), TSS/acidity ratio (0.42) and significant negative correlation with phenol content in pericarp (-0.64) and days from fruit set to maturity (-

0.44). Petiole length had highly significant positive correlation with leaflet length (0.61), panicle length (0.67), panicle width (0.61), number of fruits per cluster (0.62), seed length (0.77), seed breadth (0.77), seed weight (0.76) and significant positive correlation with total sugar (0.37), reducing sugar (0.39), TSS/acidity ratio (0.38) and significant negative correlation with phenol in pericarp (-0.49). Leaflet length had highly significant positive correlation with panicle length (0.60), panicle width (0.49), number of fruits per cluster (0.66), seed length (0.60), seed breadth (0.65), seed weight (0.54) and significant positive correlation with panicle width (0.43), days from fruit set to maturity (0.37), yield per plant (0.45), reducing sugar (0.44) and significant negative correlation with phenol in pericarp (-0.49) and flavonoids in pericarp (-0.40). The duration of flowering had highly significant positive correlation with panicle length (0.49), number of fruits per cluster (0.48), seed breadth (0.48) and significant positive correlation with panicle width (0.38), yield per plant (0.43), total sugar (0.38), seed length (0.41) and anthocyanin (0.37).

Length of panicle had highly significant positive correlation with panicle width (0.87), number of fruits per cluster (0.75), yield per plant (0.63), total sugar (0.49), reducing sugar (0.55), seed length (0.72), seed breadth (0.81), seed weight (0.63) and significant positive correlation with TSS/ acidity ratio (0.42) and significant negative correlation with phenol in pericarp (-0.68). Width of panicle had highly significant positive correlation with number of fruits per cluster (0.58), yield per plant (0.47), total sugar (0.57), reducing sugar (0.52), TSS/acidity ratio (0.56), seed length (0.71), seed breadth (0.76), seed weight (0.58) and significant negative correlation with total phenol in pericarp (-0.68) and titratable acidity (-0.46). Mayavel *et al.* (2018) and Challapillai *et al.* (1995) evinced significant and positive association with length of inflorescence and number of flowers/inflorescence for number of fruits/inflorescence.

Per cent of female flower had highly significant positive correlation with number of fruits per cluster (0.50), yield per plant (0.50) and significant positive correlation with anthocyanin content in

pericarp (0.46). Majumder *et al.* (2012) also revealed that per cent perfect flower had highly positive significant correlation with number of fruits per plant. Correlation between per cent perfect flower and number of fruits per plant was highly positive and significant. Thus, an increase of per cent perfect flower and number of fruits accompanies increase in yield per plant. The similar finding was also reported by Chakrawar and Jathure (1980).

Number of fruits per cluster have very significant positive correlation with fruit length (0.52), yield per plant (0.79), total sugar (0.48), reducing sugar (0.47), seed length (0.67), seed breadth (0.72), seed weight (0.62) and anthocyanin in pericarp (0.48) and significant negative correlation with ascorbic acid (-0.43) and phenol in pericarp (-0.44). On the contrary, Majumder *et al.* (2012) found negative and insignificant correlation of number of fruits per plant with fruit weight and fruit length. Assefa *et al.* (2016) found that mean total number of fruits of papaya had positive and significant genotypic correlations with marketable fruit yield (0.81), canopy diameter (0.42), inter-node length (0.31) and total fruit yield (0.98). The similar findings were also reported earlier by Divakara (2008).

Fruit length had highly significant positive correlation with fruit weight (0.76), yield per plant (0.64), TSS (0.54), seed length (0.50), seed weight (0.59), chlorophyll A (0.48), chlorophyll B (0.50), total chlorophyll (0.50), anthocyanin (0.50) and significant positive correlation with fruit diameter (0.43), aril weight (0.42), total sugar (0.44), reducing sugar (0.43) and seed breadth (0.44). Mayavel *et al.* (2018) exhibited significant and positive correlation of fruit length with length of inflorescence, number of flowers/inflorescence and number of fruits/inflorescence. Shivanandam and Raju (1988), Divakara (2008) and Singh and Nandhini (2014) also observed similar associations with one or more characters for the trait fruit length. Fruit diameter had highly significant positive correlation with fruit weight (0.53), aril weight (0.74), TSS (0.56), chlorophyll B (0.48), total chlorophyll (0.47) and significant positive correlation with ascorbic acid (0.45), chlorophyll A (0.44) and phenol in pericarp (0.44). Ahmed

(2005) observed significant positive correlation of fruit length with average fruit weight in lime. Fruit breadth possessed significant and positive association with length of inflorescence, number of flowers/inflorescence, number of fruits/inflorescence and fruit length (Mayavel *et al.,* 2018). The similar results were reported by Shivanandam and Raju (1988) and Singh and Nandhini (2014). Torres *et al.* (1986) reported negative association of fruit diameter and yield in case of Valencia orange. However, Ahmed (2005) reported significant and positive association of fruit circumference and yield per plant in lime. Sinha *et al.* (2018) found that fruit diameter had positive and highly significant correlation with fruit weight in pomegranate at phenotypic and genotypic levels

Fruit weight had highly significant positive correlation with aril weight (0.75), TSS (0.47) and significant positive correlation with yield per plant (0.44), total sugar (0.45), reducing sugar (0.43), seed length (0.41), seed breadth (0.41) and seed weight (0.39). But Agrawal (2010) found significant negative correlations between weight of fruit and TSS. Assefa *et al.* (2016) found that average fruit weight in papaya also showed significant positive association with fruit diameter (0.83, 0.81), length (0.28, 0.37) and number of marketable fruit yield (0.62, 0.33) per plant at both genotypic and phenotypic levels, respectively. Similarly, da Silva *et al.* (2007) and Jambhale *et al.* (2014) reported that average fruit weight showed significant positive correlation with fruit diameter, length, and number of marketable fruit yield per plant at both levels. Mir *et al.* (2006) observed highly significant correlation between fruit weight, fruit diameter, fruit volume, rind weight, juice content, fruit set, number of fruits/plant and gross fruit yield and between fruit diameter with the same characters of fruit weight in pomegranate. Positive association of fruit weight with fruit diameter was also reported by Pandey and Bist (1998) and fruit weight with yield by Bisla and Daulta (1987). Correlation studies in strawberry by Verma *et al.* (2002) showed positive association of fruit weight with fruit diameter and fruit volume.

From these associations it is indicated that higher fruit weight can be obtained by increasing the seed size for improvement of this crop. Positive association between fruit weight and seed size has been required. More or less similar results were also reported by Prajapati *et al.* (1996), Gupta and Mehta (2000). The fruit weight exhibited significant and positive association with length of inflorescence, number of flowers/inflorescence, number of fruits/inflorescence, fruit length and fruit breadth (Mayavel *et al.,* 2018). Challapilli *et al.* (1995) and Divakara (2008) reported that the fruit weight is positively and significantly associated with pulp, fibre, seed weight, fruit length and breadth.

Yield per plant had highly significant positive correlation with seed length (0.53), seed breadth (0.60), seed weight (0.47), chlorophyll A (0.58), chlorophyll B (0.49), total chlorophyll (0.57), anthocyanin in pericarp (0.65) and significant positive correlation with TSS (0.38), total sugar (0.43), reducing sugar (0.46) and significant negative correlation with phenol in pericarp (-0.41) and flavonoids in seed (-0.43). Assefa *et al.* (2016) found that fruit yield per plant had significant and positively correlated with total number of fruit (0.85) and marketable fruit yield (0.98). The significant positive correlation was reported between fruit yield per plant and number of fruit per plant (da Silva *et al*., 2007; Kumar *et al*., 2015). Majumder *et al.* (2012) showed that yield was positively and significantly correlated with plant height, percent flowering shoot but it was positive and not significantly correlated in case of leaf area, initial fruit set per inflorescence, fruit weight and fruit length**.**

TSS had highly significant positive correlation with total chlorophyll (0.46) and significant positive correlation with reducing sugar (0.38), chlorophyll A (0.45) and chlorophyll B (0.45). Ascorbic acid had highly significant positive correlation with flavonoids in pulp (0.48) and significant positive correlation with flavonoids in pulp (0.45) and very significant negative correlation with seed weight (-0.51) and significant negative correlation with seed length (-0.46) and seed breadth (-0.39). Total sugar had highly significant positive

correlation with reducing sugar (0.70), seed length (0.59), seed breadth (0.56), seed weight (0.63), anthocyanin in pericarp (0.56) and very significant negative correlation with phenol in pericarp (-0.62) and significant negative correlation with phenol in pulp (-0.45). Titratable acidity had highly significant positive correlation with phenol in pericarp (0.46) and significant correlation with phenol in pulp (0.43), and very significant negative correlation with TSS/acidity ratio (-0.95) and significant correlation with reducing sugar (-0.40) and reducing sugar had highly significant positive correlation TSS/acidity ratio (0.52), seed length (0.48), seed breadth (0.50), seed weight (0.50) and significant correlation with anthocyanin in pericarp (0.44) and very significant negative correlation with phenol in pericarp (-0.68) and significant correlation with total phenol in pulp (-0.37) and flavonoids in pericarp (-0.39). TSS/acidity ratio had highly significant negative correlation with phenol in pericarp (-0.59) and significant correlation with phenol in pulp (-0.43). Thus, it is clear from the study that there was inter-relationship between the chemical characters *viz*., T.S.S., reducing sugar, total sugar, phenol and flavonoids in increasing or decreasing the quantity of the fruits.

Agrawal (2012) found that total soluble solids showed positive correlation with reducing and total sugars. The total sugars showed a positive significant correlation with reducing. Reducing had also significant positive correlation. The more or less similar results were also reported by Tripathi and Gangwar (1971) in guava, Chakrawar and Solanki (1981) in ber, Singh *et al*. (1985) in mango, Kurmi (1992) and Pandey *et al.* (1997) in guava. Mir *et al.* (2006) observed significant negative correlation between acidity and TSS/ acid ratio. This indicated that increase in TSS/acid ratio was associated with reduction in acidity. Mayavel *et al.* (2018) recorded significant and positive correlation of ascorbic acid with total sugar (%) whereas, it expressed significant and negative association with acidity. Acidity expressed significant and negative association with total sugar. Kaiser and Hulmani (1993), Abilash *et al.* (2016) in guava, Chakrawar and Jathure (1980) in lime, Saha (2004) in lemon and Krishna *et al.*

(2017) in mango also observed similar associations with one or more characters.

Seed length had highly significant positive correlation with seed breadth (0.92), seed weight (0.86) and very significant negative correlation with total phenol in pericarp (-0.62). Seed breadth had highly significant positive correlation with seed weight (0.80) and very significant negative correlation with total phenol in pericarp (-0.66). Seed weight had highly significant negative correlation with phenol in pericarp (-0.64). Seed weight possessed significant and positive correlation with fruit length and fruit weight (Mayavel *et al.,* 2018; Samiullah *et al.,* 1993).

Chlorophyll A had highly significant positive correlation with chlorophyll B (0.84), total chlorophyll (0.99). Chlorophyll B had highly significant positive correlation with total chlorophyll (0.91). Total phenol in pulp had significant positive correlation with phenol in pericarp (0.40) and flavonoids in pulp (0.41). Total phenol in pericarp had significant positive correlation with flavonoids in pericarp (0.41). Flavonoids in pulp had significant positive correlation with flavonoids in seed (0.46). Flavonoids in pericarp had significant negative correlation with flavonoids in seed (-0.44) and flavonoids in seed had significant negative correlation with anthocyanin in pericarp (-0.45). The anthocyanin content exhibited significant and positive correlation with number of fruits/inflorescence and pulp weight in pomegranate (Mayavel *et al.,* 2018).

4.8 Path coefficient analysis for yield and yield attributing characters

The significant correlation coefficient between two characters does not always indicate presence of linkage between them (Majumder *et al.,* 2012). Two characters having a common physiological or biochemical chain may also show such genetic correlation (Hohenboken 1985). Yield being a complex trait, it is difficult to exploit various yield contributing characters through the knowledge of correlation, therefore it is important to carry out other

analysis including path coefficient that provide a clear indication for selection criterion (McGiffen *et al.,*1994). The coefficients generated by path analysis measure the direct and indirect influence of variable upon other (Dewy and Lu 1959). In breeding programmes, we are often concerned with the improvement in fruit weight as an overall product dependent on a number of morpho-physiological attributes. Such characters are often inter-related, hence their effect on fruit weight is also modified by others. Path coefficient analysis helps in separating the direct effect of a component character on fruit weight from indirect effects of other traits. In order to find out a clear picture of the relationship between fruit yield and their components, path analysis study was done. This allows the partitioning of the correlations between yield and its components into direct and indirect effects. The residual effects of path analysis were -0.02124 revealed higher genetic variability and also proved lower percent of environmental influence on the selected characters of litchi. Direct and indirect effects of different yield contributing characters toward yield of litchi have been presented in table 4.8.1. A perusal of path coefficient analysis indicated that positive direct effect on yield were exhibited by crown diameter, tree volume, petiole length, length of leaflet, duration of flowering, panicle length, days from fruit set to maturity, number of fruits per cluster, fruit diameter, aril weight, ascorbic acid, seed breadth, seed weight, chlorophyll A, B and total chlorophyll and negative direct effect on yield were exhibited by plant height, trunk girth, number of leaflet per leaf, rachis length, width of leaflet, width of panicle, per cent of female flower, fruit length, fruit weight, total sugar and seed length.

From path coefficient analysis, it was observed that plant height had highly negative direct effect (-0.949) on yield per plant and highly positive indirect effect via tree volume, length of leaflet, seed breadth and number of fruit per cluster. On the other hand, negative indirect effect on yields was observed via number of leaflet, rachis length and panicle width. Majumder *et al.* (2012) also observed that plant height had highly positive direct effect on yield per plant. But

Nagar *et al.* (2015) found that plant (*Cordia myxa*) height of (0.040) had positive direct effect but it also had indirect negative effects via fruits per cluster (-0.003), acidity (-0.112) and leaf width (-0.277). Plant spread (0.140) had positive direct effect but, it also had indirect negative effects via fruits per cluster (-0.001), acidity (-0.141) and leaf width (-0.329) and trunk girth had negative direct effect (-0.003) on yield and this trait exerted positive indirect effect via tree volume, length of leaflet, panicle length, number of fruits per cluster and seed breadth. This trait exerted negative indirect effect via plant height, rachis length, panicle width, length and weight of fruit. Crown diameter had direct low positive effect (0.044) on yield and this trait exerted positive indirect effect via tree volume and TSS/acidity ratio. Prasad (1987) observed direct positive effect of canopy spread, plant height and stock diameter on fruit yield of mango. Tree volume had highly positive direct effect (0.625) on yield and this trait exerted indirect positive effect via length of leaflet, number of fruits per cluster and seed breadth and negative indirect effect via plant height, number of leaflet, rachis length and panicle width. Rai *et al.* (2001) also reported the direct positive effect of tree volume on fruit yield of mango. Prasad (1987) observed the indirect effects for fruit yield were mostly via plant height, stem diameter and canopy spread in mango.

Length of leaflet had highly positive direct effect (0.459) on yield and this trait exerted positive indirect effect via tree volume, petiole length, panicle length, number of fruits per cluster, seed breadth, seed weight and negative indirect effect via plant height, number of leaflet, rachis length, panicle width and seed length. But, Nagar *et al.* (2015) found that leaf length in lahsua had negative direct effect and it also had negative indirect effect via fruit size, TSS and also had negative correlation coefficient with fruit weight. Leaf width had positive direct effect and it also had positive indirect effect via fruits per cluster, TSS and acidity. Width of leaflet had low negative direct effect (-0.041) on yield and this trait exerted positive indirect effect via tree volume, petiole length, length of leaflet, duration of flowering, number of fruits per cluster, seed breadth and negative

indirect effect via plant height, rachis length, panicle width and fruit length but Raghava and Tiwari (2008) recorded that leaf length and maximum leaf breadth showed positive high direct effect on fruit yield of guava.

Duration of flowering had highly positive direct effect (0.316) on yield and this trait exerted positive indirect effect via tree volume, panicle length, number of fruits per cluster, seed breadth, seed weight and negative indirect effect via plant height and panicle width. Panicle length had high positive direct effect (0.199) on yield and this trait exerted positive indirect effect via tree volume, petiole length, length of leaflet, duration of flowering, number of fruits per cluster, TSS/acidity ratio, seed breadth seed weight. Width of panicle had highly negative direct effect (-0.299) on yield per plant and this trait exerted positive indirect effect via tree volume, petiole length, length of leaflet, duration of flowering, number of fruits per cluster, seed breadth, seed weight. Mayavel *et al.* (2018) revealed that the length of inflorescence (2.18) in red tamarind is the most pronounced character contributing directly to the yield followed by fruit length (1.35), anthocyanin content (0.61) and total sugar (0.20).

Per cent of female flower had highly negative direct effect (-0.206) on yield and this trait exerted positive indirect effect via length of leaflet, number of fruits per cluster, seed breadth, seed weight and low negative indirect effect via rachis length. Mayavel *et al.* (2018) also reported that the number of flowers/inflorescence recorded negative direct effects (-1.91). Number of fruits per cluster had highly positive direct effect (0.595) on yield and this trait exerted positive indirect effect via tree volume, petiole length, length of leaflet, duration of flowering, panicle length, seed breadth, seed weight and negative indirect effect via plant height, number of leaflet, rachis length, panicle width, fruit length and seed length. Hence, the direct selection of number of fruits per cluster were found important for fruit yield improvement due to its direct high positive effect on fruit yield and positive indirect effect on other traits. Nagar *et al.* (2015) also found that number of fruits per cluster (-0.125) had negative direct

effect in lahsua. But, Assefa *et al.* (2016) found that total number of fruit per plant had positive indirect effect on leaf number, and stem girth and fruit diameter. Mir *et al*. (2006) reported that maximum positive direct effect on gross fruit yield was through number of fruits/plant (0.587) followed by fruit weight (0.552), fruit volume increase (0.202), fruit set (0.131) and days to first flower opening (0.104). Baiyeri and Ortiz (1995) also reported that yield was more closely related to number of fruits/plant in banana.

Fruit length had highly negative direct effect (-0.326) on yield and this trait exerted positive indirect effect via tree volume, petiole length, length of leaflet, number of fruits per cluster, fruit diameter, seed breadth, seed weight, chlorophyll B and negative indirect effect via plant height, rachis length, fruit weight and seed length. Similar results was also reported by Assefa *et al.* (2016) where fruit length in papaya had direct negative effect on fruit yield (-1.24), but it showed indirect high positive effect on average fruit and canopy width, and moderate on fruit diameter and leaf number. Fruit diameter had highly positive direct effect (0.332) on yield and this trait exerted positive indirect effect via rachis length, chlorophyll B and negative indirect effect via length of leaflet, fruit length, fruit weight and seed weight. But Assefa *et al.* (2016) found fruit diameter in papaya had the negative direct effect on fruit yield (-1.34). Mir *et al.* (2006) also found fruit diameter had the highest positive direct effects on yield.

Fruit weight had highly negative direct effect (-0.279) on yield per plant and this trait exerted positive indirect effect via tree volume, length of leaflet, number of fruits per cluster, fruit diameter, seed breadth, seed weight and negative indirect effect via plant height, rachis length and fruit length. But Jambhale *et al.* (2014) and Jana *et al.* (2006) found positive direct effect of average fruit weight on fruit yield per plant. Direct positive effect of fruit weight on yield in ber has been reported by Bisla and Daulta (1987). Assefa *et al.* (2016) found positive direct effect of average fruit weight (2.91), total number of fruit per plant (2.75) and plant height at flowering (1.20) on fruit yield per plant and had also indirect positive effects on girth diameter, leaf

number and inter-node length. Most other characters associated to fruit yield are contributing indirectly through above characters. Similar findings were reported by Kulkarni *et al.* (1995); Divakara (2008) and Singh and Nandhini (2014).

Ascorbic acid had high positive direct effect (0.258) and total sugar had high negative direct effect (-0.221) on yield. Aril weight had low positive direct effect (0.061) on yield and this trait exerted positive indirect effect via fruit diameter and negative indirect effect via fruit length and fruit weight. Seed length had high negative direct effect (-0.238) on yield and this trait exerted positive indirect effect via tree volume, petiole length, leaflet length, duration of flowering, panicle length, number of fruits per cluster, seed breadth, seed weight. Seed breadth had high positive direct effect (0.371) and indirect positive effect via tree volume, petiole length, leaflet length, duration of flowering panicle length, number of fruits per cluster and seed weight. Seed weight had high positive direct effect (0.393) and positive indirect effect via petiole length, leaflet length, duration of flowering, panicle length, number of fruits per cluster, seed breadth Chlorophyll A, B and total had positive effect (0.055, 0.210 and 0.178, respectively) on yield per plant.

4.9 Genetic diversity in litchi:

However, Pathak *et al.* (2014) and Bajpai *et al.* (2016) tried to grouping Indian litchi cultivars by using markers AFLP, ISSR, SSR, RAPD and combined micro-satellite but no attempt has been made on grouping with morphological traits. Knowledge about genetic variability of a crop allows more efficient and effective use of genetic resources in crop improvement programmes. Cluster analysis of both qualitative and quantitative data performed in this study. Hierarchical clustering method is relevant for analysing the phenotypic and genetic diversity of germplasm. Clustering method grouped genotypes of litchi based on the characters they possessed. The groupings of genotypes were done as observed in cluster analysis. The results of cluster analysis on 30 litchi genotypes suggested that there is enough variation among the genotypes for different morphological traits.

Accessions with greater similarity for morphological traits were placed in the same cluster. Cluster analysis is of great practical significance for plant breeders as it distributes the genotypes into different clusters. Representative genotypes from each cluster can be selected for use in crop improvement programmes. Maximum variation in the populations can be achieved by selecting and using genotypes from diverse clusters. The information of relationships achieved from these studies may be useful in exploitation of the available germplasm resources.

Based on clustering pattern of genotypes in the dendrogram, three genotypes *viz.,* IC-0615593, IC-0615596 and IC-0615604 were in one group and four genotypes *viz.,* IC-0615586, IC-0615589, IC-0615605 and Coll. 39 were in the other group, and other four genotypes *viz.,* IC-0615595, IC-0615599, IC-0615613, IC-0615588 were in another group, and genotypes IC-0615590, IC-0615591, IC-0615592, IC-0615603, IC-0615611, Coll. 36, Coll. 37 and Coll. 38 showed maximum similarity. Similarity among genotypes was detected mainly on basis trunk surface, tree growth habit, young leaf colour, young shoot pubescence, leaflet shape, leaflet apex shape, leaflet midrib appearance, leaflet curvature, position of inflorescence, fruit maturity group, fruit ripening, fruit bearing habit, fruit bearing intensity, fruit clustering habit, fruit segmentation and aril quality.

The genotypes *viz*., IC-0615594, IC-0615597, IC-0615600, IC-0615602, IC-0615610, IC-0615606, IC-0615610 and Coll. 35 also showed maximum similarity. Similarity among genotypes was detected mainly on basis branching density, young shoot pubescence, leaflet shape, leaflet apex shape, leaflet midrib appearance, position of inflorescence, fruit maturity group, fruit shoulder, fruit segmentation, fruit cracking, distribution of colour on skin, aril quality and seed shape. Paudyal *et al.* (2008) who revealed significance of fruit shape, pulp colour, seed number, leaf shape and petiole wing shape in citrus germplasm characterization as they are mostly genetically controlled and less independent to the environmental response. Although quantitative characters are

influenced by the environmental conditions, Yao (2007) was of the view that these characters still serve an important role in different processes of crop diversity studies. All characters analyzed were important in extent of genetic diversity present among genotypes. So, litchi germplasm were characterized based on qualitative and quantitative traits separately and combined. The clustering of genotypes done separately with 44 qualitative (Figure 4.21) and 39 quantitative (Figure 4.22) traits were not much accurate but clustering with combined 83 qualitative and quantitative traits (Figure 4.22) showed most realistic, accurate and conclusive result and all genotypes were placed where they actually deserve. Therefore, grouping of litchi genotypes based on combined traits (qualitative and quantitative) is most appropriate technique. Illoh and Olorode (1991) also stated the importance of combined quantitative and qualitative data analysis as more accurate and conclusive in differentiating genotypes of mango and hence contributed more towards clustering and groups formation. Likewise, Habindavyi (2009) stated that quantitative characters alone should not be used for diversity analysis, since they are closely related to the ecological conditions where the crop is grown.

CHAPTER VI
SUMMARY, CONCLUSION AND SUGGESTIONS FOR FUTURE WORK

Summary, Conclusions and Suggestions for Further Work

6.1 Summary

The present investigation entitled “Genetic studies of litchi (*Litchi chinensis* Sonn.) germplasm” was conducted at ICAR-National Research Centre on Litchi, Muzaffarpur, Bihar during 2016-17 and 2017-18. The salient findings of the experiment are summarized in this chapter.

- In the 30 studied genotypes, rough surface was observed as the dominant habit (70.0%) that includes 21 genotypes while 7 genotypes (23.33.0%) had smooth surface and two genotypes (6.66%) had very rough surface.
- The two crown shapes was observed within the 30 studied genotypes, with broadly pyramid as the most frequent (76.66%) and represented by 23 genotypes, a quite frequent type of crown shape was spherical (23.33%) and consists of 7 genotypes.
- Three types of growth habit was observed within the 30 studied genotypes, with semi-erect as the most frequent (70.00%) and represented by 21 genotypes, a quite frequent type of growth habit was spreading (20.00%) and consists of 6 genotypes, and drooping habit had a lower representation (10.00%) and consists of three genotypes.
- In the present study, the genotypes showed branching density types as high, medium and low. The branching density was mostly medium (73.33%) and high (16.66%) comprising of 22 and 5 genotypes, respectively whereas low branching density was quite frequent in 3 genotypes (10.00%).
- We have found irregular branching pattern as dominant (66.66%) and represented by 20 genotypes and a quite dominant type of branching pattern was verticillate (33.33%) and consists of 10 genotypes.

- Predominantly, young shoot was glabrous (90.00%) and represented by 27 genotypes as dominant characters and 10% genotypes showed pubescent young shoot.
- The variation in tree height ranged from 2.50 to 4.60 m and maximum height was recorded in genotype Coll. 39 (4.60 m) and lowest height was noticed in IC-0615599 (2.50 m).
- The variation in trunk girth varied from 35.50 to 68.00 cm and maximum girth was found in genotype IC-0615597 (68 cm) and lowest girth was recorded in IC-0615587 (35.50 cm).
- The crown diameter varied from 3.61 to 6.56 m among the studied genotypes. The maximum crown diameter was recorded in genotype IC-0615593 (6.56 m) and lowest in IC-0615599 (3.617 m).
- The variation in tree volume ranged from 6.43 m^3 in IC-0615599 to 39.09 m^3 in IC-0615593. The highest increases in tree volume were recorded in genotypes IC-0615599 (27.21 %) and lowest in genotypes IC-0615603 (1.34 %).
- Four types of colour in young leaf was observed within the 30 studied genotypes, with yellowish green colour as the most frequent (40.00%) and represented by 12 genotypes, a quite frequent type of leaf colour was pink (30.00%) and consists of 9 genotypes, bright pink colour had a lower representation (20.00%) while deep pink had the lowest representation (10.00%).
- The genotypes showed mature leaf colour as dark green in most of the genotypes (46.66%) that include 14 genotypes while it was green (36.66%) in 11 genotypes.
- The opposite arrangement of leaflet was most frequent (70.00%) that include 21 genotypes while it was both opposite and alternately arranged by 9 genotypes (30.00%).
- The elliptic shape of leaflet was as the most frequent (96.66%) and represented by 29 genotypes, lanceolate shape had a lower representation (3.33%) which includes IC-0615586.

- Acute leaflet apex shape was noticed in all germplasm and cuneate leaflet base shape as the most frequent (73.33%) and represented by 22 genotypes, a quite frequent type of leaflet base shape was attenuate (20.00%) and consists of 6 genotypes, oblique shape had a lower representation (6.66%) and includes IC-0615586 and IC-0615603.
- The pubescence on upper surface and lower surface was absent in all germplasm.
- The leaflet midrib appearance was prominent in all germplasm and predominantly leaflet venation appearance was observed as slightly prominent (73.33%) that include 22 genotypes while 20.00% of the genotypes had prominent venation and consists of 6 genotypes and 6.66 % of the genotypes had not prominent leaflet venation.
- The upward curve of leaflet was the most frequent (70.00%) and represented by 21 genotypes, a quite frequent type of curvature was downward curve (26.66%) and consists of 8 genotypes and flat leaflet had a lower representation (3.33%) and include IC-0615605 and protuberance on petiole was present in all germplasm.
- The maximum numbers of leaflets were recorded in genotype Coll. 35 (7.29) and the minimum was in IC-0615587 (5.05).
- The significant variation was observed in rachis length ranging from the highest in genotype IC-0615608 (15.40 cm) to the lowest found in IC-0615588(6.45 cm).
- The variation in length of petiole varied from 2.54 cm to 4.83 cm. The maximum length of petiole was recorded in genotype IC-0615597 and minimum in IC-0615595.
- The significant variation was observed in leaflet length ranging from the highest in genotype IC-0615608 (15.98 cm) to the lowest in IC-0615595 (8.10 cm) and maximum leaflet blade width was recorded in genotype IC-0615608 (15.98 cm) and lowest in IC-0615595 (8.10 cm).

- The genotypes *viz.,* IC-0615602, IC-0615610 and IC-0615613 seem to be early in panicle emergence, while genotypes IC-0615586 and IC-06015599 are late in this respect.
- The date of initiation of male flower varied from 2nd March to 22nd March for both the years. The opening of male flower was firstly ended in IC-0615602 (8th March, 2017 and 13th March, 2018) and opening of male flower was lastly ended in IC-0615599 (26th March, 2017 and 28th March, 2018).
- The first opening of female flower was reported in genotype IC-0615602 (9th March, 2017) and IC-0615587 (9th March, 2017 and 14th March, 2018). The opening of female flower was firstly ended in genotype IC-0615587 (14th March, 2017) and IC-0615587, IC-0615588 and IC-0615602 (19th March, 2018) and lastly ended in genotype IC-0615599 (30th March, 2017 and 1st April, 2018) followed by Coll. 36 (28th March, 2017 and 30th March, 2018).
- The first opening of Hermaphrodite male flower was found in genotype IC-0615602 (14th March, 2017) and IC-0615587, IC-0615588 and IC-0615602 (20th March, 2018) and the opening of Hermaphrodite male flower was eventually recorded in IC-0615599 (30th March, 2017 and 1st April, 2018).The opening of Hermaphrodite male flower was firstly ended genotype IC-0615587 (21st March, 2017 and 26th March, 2018) and the opening of Hermaphrodite male flower was finally ended in genotype IC-0615599 (6th March, 2017 and 8th March, 2018).
- The flower disc colour in 25 genotypes (83.33%) was light yellow while 3 genotypes (10.00%) namely, IC-0615997, IC-0615602 and IC-0615608 had pink flower disc colour.
- The sparse flower was noticed in genotypes *viz.,* IC-0615595 and IC-0615599 while moderate flower was found in genotypes *viz*., IC-0615585, IC-0615588, IC-0615613 and IC-0615605 and rest genotypes showed profuse flowers in panicle.
- The duration of flowering varied from 15 to 24 days in studied litchi germplasm. The maximum duration of flowering was found in

genotype IC-0615610 (24 days) and minimum days were recorded in genotype IC-0615586 (15 days).

- The position of inflorescence in 24 genotypes (80.00%) was terminal while 6 genotypes (20.00%) had both terminal and axillary inflorescence.
- The length of inflorescence was found maximum in genotype IC-0615610 (47.50 cm) while minimum in IC-0615613 (16.20 cm) and genotype IC-0615602 produced maximum width of inflorescence (33.50 cm) while minimum width was found in genotype IC-0615613 (9.15 cm).
- The genotype Coll. 36 produced maximum per cent of female flowers (43.32 %) while the minimum was found in genotype IC-0615585 (3.96 %).
- The initiation of fruit-set was earliest in genotype IC-0615602 in both the years (17th March 2017 and 23rd March 2018) while it was late in IC-0615599 (5th April 2017 and 7th April 2018).The end of fruit set was firstly recorded on 20th March in genotypes IC-0615601 and IC-0615602 during 2017 and IC-0615602 (26th March) in 2018, while, it was eventually ended on 10th April in genotype IC-0615599 during 2017 and on 10th April in genotype IC-0615599 during 2018.
- Based on maturity, litchi fruit was grouped into three classes. Mid ripening group was most frequent (53.33%) that consists of 16 genotypes, while early ripening group was quite frequent (33.33%) and late ripening group (13.33%) represented by four genotypes.
- The synchronous ripening in the evaluated genotypes was most frequent (90.00%) that include 27 genotypes while it was non-synchronous ripening (10.00%) in 3 genotypes.
- The genotypes (96.66%) were regular bearer while 3.33% of the genotypes had partially regular bearer.
- The heavy fruit bearing intensity was most frequent (56.66%) that comprise of 17 genotypes while it was medium (23.33%) in 7 genotypes and poor (20.22%) in 6 genotypes.

- All the genotypes were produced fruit in cluster except genotype IC-0615595 which produced single fruit.
- The nine genotypes (30.00%) possessed oval fruit shape while conical fruit shape was detectable in 8 genotypes (26.66%).The elliptic fruit shape was found in five genotypes (16.66%) and cordate shape observed in four genotypes (13.33%).
- The nature of fruit shoulder was mostly protruding (56.66%) that comprise of 17 genotypes and while it was smooth (43.33%) in 13 genotypes.
- Three types of fruit tip was observed within the 30 studied genotypes, with obtuse fruit tip as the most frequent (70.00%), while, a quite frequent type of fruit tip was round (16.66%) and acute fruit tip had a lowest representation (13.33%).
- Four types of segment on fruit skin was observed within the studied genotypes, with sharp pointed as the most frequent (43.33%) and a quite frequent type of segment was nipple shaped (30.00%). The swelling type segment had a lower representation (23.33%) while smooth segment had the lowest representation (3.33%) shown by genotype IC-0615587.
- The fruit free from cracking was recorded in 18 genotypes (60.00%) while 7 genotypes (23.33%) were prone to cracking and 5 genotypes (16.66%) were highly prone to cracking.
- The most frequent type of fruit colour was reddish yellow and crimson red each (23.33%) and a quite frequent type of fruit colour was rosy red (16.66%) and deep pink had a lower representation (10.00%) while scarlet and greenish red had the lowest representation each (3.33%).
- The uniform distribution of colour on fruit surface was found in 23 genotypes (76.66%) while 7 genotypes (23.33%) showed partial distribution of colour on fruit surface.
- Four shapes of tubercles was observed within the studied genotypes, with sharp pointed shape as the most frequent (43.33%) while a quite

frequent type of tubercle shape was slightly pointed (30.00%) and obtuse shape had a lower representation (23.33%) while smooth shape had the lowest representation (3.33%).

- The tubercles density was sparsely in 17 genotypes (56.66%) while 8 genotypes (26.66%) showed dense tubercles and 5 genotypes (16.66%) had medium density of tubercles.
- The presence of suture was mostly prominent (46.66%) while 43.33% of the genotypes had weak suture and 10.00% of the genotypes had no suture.
- Excellent fruit appearance was dominant character found in 14 genotypes (46.66%) while it was good in 9 genotypes (30.00%) and six genotypes had intermediate and poor attractiveness was found in IC-0615599.
- Aril texture was categorized into four classes and leathery aril texture was most frequently observed in 14 genotypes (46.66%), whereas soft aril texture (33.33%) that comprise of 10 genotypes and firm aril texture (10.00%) represented by three genotypes as well as melting aril texture (10.00%) represented by three genotypes.
- The sweet aril was found in 76.66 per cent genotypes while bitter aril in 13.33 per cent genotypes and only 10.00 per cent genotypes showed acidic fruits.
- Aril flavour was categorized into four classes and strong flavour was most frequently observed in 14 genotypes (46.66%), whereas intermediate flavour found in nine genotypes (30.00%) and weak flavor in five genotypes (16.66%) while good flavour in two genotypes (6.66 %).
- The aril was Juicy in 86.66 per cent genotypes as well as dull white colour of aril was observed in 90 per cent genotypes.
- The genotype IC-0615585 has taken maximum days (70.5) to mature from fruit set and genotype IC-0615608 has taken minimum only 55.5 days to mature.

- The maximum number of fruits per cluster was observed in genotype IC-0615590 (13.51) whereas, the lowest number of fruits per cluster was found in genotype IC-0615595 (1).
- The maximum fruit length was recorded in genotype IC-0615585 (42.45 mm) while minimum was found in genotype IC-0615587 (27.94 mm) and the maximum fruit diameter was observed in genotype IC-0615613 (35.81 mm) while lowest in genotype IC-0615595 (27.97 mm).
- The fruit weight was found maximum in genotype IC-0615585 (25.76 g) whereas, lowest in genotype IC-0615595 (15.55 g) and aril weight was found maximum in genotype IC-0615613 (17.66 g) whereas, the lowest aril weight was recorded in genotype IC-0615595 (7.27 g).
- The maximum aril thickness was found in genotype IC-0615593 (11.00 mm) whereas, the lowest aril thickness was recorded in genotype Coll. 39 (4.25 mm).
- The maximum fruit yield was found in genotype IC-0615611(25.64 kg/plant) whereas, minimum yield was recorded in genotype IC-0615595 (8.70 kg/plant).
- The maximum total soluble solids were observed in genotype IC-0615610 (19.98 °Brix) and lowest TSS was recorded in genotype IC-0615589 (17.04 °Brix).
- The maximum ascorbic acid was found in genotype IC-0615613 (47.50 mg/100 g) and minimum in IC-0615595 (14.62 mg/100 g).
- The maximum total sugar was observed in genotype Coll. 35 (13.54 %) and lowest in genotype IC-0615586 (10.05 %).
- The titratable acidity was found maximum and equal in two genotypes IC-0615585 and IC- 0615599 (0.55 %) and lowest in genotype IC-0615601 (0.23 %).
- The highest reducing sugar was observed in genotype IC-0615601 (10.78 %) and lowest in IC-0615589 (7.69 %).

- The highest TSS/acidity ratio of the fruit was observed in genotype IC-0615602 (84.42) and lowest TSS/acid ratio was found in genotype Coll. 39 (32.69).
- The fourteen genotypes (46.66 %) showed oblong and 30 per cent genotypes showed oval seed shape and 73.33 per cent genotypes sowed brown seed coat colour while 20 per cent showed light brown.
- The maximum seed length was observed in genotype IC-0615585 (23.82 mm) and minimum seed length was found in genotype IC-0615613(16.63 mm).
- The maximum seed breadth was observed in genotype IC-0615600 (13.84 mm) while, the minimum in genotype IC-0615595 (8.18 mm).
- The maximum Chlorophyll A was found in genotype Coll. 36 (11.69 mg/100 g) while lowest Chlorophyll A was recorded in IC-0615595 (1.94 mg/100g) and maximum Chlorophyll B was found in genotype IC-0615611 (3.95 mg/100 g) whereas, minimum was recorded in genotype IC-0615595 (0.35 mg/100 g). The total Chlorophyll content was found maximum in genotype IC-0615596 (15.19 mg/100 g) whereas, lowest was observed in genotype IC-0615595 (2.30 mg/100 g).
- The phenol content in pulp was found maximum in genotype IC-0615593 (8.41 mg GAE/g) whereas, the lowest phenol was recorded in genotype IC-06155600 (0.20 mg GAE/g). Similarly, maximum pericarp phenol was found in genotype IC-0615613 (61.24 mg/g) whereas, lowest phenol was found in IC-0615606 (8.57 mg/g) and maximum seed phenol was found in genotype IC-0615597 (86.56 mg GAE/g) / whereas, the minimum seed phenol content was recorded in Coll. 35 (23.68 mg GAE/g).
- The maximum pulp flavonoid was found in genotype IC-0615613 (23.88 mg CE g^{-1}) while minimum pulp flavonoid was found in genotype Coll. 36 (0.50 mg CE g^{-1}). The maximum flavonoid in pericarp was recorded in genotype Coll. 37 (96.49 mg CE g^{-1}) whereas, the minimum pericarp flavonoid content was observed in genotype IC-0615610 (0.75 mg CE g^{-1}). The maximum flavonoid

content in seed was observed in genotype IC-0615586 (27.50 mg CE g $^{-1}$) and minimum flavonoid content was found in genotype IC-0615587 (2.41 mg CE g $^{-1}$).

- The maximum anthocyanin content in pericarp was observed in genotype IC-0615610 (107.6 mg/100g) whereas, the minimum pericarp anthocyanin content was found inIC-0615613 (17.7 mg/100g).

Correlation Coefficient

- Yield per plant has highly significant positive correlation with seed length (0.53), seed breadth (0.60), seed weight (0.47), chlorophyll A (0.58), chlorophyll B (0.49), total chlorophyll (0.57), anthocyanin in pericarp (0.65) and significant positive correlation with TSS (0.38), total sugar (0.43), reducing sugar (0.46) and significant negative correlation with phenol in pericarp (-0.41) and flavonoids in seed (-0.43).

Path analysis

- The path coefficient analysis indicated that positive direct effect on yield were exhibited by crown diameter, tree volume, petiole length, length of leaflet, duration of flowering, panicle length, days from fruit set to maturity, number of fruits per cluster, fruit diameter, aril weight, ascorbic acid, seed breadth, seed weight, chlorophyll A, B and total chlorophyll and negative direct effect on yield were exhibited by plant height, trunk girth, number of leaflet per leaf, rachis length, width of leaflet, width of panicle, per cent of female flower, fruit length, fruit weight, total sugar and seed length.

Clustering

- The pattern of genotype clustering on combined traits basis presented more accurate result.
- Cluster analysis separates 30 genotypes into Cluster I and Cluster II with Cluster I that was sub-divided into small clusters: sub-cluster-I and sub-cluster-II and Cluster-II was sub-divided into small clusters: sub-cluster-III and sub-cluster-IV. Sub-cluster-I composed of three genotypes.

- Sub-cluster-II was again divided in to minor sub-cluster-I and minor sub-cluster-II.
- Sub-cluster-I composed of three genotypes *viz.,* IC-0615604, IC-0615593 and IC-0615596, and minor sub-cluster-I and minor sub-cluster-II composed of four and five genotypes, respectively.
- Sub-cluster-III and sub-cluster-IV composed of nine genotypes each which showed maximum similarity in the group.

6.2 Conclusions

A good genotype must be possessed with maximum crown diameter, tree volume, petiole length, length of leaflet, duration of flowering, panicle length, days from fruit set to maturity, number of fruits per cluster, fruit diameter, aril weight, ascorbic acid, seed breadth, seed weight, chlorophyll A, B and total chlorophyll. To understand the morphological diversity present among the genotypes is indispensable for efficient exploitation of crop genetic resources. This characterization study based on morphological characters showed a wide range of variation recorded in both quantitative and qualitative characters among the 30 studied litchi genotypes. Based on ANOVA results of the present trial, most of the genotypes assayed presented typical characteristics of the species they belong to and could be easily distinguished in groups. Trunk surface, tree growth habit, branching pattern, young leaf colour, mature leaf clour, leaflet curvature, flower disc colour, fruit shape, fruit tip. Segment on fruit skin, cracking to skin, mature fruit colour and shape of tubercles presented marked variation among the 44 qualitative traits studied while among the 39 quantitative traits, higher variation was observed for tree volume, panicle length, panicle width, per cent of female flowers, number of fruits per cluster, yield per plant, ascorbic acid, titratable acidity, TSS/acidity ratio, seed weight, chlorophyll content in leaf, total phenol, flavonoids and anthocyanin in fruit presented marked variation among the 39 quantitative traits studied. The cluster analysis techniques for determining genetic relatedness among genotypes and identification of important contributing traits are consistent with each other. Cluster analysis based on qualitative and

quantitative traits resulted in the separation of accessions into two main groups representing highly variable assembly of genotypes.

6.3 Suggestions for further work

It can be characterized based on molecular markers.

It can be characterized based on more number of biochemical found in different parts of plants.

A correlation may establish between yield and important yield attributing traits like chlorophyll content.

Germplasm may characterize based on physiological traits.

This work will provide a platform to breeder to select most attributing traits which strongly and directly related with yield.

This work will help to breeder to select traits specific parent to develop a new cultivars.

CHAPTER VII
BIBLIOGRAPHY

BIBLIOGRAPHY

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CHAPTER VIII
APPENDICES

Appendix 1

Mean monthly weather data from June 2016 to May 2018 at Muzaffarpur

Month and Year	Max Tem (°C)	Min Tem (°C)	Max Humidity (%)	Min Humidity (%)	W/S (km/hr)	Rainfall (mm)	Evaporation (mm)
June, 16	35.16	25.98	82.20	61.40	7.10	26.26	4.92
July, 16	31.78	25.98	91.50	78.50	7.28	76.03	3.10
Aug, 16	33.68	26.08	86.40	68.80	6.66	25.28	3.94
Sep, 16	31.15	24.98	92.50	79.00	5.08	75.90	2.75
Oct, 16	32.93	23.28	88.75	59.25	2.55	8.65	2.85
Nov, 16	29.18	16.22	86.20	45.40	1.52	0.00	1.98
Dec, 16	21.90	11.08	90.50	65.25	2.78	0.00	0.78
Jan, 17	22.50	8.60	92.75	61.75	2.73	0.00	1.23
Feb, 17	25.40	10.80	91.00	59.25	3.08	0.00	2.08
March, 17	29.56	15.28	86.00	54.00	4.66	2.12	3.28
April, 17	34.25	21.78	75.25	52.75	7.48	15.90	5.65
May, 17	34.28	24.08	83.20	65.00	6.60	23.84	4.80
June, 17	35.13	26.78	86.25	65.75	5.93	21.55	4.70
July, 17	32.33	26.28	88.75	76.00	6.78	105.05	4.38
Aug, 17	32.56	26.28	90.40	76.40	4.62	77.50	3.70
Sep, 17	33.93	26.30	88.75	67.00	3.95	10.95	3.93
Oct, 17	32.80	23.40	88.50	67.00	3.53	0.88	3.15
Nov, 17	28.70	15.30	87.20	59.40	1.92	0.00	2.46
Dec, 17	24.13	11.03	93.75	69.00	2.00	0.00	1.63
Jan, 18	16.00	7.70	93.00	77.00	2.70	0.00	0.50
Feb, 18	25.60	11.90	90.00	65.00	2.90	0.00	2.60
March, 18	32.20	16.00	79.00	55.00	3.30	0.00	4.30
April, 18	33.70	20.60	79.00	59.00	5.80	41.40	5.10
May, 18	34.00	24.30	82.00	64.00	8.00	3.05	5.30

Appendix 2
Research Publication

Curriculum Vitae

The author of this thesis Narayan Lal (ARS) S/O Late Shri Sudhu Ram Sahu was born on 6th April, 1985 in the lap of Mahanadi River at village Soram, Dhamtari (C.G.). He has qualified JRF in Horticulture (ICAR) in 2007 and 2008. He has served as Lecturer in Agriculture in State Education Department, CG in 2011 and as Agriculture Officer in Bank of India in 2012. He has qualified ICAR-NET (Horticulture) and ICAR-Agricultural Research Service (ARS) 2012 and posted as Scientist at ICAR- National Research Centre on Litchi, Muzaffarpur, Bihar. He has also qualified ICAR-SRF in 2015. He has completed his education from different institution are given below:

Name of Certificate/Degree	**University/Institute**	**Year of Completion**	**Marks (%)**
Ph.D. (Horticulture-Fruit Science)	JNKVV, Jabalpur, MP	2018	78.3
M.Sc. (Ag) in Horticulture	AAU, Jorhat, Assam	2010	83.9
B.Sc. (Horticulture)	IGKV, Raipur, CG	2007	73.1
Higher Secondary School Certificate	CG Board, Raipur, CG	2003	54.2
High School Certificate	MP Board, Bhopal, MP	2001	65.4

The author carried his doctorate studies from the Department of Horticulture, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.). This thesis is a bonafide research being submitted by his as a partial fulfillment for the award of Ph.D. (Horticulture) in Fruit Science degree.

Publication:

Research Paper:

Diwan G, K Sinha, **Lal N** and Rangare NR. 2018. Tradition and medicinal value of Indian gooseberry: A review. Journal of Pharmacognosy and Phytochemistry 7(1): 2326-2333.

Lal N, Gupta AK and Nath V. 2017. Fruit Retention in Different Litchi Germplasm Influenced by Temperature. International Journal of Current Microbiology Applied Science 6(12): 1189-1194.

Narayan Lal and RP. Das. 2017. Effect of Plant Growth Regulators on Yield and Quality of Guava (*Psidium guajava* L.) cv. Allahabad Safeda. International Journal of Current Microbiology Applied Science 6(5): 857-863.

Narayan Lal and Nisha Sahu. 2017. Management Strategies of Sun Burn in Fruit Crops-A Review. International Journal of Current Microbiology Applied Science 6(6): 1126-1138.

Narayan Lal, Nisha Sahu, Govind Shiurkar, Dalit Kumar Jayswal and Sonbeer Chack. 2017. Banana: Awesome fruit crop for society (Review). The Pharma Innovation Journal. 6(7): 223-228.

Narayan Lal, Nisha Sahu, E.S. Marboh, A.K. Gupta and RK. Patel. 2017. A Review on Crop Regulation in Fruit Crops. International Journal of Current Microbiology Applied Science 6(7): 4032-4043

Book Chapter:

Sunil Kumar, **Narayan Lal** and Vishal Nath. 2016. Tendu (*Diospyros melanoxylon* (roxb) inUnderutilized Fruit Crops: Importance and Cultivation. p1327-1338 Edited by Dr SN Ghosh et al**.**

Narayan Lal and Vishal Nath. 2017. Sweet Tamarind (*Pithecellobium dulce* (Roxb.) Benth.) in MINOR FRUITS:NUTRACEUTICAL IMPORTANCE AND CULTIVATION. Pp3 901-912, edited by Dr S.N. Ghosh, Jaya Publishing House

Narayan Lal, Alok Kumar Gupta, Neetu Singh Kushwah and Vishal Nath. 2017. Sapindaceous Fruits: In Horticultural Crops of High Nutritive Values, pp 339-370, edited by KV Peter. Brillion Publishing, New Delhi.

Article:

Narayan Lal, Jayshri Barcchiya, Neelesh Raypuriya and Govind Shiurkar. 2017. Anti-nutrition in legumes: effect in human health and its elimination. Innovative Farming 2(1): 32-36

Narayan Lal, Nisha Sahu and Jayshri Barcchiya. 2017. Honey Bees: a model insect in horticultural crop production. Innovative Farming 2(1): 72-76

Narayan Lal and Nisha Sahu. 2017. Banana: A miracle Fruit of India, किसान ज्ञान Year-1 Issue: 5 September- 2017

Narayan Lal and Alok kumar Gupta. 2017. नये बागोनों के लिए लीची के किस्मों का चुनाव, छत्तीसगढ खेती