स्व:फलोत्पादकता के लिए अर्का सहन सीताफल संतति का मूल्यांकन एवं लक्षण-वर्णन

EVALUATION AND CHARACTERIZATION OF ARKA SAHAN CUSTARD APPLE PROGENIES FOR SELF FRUITFULNESS

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NEW DELHI – 110 012, INDIA

2023

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EVALUATION AND CHARACTERIZATION OF ARKA SAHAN CUSTARD APPLE PROGENIES FOR SELF FRUITFULNESS

A thesis

By

SUSHMITHA B H

Submitted to post graduate school

Indian Agricultural research institute, New Delhi

In partial fulfillment of the requirements

for the award of degree of

DOCTOR OF PHILOSOPHY

IN

HORTICULTURE – FRUIT SCIENCE

(IARI PG outreach program at ICAR-IIHR, Bengaluru)

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This is to certify that the thesis entitled with **"Evaluation and Characterization of Arka Sahan Custard apple Progenies for Self fruitfulness"** submitted to faculty of Post Graduate School, Indian Agricultural Research Institute, New Delhi, in partial fulfillment of the requirements for the degree of **Doctor of philosophy in Horticulture-Fruits and Horticulture Technology** by **Ms. Sushmitha B H., Roll No. 11516** embodies the results of *bonafide* research work carried out by her under my guidance and supervision, no part of the thesis has been submitted for any other degree or diploma.

It is further certified that only help or source of information, as been availed for this work, has been duly acknowledged.

Date: 27.10.2023
Place: ICAR-IIHR, Bengaluru

(Dr. T. Sakthivel)
(Chairman, Advisory committee)


Dedicated to
My guide
My ever-loving
parents
and brother

ACKNOWLEDGEMENT

First and foremost, I would like to express my deepest sense of gratitude to the almighty “God” for giving me the courage patience, endurance and strength to overcome entire hurdle in course of accomplishing the paramount milestone of my academic career.

With the deep sense of veneration and gratitude, I express my profound indebtedness to Dr. T. Sakthivel, Chairman of the Advisory Committee (Principal Scientist, Division of fruit crop ICAR-IIHR). ICAR-IIHR, Bengaluru, for suggesting the suitable research problem, timely advice, sustained interest, valuable and generous guidance and constructive criticism during the course of this investigation and preparation of manuscript. Indeed, I am honored and feel blessed to be one of his students.

I would like to extend the heartfelt gratitude to Dr. M. Sankaran co-chairman of my advisory committee (Principal Scientist and Head, Division of fruit crop ICAR-IIHR) for his unstinted support, critical comments and valuable suggestions during the research work and preparation of this manuscript.

I emphatically owe my heartiest thanks to my advisory committee members Dr. K.S. Shivashankara (Principal Scientist and Head, Division of Plant Physiology and Biochemistry), Dr. M.V. Dhananjaya (Division OF Vegetable Crops), Dr. Lakshmana Reddy (Principal Scientist, Division of Biotechnology)and Dr. R. Venugopalan, (Principal Scientist, Division of Social science and training), for their valuable suggestions and kind cooperation throughout the course of investigation.

I wish to express my sincere thanks to Dr. Reju M. Kurian, Principal Scientist Division of Fruit Crops, for his guidance, help and cooperation during the course of study.

I would like to extend my heartfelt gratitude to Dr. Sriram, Dr. Samuel, Dr. Hima Bindu, Dr, PVR Reddy Dr. Usha Bharthi, and Dr. Raghu, for their invaluable contributions and guidance in the doctoral degree program.

I also express my deep sense of gratitude to Dr.S.K.Singh, Director, ICAR-IIHR, for his constant support and help for carrying out my research work in a smooth way.

I am thankful to Sh. M.Laksmipathi (Senior technicians) Sh. M.V. Giri sir (Personal Assistant), field staff as well as lab staff of Division of Fruit Crops for providing painstaking support during my research work.

I sincerely acknowledge the help and encouragement received from Dr.P. L.Anushma, Dr.Linta Vincent and Dr. Anupa Naik and my dearest friends Yathish V C, Lavanya H. N., Harish T, Sangeetha Priya for completion of this investigation.

I sincerely acknowledge encouragement and help received from my seniors Sajana, Kaluram, Prashanth, Parvathi, Kiran Kumar, Pradeep, Nanda kishore and feel pleasure to extend my thanks for my classmates Bindu, Ayesh, Chethana Jyothi, Vittal Kamble.

I am extremely thankful to my juniors Kiran, Pavan, Sinchana. I convey my thanks to all the staff of Division of Fruit Crops, ICAR-IIHR, Bengaluru for their help rendered during the investigation.

I find no such measures adequate to quantify all that my parents Sh. Hanumatha Reddy B T and Smt. Ratnamma G B have done for me. I will forever remain indebted to them for their love, prayers, sacrifices and whose unfailing courage and counsel nurtured and motivated me to pursue this research. I take this moment to express my immense thanks to my younger brothers Dr. Sumanth Reddy and Dr. Bharath Reddy for their affectionate love, silent support and constant encouragement.

The financial assistance provided by the Indian Agriculture Research Institute (ICAR-IARI), New Delhi in the form of IARI-merit fellowship during the tenure is gratefully acknowledged. Last but not the least, I record my sincere thanks from the core of my heart to all the well wishers who could not find the place in the text, but whose blessings propelled me to achieve my dreams.

Place: Bengaluru

Dated: 27-10-2023 (Sushmitha B H)

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ABBREVIATIONS USED AND THEIR EXPANDED FORM

Symbols & Abbreviations		Expansion
%	:	Per cent
@	:	at the rate
°C	:	Degree centigrade
ANOVA	:	Analysis of variance
SE(d)	:	Standard error of difference
SD±	:	Standard deviation
Cm	:	Centimetre
Cv	:	Cultivar
TSS	:	Total soluble solids
Kg	:	Kilogram
G	:	Gram
Mg	:	Milligram
µg	:	Microgram
Ml	:	Milliliter
Mm	:	Millimeter
MSL	:	Mean sea level
et al.	:	Etalia (Co - workers)
^{0}Brix	:	Degree Brix
Fig.	:	Figure
e.g.	:	For example, for instance
G	:	Gram
MT	:	Metric tonnes

Symbols & Abbreviations		Expansion
IC	:	Indigenous collection
i.e.	:	id est (that is)
std.	:	Standard
Vol.	:	Volume
wt.	:	Weight
Max.	:	Maximum
Min.	:	Minimum
OD	:	Optical density
Rpm	:	revolutions per minute
DNA	:	Deoxy ribonucleic acid
V	:	Volume
W	:	Weight of sample
Ppm	:	Parts per million
NaCl	:	Sodium chloride
PVP	:	Polyvinyl pyrrolidone
NaOH	:	Sodium Hydroxide
H2SO4	:	Sulfuric acid
NaNo2	:	Sodium nitrite
MgCl2	:	Magnesium chloride
dNTPs	:	Deoxynucleoside triphosphates
EDTA	:	Ethylene diamine tetra acetic acid
TE	:	Tris ethylene diamine tetra acetic acid
Na EDTA	:	Sodium ethylene diamine tetra acetic acid

Symbols & Abbreviations		Expansion
SSR	:	Simple sequence repeats
SRAP	:	Sequence related amplified polymorphism
pH	:	Puissance de hydrogen
PCR	:	Polymerase chain reaction
Ta	:	Annealing temperature
Nm	:	Nanometer
µmol	:	Micromole
mM	:	Milli molar
UV	:	Ultraviolet
no.	:	Number
bp	:	Base pair
GCV	:	Genotypic co-efficient variance
PCV	:	Phenotypic co-efficient variance
PIC	:	Polymorphic information content
Na	:	Mean number of alleles
Ne	:	Effective number of alleles
I	:	Shannon information index
Ho	:	Observed heterozygosity
He	:	Expected heterozygosity
f	:	Fixation index
ANOVA	:	Analysis variance
IIHR	:	Indian Institute of Horticultural research
ICAR	:	Indian council of Agricultural Research

INTRODUCTION

CHAPTER 1 INTRODUCTION

Annona is a genera has got 166 species belonging to the Annonaceae family and one of the oldest groups of flowering plants in the Magnoliales order of the Magnoliid clade (APG III, 2009; Gupta *et al.*, 2015). These plants are native to the tropical regions and produce six edible fruit species:- viz., *A. squamosa* L. (sitaphal, custard apple, sharifa, sugar apple, sweet sop), *A. reticulata* L. (Bullock's Heart), *A. cherimola L.*(cherimoya), *A. muricata* L. (Guanabana or soursop), *A. Atemoya* (a natural hybrid of *A. squamosa* x *A. cherimola*), and *A. glabra* (pond apple) (Larranaga and Hormaza, 2015). Atemoya has better fruit quality than sugar apple, but it suffers from low fruit set and yield (Rathore, 1985). *A. diversifolia* is another species that produces edible fruits. Most of the edible Annona species originated in South America and Antilles, except for *A. squamosa*, which has India as its secondary centre of origin, and *A. muricata*, which came from Africa (Pinto *et al.*, 2005). Most of the Annona species have a diploid chromosome number of 2n = 2x = 14 and 16, except for *A. glabra*, which is tetraploid with 2n = 4x = 28.

Custard apple is a common name for some Annona species that grow well in the arid semi arid regions, where they can tolerate heat and drought better than other fruit crops. They have a deep root system that can access soil moisture efficiently and a perennial habit that allows them to survive harsh conditions. They also produce fruits with high consumer preference and demand, especially in the local markets. However, they have some drawbacks such as small fruit size, frequent cracking at maturity, poor shelf life, and high perishability. These factors limit their commercial potential and make their marketing localized (Rao, 2016)

Custard apple originated in lowland Central America and spread to Mexico and other tropical American countries. It is one of the most popular fruits in northeastern Brazil. The fruits of different Annona species have similar morphology but distinct characteristics such as shape, size, skin surface, pulp, colour, texture, flavour and taste. Among the edible annonas, cherimoya (*Annona cherimola* Hort.), custard apple (*Annona squamosa* L.) and atemoya, the hybrid between them, are the most popular.

Annona breeders should aim to develop a cultivar that meets the needs of the grower, the retailer and the consumer. The market preferences for fruit quality may vary, but generally, fruits with a symmetrical shape, good size (depending on the annonaceous fruit), smooth skin, and resistance to bruising are preferred. Other desirable traits include attractive skin colour, low seed number, good flavour, slow ripening, firmness when ripe and good shelf life. The growers are interested in traits such as precocity, high fruit set, self-pollination, good shelf life, and high yield, as well as resistance to common pests and diseases of local importance (Lora *et al*., 2018).

ICAR-Indian Institute of Horticultural Research, Bangalore, has developed an Annona hybrid known as "Arka Sahan" with improved fruit quality. Arka Sahan is an interspecific hybrid between atemoya cv. Island Gem (*Annona atemoya* Hort.) x Custard apple cv. Mammoth (*A. squamosa* L.). Arka Sahan fruits are harvested in September-October. The average fruit weight is 400-450g and the ripening time is 6-7 days. The skin is light green with a waxy bloom and moderately thick (0.5 cm). The pulp is creamy white, juicy, mildly aromatic and has few seeds (9/100 g). The pulp is very sweet with 22.8% total sugars and TSS more than 30°B compared to 24°B in Mammoth. A 100g pulp of Arka Sahan contains 2.49 g of crude protein, 42.29 mg P and 225 mg Ca compared to 1.33 g, 17.05 mg and 159 mg respectively in Mammoth. The average yield is 12 tonnes of fruits per hectare.

Annona breeding work was started in India in 1989 at ICAR- Indian Institute of Horticultural Research, Bangalore, to develop a custard apple cultivar with fewer seeds, more edible pulp, better quality and longer shelf life. More than 2000 inter- and intra-species Annona hybrids were created and evaluated, resulting in the release of the hybrid "Arka Sahan". It is an exceptional recombinant derived from the cross of "Island Gem" (atemoya) and "Mammoth" (custard apple). However, to improve the fruit-set, size and shape of this rare interspecific recombinant, pollination with *Annona squamosa* pollen was found to be most effective as it exhibits metaxenia or pseudoxenia phenomenon (Jalikop and kumar, 2007). The importance of different species in the breeding program was highlighted by Cliff (1977), which is especially relevant in Annona species where variability within a species is limited. *A. glabra* L. is useful for breeding for drought

tolerance and coloured pulp, *A. atemoya* Hort. for fruit size, *A. squamosa* L. for quality, *A. reticulata* L. for late season crop, *A.purpurea* Mocine and Sesse., *A. scleroderma* and *A. testudinea* Safford for their thick-skinned insect resistant fruits, and *A.purpurea*, *A.spinescens* and *A.diversifolia* for their coloured pulp. The main goal of the Annona breeding program is to select types with high fruit set and self-fruitfulness (George *et al.*, 1986; Jalikop, 2011), indicating the presence of the phenomenon known as protogynous dichogamy i.e. maturation of carpels before the stamens, limiting selfing (Pinto *et al.*, 2005).

Poor fruit set is common problem in Annona, which can be overcome by hand pollination (Escobar *et al.*, 1986; Saavedra, 1977) or insect pollination (Gazit *et al.*, 1982; George *et al.*, 1989; Pena *et al.*, 2002), however both methods have limitations. Hand pollination is time-consuming and requires a suitable pollen source, while insect pollination is unreliable and unspecific. Hand pollination can improve fruit set and increase fruit yield per tree by enhancing the fruit size and number, the main yield components (Pritchard and Edwards, 2006). However, it is only worthwhile for varieties that produce high-quality fruits with desirable xenic effects, which are the influence of pollen on seed (xenia) and fruit (metaxenia) characteristics (Denney 1992). Kahn *et al.*, (1994) observed that xenic effects can affect fruit set, shape, and quality in annona, depending on the pollen parent. Therefore, exploiting xenic effects at the F_0 level, similar to heterosis at the F_1 level, can be rewarding. 'Arka Sahan', the annona hybrid, is an excellent recombinant derived from the cross of 'Island Gem' (*A. squamosa* x *A. cherimola*) and 'Mammoth' (*A. squamosa*) and released for commercial cultivation (Jalikop and Kumar, 2000). However, it needs assisted pollination to produce large sized fruits with good shape and size. This is a labor intensive process and there is a need for self fruitful Annona varieties that do not require assisted pollination. This can be achieved by interspecific crosses (George *et al.* (2002) Jalikop, 2011), back cross and mutation breeding (George *et al.*, 2002). Attempts to induce polyploids were unsuccessful. Islam (1960) reported that colchicine induced tetraploids of *A. squamosa* were unproductive even with the hormonal application. However, George *et al.* (2002) suggested that it may be possible to produce tetraploids using colchicine applications to juvenile buds. Another approach is to make inter varietal

crosses between Arka Sahan and Balanagar to obtain recombinants among the segregating population for self fruitfulness.

Considering the above points, the study was carried out with the following objectives;

1. To evaluate the progenies of Arka Sahan x Balanagar for growth, yield, quality and self fruitfulness
2. To study the floral biology in self fruitful and unfruitful Arka Sahan progenies
3. Assessment of genetic relatedness between parents and progenies of Arka Sahan x Balanagar

REVIEW OF LITERATURE

CHAPTER 2 REVIEW OF LITERATURE

All the relevant literature related to **"Evaluation and Characterization of Arka Sahan Custard apple Progenies for Self fruitfulness**" has been reviewed in the following headings,

2.1 To evaluate the progenies of Arka Sahan x Balanagar for growth, yield, quality, and self-fruitfulness

2.2 To study the floral biology in self-fruitful and unfruitful Arka Sahan progenies.

2.3 Assessment of genetic relatedness between parents and progenies of Arka Sahan x Balanagar

2.1 To evaluate the progenies of Arka Sahan x Balanagar for growth, yield, quality, and self-fruitfulness.

2.1.1 Hybridization

According to Jordan and Botti (1992), there is great scope in edible annonas for gene transfer across species boundaries, for widening the genetic base, and for developing strategic breeding reserves. Gene exchange among annonas should result in interesting novel recombinants, with the popular atemoya being the most esteemed one currently available. Additionally, Annona species vary in their climatic adaptation. In the tropics, at higher altitudes, cherimoya grows well and at lower altitudes sugar apple grows well, while the atemoya an interspecific hybrid, is intermediate between its parents (Purseglove, 1968, Rasai *et al.*, 1995). *A. reticulata* flourishes well in coastal lowlands. This adaptation suggests that it may be possible to break the geographical barriers of annonas through interspecific hybridization and construct new annonas suitable to wider or new climatic zones.

Ezzat *et al.*, (1974) studied the evaluation and determination of the maturity stage of the fruits of some Annona varieties and found that hybrid between *A. squamosa* and *A. cherimola* was earlier to mature than other varieties of Annona. A hybrid from a cross of *Annona squamosa* with *Annona cherimola* has well-flavoured fruits weighing up to 450 g

with a pulp content of 60-70% and soluble solids content of 24-28% (Anon, 1976). Rokba *et al.*, (1977) evaluated some annona varieties and reported that a cross between *A. squamosa* and *A. cherimola was* found to be good for growth, flowering, fruit set, and yield.

Gefner, African Pride, PR-3E and Bradley are the varieties of custard apples (*Annona cherimola* x *Annona squamosa)* in San Francisco that performed well under irrigated conditions (Santos *et al.*, 2001). Mathakar (2005) screened 24 hybrids of *Annona atemoya* x *A. squamosa, A. atemoya* x *A. reticulata* and *A. squamosa* x *A. squamosa.* Out of this Hybrid No. 6, 13, and 22 were found to be the most promising ones based on fruit quality traits.

2.1.2. Growth and yield parameters

Morton and Miami (1987a) described the sugar apple, *Annona squamosa*, stating that it typically reaches a height of 10 to 20 feet (3-6 meters) with an open crown, irregular branches, and somewhat zigzag twigs.

In a study conducted by DaSilva *et al.* (1999) to assess the conservation, characterization, and evaluation of custard apple germplasm in Brazil's semi-arid conditions, the researchers found that the accession Moxoto 20.2 exhibited the tallest plant height, measuring 3.80 meters, while Moxoto 16.3 had the shortest height at 2.90 meters. The plants had an average height of 3.46 meters among the different types of accessions that were tested. Sugar apple (A. squamosa) trees produced more fruits than soursop trees, with 50 and 20-24 fruits per tree respectively. The soursop trees had a variation in yield from 7.7 kg to 29.6 kg per tree.

Shete *et al.* (1991) reported that the number of fruits in *Annona squamosa* seedlings ranged from 27 to 49 per tree, and the average yield per tree varied from 4.26 kg to 8.70 kg from the seedling of *A. squamosa* under Rahuri conditions. *Annona muricata* clones in Venezuela produced 12 to 24 fruits per tree (Laboren, 1994).

Carvalho *et al.*, (2000) studied the performance of custard apple (*Annona squamosa* L.) genotypes in Brazil and results revealed that the height of the ten most promising genotypes of *A. squamosa* ranged from 4.3 to 5.5 m. The highest mean annual yields were obtained from IPA (18.2), IPA (17.2) and IPA (17.3) and yielded 11.73, 10.58, and 10.56 kg/tree, respectively.

Girwani *et al.* (2011) examined various custard apple hybrids to determine their fruit yield and quality characteristics. Their findings revealed that Hybrid-1, resulting from the crossbreeding of '17/4 Atemoya' and 'Balanagar', exhibited the highest number of fruits per tree (94). Hybrid-6, derived from the combination of '15/3 Red Sitaphal' and 'Atemoya', followed closely with a yield of 67 fruits. Similarly, Prajapati *et al.*, (2016) recorded that the local custard apple cultivar demonstrated a significant number of fruits (67.30) and a yield of 14.83 kg.

Karbhari (2017) studied the influence of plant growth regulators on the Custard apple cultivar Balanagar and reported variation in the number of fruits from 48 to 67 and yield from 8 kg to 14.5 kg.

Mathakar (2005) evaluated 24 hybrids for plant height and reported that it ranged from 1.98 to 3.23 m. The yield potential was found to vary from 7.2 kg to 15.1 kg per tree under Rahuri conditions. In custard apple germplasm, 17 accessions were evaluated at Aruppukotai, out of which AS-16 recorded the maximum height (5.03 m) while the least was observed in AS-14 (3.45 m) (Anon, 2006).

Custard apple variety APK(Ca)-l, recorded 3.75 m plant height in 2004 and 3.86 m in 2005 respectively in the years 2004 and 2005 (Anon, 2008).

Folorunso and Olorode (2006) studied four species of *Annona* found in Nigeria and characterized them as important under-utilized species. Morphological characters revealed an intra-generic relationship among the *Annona* species. Leaf shape was a strong factor in the clustering of Annonaceae such as *A. senegalensis*, *A. sqamosa* and *A. reticulata* have elliptic leaves.

Jagtap and Kokate (1991) selected the five best promising types of custard apple *viz.*, P-36, P-42, D.77, Y-72, and D-90 based on yield which ranged from 40.30 kg to 49.75 kg /tree.

Xie *et al.* (1999) found that the cherimoya cultivar AP introduced to China in 1981 is precocious and productive in the Guangzhou area of Guangdong; yields from 3 to 5-year-old trees are 337.5% higher than yields from other cultivars.

George and Nissen (2002) concluded that the mean marketable yields of custard apple (*Annona squamosa* x *A. cherimola*) cv. African Pride was 18.7 t/ha on cherimoya (*A. cherimola*) rootstock and 9.2 t/ha on sugar apple (*A. squamosa*) rootstock. Comparative yields for cv. Pinks Mammoth were 7.2 and 6.2 t/ha, respectively. The trial showed that satisfactory yields could be obtained with African Pride without hand pollination. APK(Ca)-l, a high-yielding custard apple variety, is a clonal selection from Tamil Nadu and yielded high in rainfed black soils and registered the mean yield of 14.9 kg per tree (Anon, 2003).

Sixteen custard apple (*Annona* spp.) genotypes were evaluated for yield and quality attributes under rainfed vertisol conditions in Tamil Nadu. The yield of fruits ranged from 3.33 kg to 15.02 kg per tree (Selvarajan *et al.,* 2008). Patel *et al*., (2010) reported that the fruit weight varied from 136.13 to 153.22 g in the Custard apple cultivar ‘Sindhan’.

2.1.3. Fruit quality parameters

An interspecific hybrid Arka Sahan (*A. atemoya* x *A. squamosa*) has been developed and released by IIHR, Bangalore having the desirable fruit characters and it yields high with very sweet, fragrant and low-seeded fruits having longer shelf life. 'Arka Sahan' an interspecific hybrid had the fruit weight of 450 g, roundish in shape and the number of seeds was 9/100 g fruit weight. The skin of mature fruit has a waxy bloom, and flat eyes, and the mature fruits take about seven days to ripe. The skin is light green and moderately thick (0.5 cm). The edible pulp is very sweet with 22.8 percent sugars measuring more than 30°Brix compared to 24°Brix in Mammoth. Arka Sahan had a pulp with remarkable sweetness with 22.8 per cent total sugars Jalikop and Kumar (2007).

The amount of ascorbic acid in different Annona species was measured by Pareek *et al*. (2011). They found that A. cherimola had 11.5 mg, A. reticulata had 30 mg, A. muricata had 29.4 mg and A. squamosa had 37.3 mg of ascorbic acid.

Kolekar and Tagad (2012) reported that the average weight of greenish yellow coloured custard apple fruit was about 168g, with an average length of 5.4cm and breadth of 4.3cm. The number of seeds was 26, the weight of the peel was 82.44g, and the weight of the pulp was 85.44g. The percentage juice was of 30.58% and the percentage of the waste index was 58.42% . The weight, length, and breadth of fruit may vary according to climatic conditions and from fruit to fruit.

In their investigation, Kad *et al.* (2016) analyzed the physical, morphological, and rheological characteristics of custard apple. The study unveiled various properties of the custard apple fruit, including the peel, carpellary pulp, gritty pulp, and seed weight per fruit, which were measured to be 46.77%, 35.36%, 11.63%, and 6.24% respectively. Furthermore, the rheological properties of custard apple pulp-flakes were assessed with stickiness recorded at 184.34g.

Jeevan *et al*. (2018) conducted a study to evaluate the genetic variability and quality attributes of different genotypes of custard apple (*Annona squamosa* L.) in northern Bastar of Chhattisgarh, India The investigation revealed that the traits with the highest genotypic and phenotypic coefficient of variation (GCV and PCV) were pulp weight, followed by areole weight (51.47% and 51.80) and fruit weight (44.70% and 45.10). Additionally, the study identified the traits with the highest genetic advance (GA) as fruit weight (212.64), followed by pulp weight (122.27), and areole weight (82.55).

Yashwant *et al.* (2018) studied fruit morphology and quality parameters of global custard apple (*Annona squamosa* L.) germplasm. The results showed that wide variability was present among custard apple cultivars for quantitative as well as qualitative traits. The fruit shape ranged from round to cordate, fruit weight varied from 98.8 to 170.1 g, fruit length varied from 5.47 to 7.0 cm, fruit width varied from 5.57 to 7.13cm, fruit volume varied from 77 to 178 cm^3 and pulp to seed ratio ranged from 3.69 to 32.87.

Chandel *et al.* (2018) carried out the collection and evaluation of custard apple (*Annona squamosa* L.) cultivars in Chattisgarh plains. All 18 collections were evaluated for yield parameters and physical aspects. The results revealed greater variability for yield and quality traits. The fruit physical characters *viz.,* fruit length (7.53 to 11.76cm), fruit breadth (7.14 to 10.98cm), fruit weight (155.86 to 365.78g), pericarp weight (75.85 to 162.58g), pulp weight (60.44 to 180.56g), number of seeds per fruit (48.33 to 20.00) and seed weight (15.00 to 23.00g) showed significant variation.

Karbhari (2017) conducted a study on the effects of plant growth regulators on the custard apple cultivar Balanagar. The research revealed significant variations in several parameters. The pulp weight ranged from 68.9 g to 90.5 g, while the number of seeds varied from 31 to 43. Similarly, the seed weight varied from 19.6 g to 27.8 g, and the seed-to-pulp ratio ranged from 0.21 to 0.40. The total soluble solids (TSS) ranged from 20 to 28.20º Brix, with the highest TSS observed in Hybrid-2 (28.4º Brix B) and Hybrid-24 (25.º Brix). Titrable acidity did not exhibit significant variation among the hybrids. Fruit weight varied from 187.03 g to 245.6 g, TSS ranged from 17.6^0B to 28.2^0B, and acidity varied from 0.22 per cent to 0.31 per cent. Additionally, reducing sugars ranged from 12.6% to 20.1%, non-reducing sugars varied from 1.3% to 2.07%, and total sugars ranged from 13.9% to 22.2%.

Ghawade *et al,* (2017) studied on biochemical parameters of custard apple cultivars. The experimental results showed that a large variability was present in custard apple cultivars for biochemical traits. The TSS showed distinct variation among the cultivars and ranged from 19.37 to 28.53 ^{0}B, the acidity of pulp varied from 0.18 to 0.34 per cent, TSS: acidity ratio ranged from 62.50 to 122.73, total sugars varied from 15.72 to 26.22 per cent and reducing sugars varied from 14.13 to 24.27 per cent. In fruit, qualitative characters acidity, TSS, reducing sugars and total sugars pulp per cent were recorded and it varied largely among the cultivars. In all cultivars, Bullock Heart, *Atemoya,* Chance Seedling, Mammoth and Arka Sahan recorded the highest desirable characters.

Kachhadiya and Jethva (2017) studied the physicochemical properties of custard apple. The percentage increase in dimensions of fruits (Horizontal and vertical diameter) on the tree was more rapid in the early stage of fruit setting (0 to 25 days). The average

weight, geometric mean diameter, arithmetic mean diameter, sphericity, surface area, volume, hardness for ripe and unripe fruits were 103.04 g, 57.63 mm, 60.52 mm, 10579.27 mm, 118.38 cm^3, 1.27 kg; 143.57 g, 62.39 mm, 65.60 mm, 0.85, 12283.54 mm^2, 144.09 cm, 3.66 kg respectively. The pulp content, seeded pulp content, seed content, and peel content for ripe and unripe fruits were 35.08%, 47.63%,11.38%, and 51.50%; 31.98%, 40.20%, 7.52%, and 59.29% respectively.

Vinay *et al*. (2016) studied the biochemical changes during off-season flowering in custard apple (*Annona squamosa* L.) cvs. Arka Sahan and Balanagar. Results revealed that in cv. Arka Sahan the total sugars, reducing sugars, and non-reducing sugars content differed among the treatment and ranged from 7.38 – 37.00 µg 100 mg^{-1}, 4.38 – 24.49 µg 100 mg^{-1} and 1.3 – 10.3 µg 100 mg^{-1} respectively, while in cv. Balanagar the total sugars, reducing sugars and non-reducing sugars content differed among the treatments and ranged from 17.3 - 34.5 µg 100 mg^{-1}, 9.7 – 23.9 µg 100 $mg^{-1,}$ and 1.4 – 13.4 µg 100 mg^{-1} respectively.

Prajapati *et al*. (2016) reported the average fruit weight (220.40 g) highest reducing sugars (20.18%), non-reducing sugars (2.07%), and total sugars (22.25%) in a local cultivar of custard apple.

Ghosh *et al.* (2001) observed that Balanagar exhibited the highest fruit length (8.3 cm) than the other varieties and the highest fruit weight (300 g), fruit length (8.3 cm), fruit diameter (9.0 cm), the earliest maturity date (October), the highest number of seeds per fruit (35) and content of total soluble solids (27.0º Brix), reducing sugars (11.8%), non reducing sugars (4.7%), total sugars (16.7%) and ascorbic acid (54.4 mg/100 g pulp). Atemoya and Chance Seedling exhibited the highest acidity (0.32%) content.

Neves and Yuhara (2003) studied the characteristics of fruits of atemoya cultivars produced in Northern Parana State, Brazil. They observed that the average number of seeds per fruit ranged from 23 to 38. The cultivars PR-3, Gefner, Thompson and African Pride had pulp percentages of 58, 63, 46, and 51, respectively. Titratable acidity ranged from 0.17 per cent to 0.30 per cent. Total soluble solids ranged from 16.4 to 26.1°Brix. Physical

and chemical characteristics were also evaluated for the fruit of soursop (*Annona muricata*) in Brazil.

Sahoo *et al*., (2000) observed that Balanagar exhibited the highest fruit length (8.3 cm) and weight (330 g).

Onimawo (2002) reported that variety Balanagar exhibited the highest fruit weight (330 g), fruit length (8.3 cm), fruit diameter (9.0 cm), number of seeds per fruit (35), earliest maturity (October), total soluble solid (27.0°Brix), reducing sugars (11.8%), non-reducing sugars (4.7%), total sugars (16.7%), and Vitamin C (54.4 mg/100 mg pulp).

Choudhari and Shirsath (1976) found a relation between TSS, colour, and shape of the fruit. The red-coloured fruits with red markings and ridged appearance were found to have higher TSS and hard seeds.

Annona squamosa and A. *cherimola* fruits are valued for their nutritional status as compared to other types. The fruits yield about 40-50 percent pulp having 26.4^0B TSS, 5.5 pH, and 0.5 percent tannins (Najundaswamy and Muhadeviah, 1990).

Jagtap and Kokate (1991) selected promising custard apple seedlings from the Pemgiri region in Ahmednagar. The fruits were round and attractive. P-36 recorded the highest average fruit weight (515.0g), the pulp (82.03%), high TSS of 28.20º Brix, and high reducing sugars (24.94%). The custard apple (*A. squamosa*) selections Y-72 and D-90 had the highest TSS: Acidity ratios of 194.00 and 143.50, respectively. Five promising types of custard apple (A. squamosa) viz., P-36, P-42, D-77, D-90, and Y-72 were observed for physicochemical parameters like titratable acidity which ranged from 0.135% to 0.142%. The promising types of custard apple, *A. squamosa* viz., P-36, P-42, D-77, and Y-72 had 28.2%, 28.02%, 26.5%, and 29.1% of TSS, respectively

Shete *et al.* (1991) analyzed 137 seedlings of custard apple for physico-chemical character and observed that TSS varied from 17.75% to 27.30% and the number of seeds per fruit was counted to be 22 to 72.

According to Mincione *et al.* (1993), the cherimoya (*A. cherimola*) cultivars in Calabria, namely Claudia, Anna, Bettina, Daniela, and Elena, exhibited a higher number of seeds per fruit, ranging from 35 to 42 seeds per fruit.

In Mathakar's (2005) research, a selection of 24 Annona hybrids were classified based on their fruit shape. The measured fruit width varied from 3.2 cm to 11.8 cm. Notably, specific hybrid varieties, including Annona hybrid-2, Atemoya, Balanagar and Island Gem, displayed fruit widths of 13.0 cm, 9.0 cm, 8.04 cm, and 10.7 cm respectively (Anon, 2007). The average fruit weight ranged from 187.7 g to 672.5 g, while the pulp percentage spanned from 47.4% to 73.4%. Individual fruit's pulp weight ranged between 70.79 g and 110.13 g, and the number of seeds per fruit varied from 23 to 38. Titratable acidity values were recorded within the range of 0.19% to 0.26%, and the total soluble solids (TSS) fluctuated from 16.0% to 27.0%. The TSS-to-acidity ratios in the hybrids ranged from 70.2 to 163.2. The maturity period of these hybrids ranged from 133 to 154 days. In terms of sugar content, total sugars ranged from 14.75% to 24.35%, reducing sugars ranged from 12.10% to 22.45%, and non-reducing sugars ranged from 1.65% to 2.95% among the different Annona hybrids.

In Jadhav's (2008) evaluation of Annona hybrids, a significant level of variability was observed for both morphological and biochemical characteristics. The study reported notable variations in fruit length (ranging from 5.53 cm to 10.15 cm), fruit breadth (ranging from 6.30 cm to 9.73 cm), number of seeds per fruit (ranging from 18.00 to 26.75), seed percentage (ranging from 6.72% to 11.79%), rind percentage (ranging from 33.83% to 42.59%), and pulp percentage (ranging from 46.48% to 58.96%). Furthermore, variations were observed in TSS (ranging from 20.25º Brix to 26.40º Brix), acidity (ranging from 0.21% to 0.25%), total sugars (ranging from 16.21% to 24.50%), reducing sugars (ranging from 13.73% to 21.64%), and non-reducing sugars (ranging from 1.96% to 2.86%).

A total of seventeen accessions in the custard apple germplasm were examined to assess their growth and yield characteristics. The evaluated parameters included the number of seeds per fruit, which varied from 17.13 to 96.47, and the seed weight per fruit,

which ranged from 5.17 to 27.95g. Additionally, the total soluble solids content was measured and found to range from 16.47 to 27.97 º Brix (Anon., 2006).

Dikshit *et al.* (2008) studied diversity in custard apple germplasm collections of Maharashtra. They collected twenty-one accessions of custard apple germplasm during an exploration program from six districts of Maharashtra. The physicochemical characterization of the fruits revealed variation in average fruit weight (90.8-375 g), total soluble sugar (19-26 %), number of seeds per fruit (21.2-73), weight of pulp per fruit (44.4-188 g) and fruit to pulp ratio (37-54.2).

DaSilva *et al.* (1999) evaluated soursop (*A. muricata*) germplasm in Brazil and observed that the average fruit weight ranged from 369 g to 839 g and the percentage of rind in different accessions ranged between 5.9 to 43.6 per cent and the pulp percentage varied from 54.7 to 89.0.

Dhanumjaya and Subramanyam (2011) conducted an evaluation of custard apple germplasm specifically suited for the scarce rainfall zone under rainfed conditions of Ananthapur, Andra Pradesh. Among the 35 germplasm evaluated, the variety Atemoya x Balanagar exhibited the highest fruit weight, making it a suitable recommendation for cultivation in regions with limited rainfall. Furthermore, in terms of pulp weight, the variety Y.Palli-12 demonstrated the highest measurement compared to the other varieties assessed.

Bhatnagar *et al*. (2012) reported that the maximum pulp weight of 47.0g was observed in a landrace collected from Rajasthan.

In their investigation, Girwani *et al.* (2011) conducted a study to evaluate various custard apple hybrids in terms of fruit yield and quality characteristics. The results demonstrated that Hybrid-1 (‘17/4 Atemoya’ x ‘Balanagar’) exhibited the highest fruit weight of 250 g, followed by Hybrid-6 (‘15/3 Red Sitaphal’ x ‘Atemoya’) with 225 g, and Hybrid-4 (‘1/6 British Guinea’ x ‘Atemoya’) with 220 g. The total soluble solids (TSS) content ranged from 22 to 28°B, with Hybrid-2 (‘15/2 Red Sitaphal’ x ‘Pondapple’)

displaying the highest TSS value. Additionally, Hybrid-2 had the lowest seed number per fruit, with a count of 20.

Inje (2008) selected six promising custard apple seedlings from Purandar. All the custard apple orchards in this region have sprung through seedlings. She reported that there was great variation in fruit characters from orchard to orchard and even from tree to tree in the same orchard. The six promising selections were made, taking into account the quality characters of the fruit and the yielding potential of the tree.

Rao and Subramanyam (2011) evaluated custard apple germplasm for scarce rainfall zones under rainfed conditions. Out of 35 germplasm evaluated the varieties *viz.*, *Atemoya* x Balanagar (highest fruit weight), Y. Palli-12 (highest pulp weight), NLD-8 (maximum T.S.S.), Balanagar SR (more number of fruits per tree) and Ramphal (highest yield per tree) can be recommendable for scarce rainfall zone under rainfed conditions.

Beerh *et al*. (1983) analyzed the physical and morphological properties of custard apple fruits. Linear dimensions of 100 randomly selected fruits viz., length, breadth, and thickness were 84.00, 74.25, and 65.15 mm, respectively. The size and sphericity of custard apple fruit were found to be 74.04 mm and 0.88, respectively. Titrable acidity ranged from 0.32% to 0.41%. The fruits of soursop (*A. muricata*) contained 0.83 - 0.91 per cent total acidity in an observational trial at Hawaii University, USA (Nakasone, 1972).

Custard apple pulp has a titrable acidity that varies from 0.19% to 0.33%, according to Patil and Bhore (1986). They also found that the number of seeds in each fruit of custard apple ranged from 13 to 70, depending on the type of cultivar.

Hirdayesh *et al*., (2016) studied morphological, biochemical, and molecular characters of different cultivars of *Annona* species. TSS content was measured in the fruit pulps of different cultivars of *Annona*. TSS was found in the range of 8.92 to 17.44%. The maximum amount of total soluble solids was recorded in the case of Balanagar (17.44%), which was at par with Anand Selection (16.29%), Sindhan (16.69%), and GJCA-1 (16.63%), whereas the minimum amount of total soluble sugars was recorded in *A.*

muricata (8.92%). Total soluble solids was 14.41, 22.71, 14.62, and 22.51% in *A. cherimola, A. reticulata, A. Atemoya,* and Red Sitaphal respectively.

Thakur and Singh (1966) described and classified some *Annona* species based on various characters. The length of fruit was recorded and *A. reticulata, A. cherimola,* and *A. squamosa* had 8.2 cm, 5.7 cm, and 7.8 cm, respectively. In Mexico, *A. cherimola* cv. Corte's Selection recorded an average fruit length of 14.74 cm (Agustin, *et al*., 2006).

Fuentes and Leon (1999) analyzed different ecotypes of cherimoya selected in Ecuador and observed that average fruit length varied from 8.2 to 9.4 cm and average fruit width ranged from 8.8 to 9.6 cm. Comparatively, the Benimazar and Abd El Razik cultivars of *A. squamosa* had average fruit weights of 180 g and 236.3 g, respectively. On the other hand, the fruits of *A. muricata* weighed between 4.5 and 6.8 kg. In terms of seed count, sugar apple (*A. squamosa*) exhibited a range of 20 to 38 seeds per fruit, average fruit weight ranged from 297 to 778 g and the pulp percentage varied from 80.75 to 88.98 among 13 ecotypes of cherimoya in Ecuador.

Morton and Miami (1987a, and 1987b) conducted studies highlighting the variations in fruit characteristics among different species of Annona. They observed that *A. squamosa* fruits had a length ranging from 6 to 10 cm, while *A. muricata* fruits measured between 10 and 30 cm in length. The fruit width of *A. squamosa* was found to be 8-9 cm, whereas *A. muricata* exhibited a width of 15 cm. In Mexico, the cultivar Corte's Selection of Cherimoya had an average fruit width of 10.40 cm. *Annona squamosa* had an average of 14.58 per cent total sugars, which consisted of 12.23 per cent reducing sugars and 2.35 per cent non-reducing sugars.

Promising cherimoya accessions in Loja Province, Southern Ecuador had an average fruit weight ranging from 431.6 to 926.0 g and a seed content of 1.7 to 6.7 per cent (Scheldeman and Damne, 1999).

Xie *et al.* (1999) found that the cherimoya cultivar AP introduced to China in 1981, is precocious and productive in the Guangzhou area of Guangdong and reported that the

average fruit weight (250 g) is twice that of other cultivars, The authors have also observed that the seed percentage of different genotypes varied from 1.4 to 5.1.

George *et al.* (1999) reported that the objective of the Annona breeding program is to select new varieties of atemoya (*Annona squamosa* x *Annona cherimola*) with smooth skin, symmetrical shape, low seed number (less than 10 seeds per 100 g of pulp).

In Loja Province of Southern Ecuador, cherimoya (*A. cherimola*) tree fruits had 8 per cent seeds on a total weight basis and a pulp percentage varying from 45 to 60 (Scheldeman and Damne, 1999).

In China, Liu and Liu (2000) conducted observations on the African Pride cultivar of *Annona squamosa*, which exhibited favourable performance. The average fruit weight of this cultivar was measured at 326 g, with the fruit containing approximately 18.3 per cent total sugars. Among the sugars, reducing sugars accounted for about 15.8 per cent, while non-reducing sugars constituted approximately 2.5 per cent.

Another study by Wang *et al.*, (2001) focused on investigating the impact of rootstocks on the growth and fruit quality of custard apple. Their findings revealed an average fruit weight of 457.4 g.

Additionally, Cruz and Deras (2000) researched *A. muricata* (soursop) and discovered that the average weight of seeds per fruit was 100 grams, while the fruit itself weighed approximately 1.319 kg.

Annona hybrid-2, Atemoya, Balanagar, and Island Gem recorded 36.6 g, 21.6 g, 11.6 g, and 20.83 g average seed weight, respectively, and observed for seed percentage on a weight basis which ranged from 3.33 to 6.13 per cent (Anon, 2007).

Agustin *et al*. (2006) studied the genetic resources of cherimoya (*Annona cherimola*) in Mexico and reported that the average rind weight of fruits was 139.18 g in cherimoya. The pulp weight per fruit and pulp percentage observed in the fruits of Corte's

Selection, the Mexican cherimoya cultivar was 622.88 g and 77.55 % respectively in Mexico. The TSS content was more than 23°B.

Sacramento *et al.,* (2003) studied the physical and chemical characteristics of fruits of three types of soursop (*Annona muricata*) and reported that the cultivars Lisa, Morada, and Comum had pulp percentages of 85.85, 83.57, and 83.12 respectively. The average value of acidity was 0.94 g/100 g and the cultivars on average had 13.1°Brix TSS.

Jadhav *et al.* (1992) reported a large variation in the total soluble solids of custard apple ranging from 19.3^0B to 28.0^0 B. Continella *et al.,* (1996) reported that, in cherimoya (*A. cherimola*) clones, the TSS content of the fruit was 15.8-19.3°Brix. Dhumal *et al.,* (1997) reported the range of TSS of custard apple from 20.4º to 22.0ºBrix. The TSS content of fruits of cherimoya cultivars grown in Ecuador ranged from 15.6 to 33.0°Brix (Fuentes and Leon, 1999).

The variety APK (Ca)-l registered the highest mean values with respect to TSS (27.97°Brix) (Anon., 2008).

Gardiazabal and Cano (1999) worked on the characterization of 10 cherimoya (*A. cherimola*) cultivars in Chile and reported that the peel percentage of cultivars varied from 10.7 to 14.0. The pulp percentage of cultivars varied from 73.8 to 78.9 and TSS content ranged from 12.6 to 20.0°Brix acidity content varied from 0.6 to 3.6 per cent with natural fruit set ranging from 1 to 3 per cent.

The titratable acidity of Annona Hbrid-2, Atemoya, Balanagar, and Island Gem was found to be 0.43, 0.28, 0.23, and 0.32 per cent, respectively (Anon, 2007).

Amoo *et al*., (2008) reported that the ascorbic acid content of cherimola is 48.38 mg per 100g of pulp. Boake *et al*., (2014) reported that the ascorbic content ranged from 20 to 63.67 mg of 100 pulp of *A. muricata*. Othman *et al*., (2014) reported that the ascorbic content ranged from 19.7 to 34 mg of 100 pulp of *A. muricata*.

The total sugars, reducing sugars, and non reducing sugars content of Annona hybrid-2, Atemoya, Balanagar, and Island Gem were found to be (21.02, 18.85, 2.17), (21.8, 18.30, 3.50), (24.88, 21.98,2.90) and (24.25, 21.43, 2.82) per cent, respectively (Anon, 2007).

George and Nissen (2002) studied the productivity of the Custard apple (*Annona atemoya* Hort.), factors affecting yield and fruit size, and reported that enough flowers are borne on a custard apple plant to give a good crop but the poor fruit set causes low yield. Only one to eight per cent of fruit set has been reported under natural conditions.

Continella *et al.* (1996) studied the fruit and flower biology of cherimoya *(A. cherimola)* clones where the fruit set ranged from 0.5 to 5.1 per cent. Durate and Escobar (1998) reported a very low fruit set percentage (0.98) in cherimoya.

Annona squamosa was investigated for pollen morphology, viability, pollination, and fruit set in custard apple (*Annona squamosa* L.). The results found that the fruit set ranged between 0.75 to 3.33% (Sahoo *et al.,* 2000). George *et al.,* (2002) worked on breeding new varieties of Atemoya (*Annona* spp. hybrids) in which the criteria for selection of superior atemoya cultivars was standardized which includes 3 to 5 per cent fruit set as essential for superior cultivars. The studies conducted in Malaysia involving six selected species of *Annona* revealed that *A. muricata* was low in fruit set. While, fruit set was better *in A. glabra, A. montana, and A. reticulata* (Khalid, 2002).

Vinay and Chitracheluvan, (2015) studied the induction of off-season flowering in custard apple cultivar Arka Sahan and reported that the fruit set percentage ranged from 4 to 6 % in natural pollination and it was 80% in assisted pollination and suggested that assisted pollination was good for getting maximum fruit set percentage in Arka Sahan.

2.2 To study the floral biology in self-fruitful and unfruitful Arka Sahan progenies.

Horticulturists have introduced the terms "self-fruitful" and "self-unfruitful" to classify cultivars based on their ability to produce viable commercial crops when self-pollinated. The term "fruitfulness" describes the state in which a plant not only can flower

and produce fruit but also brings these fruits to maturity. On the other hand, the condition of being unable to achieve this is referred to as "unfruitfulness" (Wani *et al*., 2010).

2.2.1 Flower characters:

Flowering behaviour is very important for fruit set in custard apple because *Annona* is cross-pollinated due to its protogynous nature. George and Nissen (2002) evaluated that the moderate drought (Psi L=-1.5 MPa) reduced shoot growth by 20-30% and increased the number of flowers per lateral by about 40% compared with well-watered controls due to reduced apical dominance and increased lateral branching.

Pinto *et al*. (2005) published a monograph having detailed information on five important *Annona* species that are *A. squamosa, A. cherimola, A. reticulata, A. muricata,* and a wild species *A. diversifolia*. Trees, branches, leaves, flowers, fruits, and seed characteristics for all the above mentioned species have been studied.

The number of flowers per branch varied between 25.87 (IGCA-49) to 43.50 (IGCA-21) with a mean value of 29.64 flowers per branch (Nag *et al.*, 2018).

The information available on node number-bearing flowers to yield and good quality fruit is meagre in fruit crops. In cherimoya, Guirado *et al*., (2001) suggested pollination of basal flowers of 1-year-old shoots as they produce heavier fruits but they have not provided the data in this respect. A similar trend was reported by George and Campbell (1991) in Atemoya.

The floral cycle of this species was earlier described (Wester, 1910), the flowers are hermaphrodites with a strategy of dichogamy protogyny to favour cross-pollination. At anthesis, the flower is female and has a receptive pistil.

Marilza *et al*. (2017) studied the effect of beetle pollination and flowering rhythm of *Annona coriacea* Mart. (Annonaceae) in Brazilian cerrado: Behavioral features of its principal pollinators, and reported that stigma receptivity was found maximum at one day before anthesis and continued up to the day of anthesis.

Nalawadi *et al*. (1975) conducted research on the floral biology of Annona squamosa variety Balanagar under Dharwad conditions. They noted that anthesis and anther dehiscence occurred during the early morning hours, while stigma receptivity was observed to precede the male phase by less than 12 hours.

In cherimoya, the anthesis takes place from 7 am to 9 am, anther dehiscence at 12 pm to 4 pm of the next day of the anthesis, and maximum receptivity is found on the day of anthesis. Atemoya flowers are borne on current season growth, the peak anthesis of flowers at 2 pm to 4 pm then the anther dehiscence occurs after a day of anthesis at 12 pm to 2 pm and the stigma receptivity starts a day before anthesis and continues up to a day after anthesis but found maximum receptivity at the day of anthesis. The anthesis takes place in *A. reticulata* flowers from 6:00 am to 8:00 am and anther dehiscence at 12 pm to 2 pm of the next day of the anthesis and stigma receptivity starts a day before anthesis and continues up to day after anthesis but found maximum receptivity at the day of anthesis. In *A. muricata*, the flowers exhibited protandrous dichogamy, the peak anthesis occurs at 2:00 pm to evening 8:00 pm, anther dehiscence at 4 am to 8 am, and stigma receptivity starts after the completion of the male phase. In *A. glabra*, the anthesis takes place from 7 am to 9 am, anther dehiscence occurs from 12 pm to 4 pm of the next day of the anthesis and maximum receptivity is found on the day of anthesis (Nalawadi *et al*., 1975).

Reynold *et al*. (1984) studied the floral biology and fruit set in mango cultivars, Carabao, Pico, and Kancha Mitha, and reported that stigma receptivity of all three cultivars started at 18 hr before anthesis and continued 72 hr after anthesis, it's optimum on the day of anthesis.

One of the most important features of stigmas is stigmatic receptivity, which is a decisive stage in fertilization success and has a large variability among plant species. In mango, anthesis starts early in the morning and completes at noon and female flower stigmas are receptive to flower anthesis (Bekker, 2009).

Kishore *et al*. (2012) studied the pollination biology of *Annona squamosa*, results revealed that the stigma type is wet, stigma size 1.36 × 1.08 mm, and the peak stigma receptivity found on the day of anthesis (7:00 am – 9:00 pm).

Stigma receptivity may last for a few days but the most receptive period is for the first 6 hours (Spencer and Kennard, 1955).

Agustin *et al*. (2006) characterized seven Mexican germplasm of *A. cherimoya* using the morphometric traits. Twenty-one morphometric characteristics (seven of leaves, nine of flowers, two of fruits, and three of seeds), plus five fruit characteristics were selected for characterizing accessions. The intra-accession variability recorded for the traits selected made them suitable for identifying cultivars.

The receptive stage lasts 1-2 days after anthesis and generally in the first hours of the evening, the cherimoya stigma starts to lose receptivity, the flower becomes male and the anthers initiate dehiscence (Roselle and Gala, 1995).

Stigmatic receptivity was gradually lost in three steps in peach (Hedhly *et al*., 2005). Thus, the stigmas appeared to first lose the capacity to offer for the penetration of pollen tubes to the transmitting tissue; then, they lost the capacity to sustain germination, and finally, the capacity to allow adherence of the pollen grains, the capacity of the stigma to offer good support for pollen grain adhesion and germination and pollen tube penetration to the transmitting the tissue decreased significantly as temperature increased from 10^0C to 30^0C.

The stigma surface began to become moist due to secreted fluid from the noon one day before bloom, being most moist at 7 pm. when petals began to separate apart. The surface was recognized to be moist until the morning of the full blooming day but slightly dry at 7 pm. when the flower opened maximum in atemoya (Kim *et al*., 2005).

2.2.2 Pollen morphology

In their study, Pritchard and Edwards (2006) examined the issue of low natural pollination rates in commercial orchards of the custard apple cultivar Hillary White

(Annona squamosa x Annona cherimola) located on the Atherton Tablelands in North Queensland, Australia. They observed that this low pollination resulted in the production of few and poorly formed fruits. To address this, the researchers conducted supplementary pollination experiments using different types of pollen. The results showed that supplementary pollination, regardless of the pollen source used, significantly increased both the overall fruit production and fruit quality beyond the levels achieved through natural pollination. However, it was found that pollen from African Pride trees, as compared to pollen from Hillary White, resulted in significantly larger and more symmetrical fruits. Importantly, the improved fruit quality did not come at the expense of quantity, as there was no significant difference in mean fruit yield between flowers treated with pollen from either variety. These findings suggest that using African Pride pollen can lead to greater economic returns for custard apple growers, as it enhances the proportion of fruits categorized as 'best' quality.

According to Walker (1971), the presence of pollen grains in tetrads or polyads is common among plants in the Cymbopetalum tribe. However, in some species belonging to the *Hexalobus tribe* (*Isolona* and *Cleistochlamys*), as well as a few species in the Annona tribe (Annona spp., *Rollinia*, and *Rolliniopsis*), pollen grains are rarely found as solitary units. These pollen grains exhibit a heteropolar (or apolar) structure and possess a bilateral (or radiosymmetric) symmetry. Additionally, the pollen grains are characterized by having a catasulcate to cataulcerate aperture, although in certain species like Isolona, Cleistochlamys and some Annona spp., they may lack apertures altogether.

In a study conducted by Donald and Dinesh (2017), the viability of pollen in various pomegranate cultivars was assessed using three different staining methods: acetocarmine (2%), tetrazolium (1%), and erythrosin B (0.1%). The results showed that the pollen viability, as determined by all three staining methods, ranged from 83.34% (MH-1) to 97.81% (Kandhari Kabuli). Interestingly, the mean pollen viability across all the cultivars was found to be the lowest (86.49%) when using the erythrosin B staining method.

The composition and concentration of media are important in pollen germination and pollen tube growth. Sugar served as a nutrient and energy source for pollen tube growth

and also regulated the osmotic potential (Zhang, 2000) while boron could affect germination by affecting H+ -ATPase activity (Feijo *et al*., 1995). The concentration of sucrose and other nutrients required for optimum pollen germination might vary with the species. The increase in sucrose concentration in the media disturbed the osmotic potential in the pollen grain, which inhibited germination in *Cucurbita maxima* (Zhang, 2000).

The duration over which pollen can retain its viability is mainly species-dependent and may range from one hour under dry conditions to several months under low temperatures (Shivanna and Mohan Ram, 1993).

Several studies have been conducted on pollen viability or germination in cherimoya (Saavedra, 1977; Yonemoto *et al*., 1999; Rosell *et al*., 2006; Lora *et al*., 2006), sugar apple (Nietsche *et al*., 2009; Mendes *et al.*, 2017) and atemoya (Neto *et al*., 2009; Pereira *et al*., 2014) among annonaceous fruit crops.

The viability and germinability of pollen grains mainly depended on ambient temperature, humidity, moisture content of the pollen, pollen maturity, and reserve substances, as well as the interactions between these factors (Vesprini *et al*., 2002; Pacini *et al*., 2006). Rosell *et al.*, (2006) found that after anther dehiscence pollen lost its viability rapidly due to its ephemeral life. Temperature and humidity play an important role in pollen dehiscence. Temperature also affects fertility and pollen tube growth (Kakani *et al.*, 2005; Hedhly, 2011). Pollen germination in cherimoya was higher (47-35%) in the temperature range of 20-30°C and considerably lower germination was observed at temperatures above 30°C and below 15°C (Rosell *et al.*, 1999).

Rosell *et al*. (2006) observed a significant reduction in germination of pollen collected after 2 hours of dehiscence in cherimoya. Neto *et al.,* (2009) recorded maximum pollen germination of around 5.9 per cent while Mendes *et al.,* (2012) observed about 19.7 per cent in sugar apple. The pollen viability was 52.5 per cent and 38.5 per cent in seedless and seeded accessions of sugar apple, respectively (Mendes *et al.*, 2012). There are many external (Hedhly *et al.*, 2005; Kremer and Jemric, 2006) and internal factors (Zhang and Fernando, 2005) that can influence pollen germination and pollen tube growth. Sever

(2012) reported that pollen tube growth has a significant negative correlation with both minimum temperature and maximum temperature during the phenophases in Quercus. In Oak, an air temperature of 20°C is needed for pollen germination and optimum tube elongation (Cecich and Haenchen, 1995).

Pollen germination was evaluated *in vitro* and *in vivo* with pollen taken at different times after anther dehiscence (Rosell *et al*., 2006). *In vitro* pollen germination increased along the first hour following sowing in the media, attaining germination values close to those obtained after 20 h of sowing. The pollen is taken up to 90 min following dehiscence (D + 90 min) performed as well as freshly dehisced pollen (D). However, the pollen taken 120 min after dehiscence (D + 120 min) showed a significant reduction in germination. Thus, while the final germination (20 h) of freshly dehisced pollen averages 60%, the pollen taken 120 min after dehiscence gave a final germination of 17%.

Pollen viability is affected by temperatures in cherimoya (Rosell *et al.,* 1999). Low temperature increases the viability of pollens so that the fruit set percentage and quality of fruits is also more when compared to high temperature.

Sahoo *et al*. (2000) recorded the viability of pollen varied from 52.30 to 93.33% in the green types and 45.10 to 93.33% in the red types of custard apple. Further, the highest pollen viability is recorded from June to August in both varieties.

Lora *et al*. (2009) reported that, at 25 ºC, which is the average field temperature during the flowering period of cherimoya, pollen had a viability of 60–70 %, starch hydrolyzed just before shedding, and pollen mitosis II was taking place, resulting in a mixture of bi- and tricellular pollen.

Jalikop and Kumar (2007) studied the pseudo-xenic effect of allied Annona spp. A total of 1080 flowers of cv. Arka Sahan in 2003 and 3420 in 2004 were pollinated with the pollen of *A. atemoya, A. cherimola, A. reticulata, A. squamosa,* and self-pollen. *A. squamosa* pollen gave the highest fruit set (greater than 91%) and the big-sized fruits (greater than 600 g). A good to moderate fruit set was recorded with *A. reticulata* and self-

pollen (31% to 86%); and with *A. atemoya* and *A. cherimola* pollen, the set was poor (4% to 13%), whereas the natural set was as low as 2%.

Germination percentages *in vivo* were highest at 23/24^{0}C. Similar results were reported for litchi where the best temperatures for *in vivo* germination were 22^{0}C /17^{0}C or 27^{0}C /22^{0}C (Stern and Gazit, 1998).

Hellenn *et al*. (2012) studied the pollen germination and fruit set in a 'Brazilian seedless' sugar apple (*Annona squamosa* L.).The percentage of pollen germination *in vitro* was highest for 'Brazilian seedless' (52.5%) and lowest for cultivar Gefner (5.9%).

In cherimoya no effect of temperature was recorded in pollen tube penetration into the style and, after 24 h, most flowers showed pollen tubes reaching the base of the style. The low number of pollen tubes in the style about the initial number of pollen grains on the stigma has also been recorded in other species and is affected by several factors (Herrero, 1992).

Microscopic observation of the stigmatic surface indicated pollen germination after a day of pollination. Moreover, *in vitro* pollen germination (40%) was found in *A. squamosa* and 35% in pollen germination in *Annona cherimola* (Kishore *et al*., 2012).

Lora *et al*. (2012) reported that, from the end of June to mid-September, the cherimoya flowering season, average daily temperatures in the field ranged from 21 to 29 ºC. The percentage of *in vitro* pollen germination during the same period was highly variable, ranging from 27 to 78 %. To evaluate the influence of water content on final pollen development, no pollen germination was observed. In detached flowers, the process appears somehow altered with the highest germination rate (53 %) at dehiscence. However, as might be expected, under field conditions pollen germination showed the highest germination rate at anther dehiscence (64%).

Azeez and Folorunso (2014) studied the pollen studies of annona species in Nigeria and reported that maximum pollen germination in *A. muricata* (37.21%) followed by *A. squamosa* (12.88%) and *A. reticulata* (12.45%).

Pereira *et al*. (2014) studied the pollen germination percentage in the Red and Lessard Thai varieties of custard apple and Gefner variety of atemoya in South Florida at different storage periods and results revealed that maximum pollen germination (37.2%) found in Gefner variety when pollen collected from female flowering stage during the late afternoon and hand pollination performed 18 h after collection, followed by variety Lessard Thai (35.6%) and (26.5%) in variety Red when pollen collected from male flowering stage followed by immediate hand pollination.

Imani (2012) and Mortazavi *et al.*, (2010) reported that germination of pollen could be promoted with boric acid in almonds, date palm, and loquat respectively. Boron has been implicated in many biochemical processes, especially carbohydrate metabolism, and membrane functions of the pollen.

The influence of pollen on seed (xenia) and fruit (metaxenia) is well-known in many crop species (Denney, 1992), including Annona, in which Kahn *et al*., (1994) observed that fruit set, morphology, and quality are dictated by choice of the pollen parent.

Kumar and Das (1996) did pollination experiments involving several almond cultivars to determine the effect of pollen parents on horticulturally desirable nut and kernel characteristics. A considerable influence of pollen parent has been observed on nut size and the time of nut maturation, but no effect was observed on shell hardness, sealing of nuts, or the percentage of double kernels.

Wallace and Lee (1999) studied the effect of pollen source on fruit set and xenia in mandarins. Pollen source significantly affected fruit set, seed number, and sugar content but not fruit weight of mandarin cv. Ellenor. In particular, `Murcott' pollen produced a significantly higher fruit set, relatively low seed number, and the highest sugar content (13.2%) significantly higher than `Imperial' pollen, bagged, and unpollinated treatments (12.5%). Fruit production, seediness, and sugar content of `Ellenor' mandarin may be improved by interplanting with `Murcott'. Cross-pollination significantly increased the seed number of `Murcott' (15±21 seeds per fruit, compared with 13±17 seeds per fruit).

In cherimoya no effect of temperature was recorded in pollen tube penetration into the style and, after 24 h, most flowers showed pollen tubes reaching the base of the style. The low number of pollen tubes in the style about the initial number of pollen grains on the stigma has also been recorded in other species and is affected by several factors (Herrero, 1992).

Annona cherimola (cherimoya) has different pollen quality depending on the phenological stage of the flowers. The in vitro pollen germination and pollen tube growth of nine ecotypes and one cultivar of cherimoya from Ecuador. The results showed that Fabulosa and Austro ecotypes and the Fino de Jete cultivar had the highest pollen germination in the male stage, while Fabulosa had the highest germination in the female stage, also suggested that Austro and Fabulosa ecotypes had the longest pollen tubes and were promising for hand pollination of cherimoya (Maitha *et al*., 2022).

2.3 Assessment of genetic relatedness between parents and progenies

2.3.1 DNA Extraction

Obtaining high-quality DNA from Annona species, such as custard apple, poses a challenge due to the presence of a substantial amount of phenols in their leaves. To address this issue, several methods were employed to establish a standardized protocol for DNA extraction from custard apple leaf samples. The goal was to isolate DNA of sufficient quality for PCR amplification. Valuable insights and guidance for optimizing appropriate protocols were obtained from relevant literature reviews.

Cheng *et al.* (2003) successfully optimized a simple and efficient method for extracting genomic DNA from woody fruit crops that have high levels of polysaccharides. This optimized method proved to be particularly useful for DNA extraction from various fruit trees, including custard apple, fig, pomegranate, mango, guava, pineapple, and papaya. The method involves a modified CTAB and SDS procedure that incorporates a purification step to eliminate polysaccharides using water-saturated ether and 1.25 M NaCl. The DNA obtained using this method was suitable for PCR and RFLP analysis and could

be stored for long periods without degradation. This procedure was successfully applied to isolate DNA from mature leaves of over 20 tropical and subtropical fruit crops.

Majumder *et al.* (2011) successfully developed an efficient DNA extraction protocol specifically for mangoes. In their study, three different plant DNA extraction protocols were evaluated, to identify the most effective method for removing highly concentrated polysaccharides from genomic DNA of woody fruit crops. Ultimately, the water-saturated ether (WSE) method combined with 1.25 M NaCl was established as the most efficient protocol. This method involved a modified CTAB or SDS procedure, which included a purification step using the WSE method to eliminate polysaccharides. Subsequently, DNA precipitation was achieved by adding an equal volume of isopropanol, resulting in the formation of a DNA pellet. The pellet was then washed with 70% ethyl alcohol and easily dissolved in TE buffer.

Soni *et al.* (2011) isolated DNA from various parts of *Annona squamosa*. They studied different parts of *Annona* for their nucleic acid content by using spectrophotometer sample analysis. Spectrophotometry serves various advantages non-destructive and allows samples to be recovered for further analysis. Spectrophotometry uses the fact that there is a relationship between the absorption of UV light by DNA/RNA and its concentration in the sample. They developed a simple, reliable, efficient, and cost-effective method for the isolation, separation, and estimation of total genomic DNA from *Annona*.

A DNA extraction method from Annona leaves was developed by Zhao *et al.*, (2011). This method resulted in the production of high-purity DNA, achieved through the purification process involving 1/10 volume of 3M sodium acetate (pH 5.2) and 2 volumes of ethanol.

Li *et al*. (2010) suggested that the silicon dioxide matrix-based DNA purification protocol allows fast, simple, and economical purification of high-quality DNA for multiple purposes in plant research. No specialized device such as a column or vacuum apparatus and no additional time-consuming and yield-reducing precipitation steps are required. In principle, the DNA preparation by the silica protocol could be easily scaled up to generate

a large amount of pure DNA and is promising for high though put DNA purification applications.

2.3.2 Molecular marker analysis

Among the various molecular markers developed in the past few decades, SSR and SNP markers are found to be efficient, robust, and reliable markers for molecular characterization, mapping, map-based cloning, or marker-assisted breeding programs. However, being genomically less informative, in the present investigation few available SSR markers were used to understand the relatedness between the Arka Sahan interspecific hybrid and the commercial *Annona Squamosa* cultivar Balanagar, Further, these markers were used to screen the progenies for self-fruitfulness.

Simple sequence repeats (SSRs), also known as microsatellites, are present in the genomes of all eukaryotes. These are ideal DNA markers for genetic mapping and population studies because of their abundance. Sequence-tagged site markers are now being increasingly developed as an alternative to RAPD and RFLP markers. These are tandemly arranged repeats of mono-, di-, tri-, tetra-, and pen-ta-nucleotides with different lengths of repeat motifs (e.g. A, T, AT, GA, AGG, AAC, etc.). These repeats are widely distributed throughout plant and animal genomes that display high levels of genetic variation based on differences in the number of tandemly repeating units at a locus. These SSR length polymorphisms at individual loci are detected by PCR, using locus-specific flanking region primers where the sequence is known (Tautz, 1989, Bhat *et al.*, 2010). An advantage of microsatellite type markers is the co-dominant mode of inheritance permitting easy transfer of markers between genetic maps of different crosses in contrast to dominant marker type RAPD which requires the generation of a new map for each cross.

Escribano *et al.* (2007) studied the genetic diversity of cherimoya germplasm using SSRs. In this study, 16 SSR loci were used to find molecular polymorphisms among 279 cherimoya accessions from a worldwide ex-situ field germplasm collection. A total of 79 amplification fragments were amplified with 16 pairs of SSR primers, with an average of 4.9 bands per SSR. Analysis of molecular variance (AMOVA) was performed to examine the distribution of genetic variation of the 148 accessions collected from putative

cherimoya origin areas in Ecuador and Peru, showing that the major variations occurred within valleys in each country. The results confirmed the usefulness of microsatellites for the identification of genetic diversity and geographic origin of *cherimoya*.

Kwapata *et al.* (2007) conducted a study to assess the genetic diversity of *A. senegalensis* Pers. using SSR markers. They collected nine populations from various locations in Malawi and utilized microsatellites or simple sequence repeats developed in *A. cherimola* to evaluate genetic diversity. The analysis revealed the presence of 23 alleles in the studied population, and measures of genetic diversity indicated high levels of heterozygosity, with 4 to 14 alleles observed per locus. The population exhibited genetic differentiation based on theta values. The findings of the study indicated a correlation between genetic and geographical distance in the species, suggesting that large-scale geographical and ecotypic variations were reflected by the SSR markers. The results demonstrated significant differences in the genetic diversity of Annona species. The suitability of SSR markers for characterizing *A. senegalensis* was confirmed, as the markers exhibited a higher level of polymorphism, allowing for the identification of populations and the acquisition of genetic diversity information using a relatively small number of loci.

Escribano *et al.* (2009) established a core collection to optimize the conservation of cherimoya using SSR. They used SSR marker data to develop a core collection in an underutilized subtropical fruit tree species, cherimoya (*Annona cherimola* Mill.), from an initial collection of 279 cultivars from different countries. They compared six alternative allocation methods to construct the core collection. The best subset was obtained with 40 accessions. In this subset, all the SSR alleles present in the whole collection were recovered and no significant differences in the frequency distribution of alleles for any of the loci studied or in variability, parameters were recorded between the core and the whole collection.

Narzary *et al.* (2009) used PCR methods *viz.* directed amplification of minisatellite DNA (DAMD) and random amplification of polymorphic DNA (RAPD) to study genetic diversity among the wild cultivars of *P. granatum* in India. The study was

performed with forty-nine accessions representing two regions of Western Himalaya. The similarity coefficient value was reported to vary from 0.08 to 0.79 across different accessions. Their results indicated that DAMD (97.08%) revealed more polymorphism in comparison to RAPD (93.72%) suggesting the efficiency of these methods in unravelling the genetic variations in wild pomegranates in Western Himalayas.

In their study, Jahnke *et al.* (2009) examined Hungarian grape varieties from the grape germplasm using SSR markers and isoenzymes. Through SSR analysis, they were able to identify 46 out of the 48 investigated varieties. Interestingly, even closely related cultivars such as 'Pinot blanc' and 'Pinot Gris, which belong to the same parentage group (Pinot), were distinguished from each other at the VMC4A1 locus. The findings highlight the importance of these specific descriptors in the registration and protection of cultivars.

Bharat *et al.* (2009) studied genetic diversity in *Annona squamosa* by molecular markers. They found that molecular characterization was a very efficient, effective, and reliable technique to study diversity amongst sugar apple cultivars and the cultivars AKCa 05, AKCa 07, and AKCa 10 can be conserved based on true genetic diversity.

Larranaga and Hormaza (2015) developed species-specific primers for barcoding the different species of Annona having agronomic interest. They used seven important Annona species available in Central and South America such as *Annona cherimola, A. reticulata, A. squamosa, A. muricata, A. macroprophyllata, A. glabra, and A. purpurea* based on the new sequence data. They validated these sequences in six other Annona species and interspecific hybrids and their discriminating power was compared with Matk and rbcL universal primers.

Yoshida *et al,* (1998) studied the genetic diversity of 19 cherimoya cultivars classified into five types based on their skin texture was taxonomically identified by amplified fragment length polymorphism (AFLP). AFLP analysis revealed 33 reproducible amplified bands with an average number ranging from 10-47 bands per primer combination. More than 30% of bands were polymorphic among the cultivars. A total of 264 AFLP bands were enabled to detect the genetic variation among cherimoya cultivars.

The large number of polymorphic loci obtained in AFLP and RAPD analyses contributed to a better resolution for the determination of the phylogeny of cherimoya cultivars than the use of morphological markers.

Huang *et al.* (2003) worked out the molecular characterization of cultivated pawpaw using RAPD markers. Pawpaw is a custard-like fruit. Thirty-four extant pawpaw cultivars and advanced selections representing a large portion of the gene pool of cultivated pawpaw were investigated using 71 RAPD markers to establish genetic identities and evaluate genetic relatedness. The consensus fingerprint profile using the genetically defined RAPD markers is a useful and reliable method for establishing the genetic identities of pawpaw cultivars and advanced selections. This also proved to be an improved discriminating tool over isozyme markers for the assessment of genetic diversity and relatedness.

Pomper *et al.* (2011) examined the genetic diversity of pawpaw cultivars using inter-simple sequence repeat (ISSR) markers. The pawpaw belongs to the genus Asimina, which is the only temperate representative of the tropical Annonaceae family, commonly known as the custard apple family. The main objective of the study was to identify ISSR markers that could be used to assess the genetic diversity in commercially available pawpaw cultivars. Additionally, the researchers aimed to compare the diversity estimates obtained from the ISSR markers with those previously reported for pawpaw using isozymes and RAPD markers.

Sadaphal (2009) reported that RAPD markers had a higher discrimination capacity. The highest level of polymorphism shown by some primers represents the capability of these primers to amplify the less conserved regions of the DNA. The RAPD analysis depicted that varieties used in the investigation showed diversity and thus can be used inbreeding program of the custard apple at the early stages of its growth. It was observed that RAPD markers may be an efficient method of fingerprinting cultivars within and between *Annona* species. Among the markers generated by these, random primers 54 putative variety-specific amplification products were generated and they could be useful for germplasm classification and introgression studies. With the advent of molecular

markers understanding of the precise genetic basis of both quantitative and qualitative characters in custard apple was possible at a cheaper and faster rate.

Ahmad *et al.* (2010) assessed the inter-relationships among four *Annona* species collected from various parts of the South Andaman ecosystem. The results demonstrated that both ISSR and RAPD markers are suitable for characterization and assessment across four *Annona* species and there is a significant difference in the genetic diversity among spp. Analysis of the overall diversity of *Annona* revealed that inter-specific diversity is more than intra-species diversity. This low intra-specific diversity is due to the high degree of gene flow in the population through random mating without a barrier. The close relationship across species might be explained by either a historical relationship to sharing a common ancestor or more likely geographical proximity and large population size which favor genetic interchange.

Cota *et al.* (2011) examined the intra- and inter-populational genetic diversity of *Annona crassiflora* species in the northern region of Minas Gerais State and found it relevant to landscape management, plant genetic resource inventory, and biological conservation of threatened species. They reported moderate genetic diversity among populations, with Shannon's *I* index varying between 0.31 and 0.44 and Nei's genetic diversity (*H*E) for the population set equal to 0.31. AMOVA indicated a greater genetic 15 variation within (77.38%) rather than among populations (22.62%), tending towards isolation by distance (Mantel's $r = 0.914$; $P = 0.089$).

Charcosset and Moreau (2004) focused on the application of molecular markers for two main purposes: the development of new cultivars and the assessment of genetic diversity. Molecular markers have emerged as valuable tools in providing insights into trait variation and the overall genetic diversity of plant species with agricultural significance. These markers enable the analysis of genetic diversity at a global level within a species, allowing for the evaluation of genetic distances or similarities between individuals and populations.

Nagori *et al*. (2018) carried out the cumulative analysis based on RAPD and ISSR data sets and revealed 73.91% polymorphism in *Annona* and a total of 251 amplicons were produced using 19 RAPD and 15 ISSR primers. The pair-wise distance matrix calculated by Dice's co-efficient showed a distance range of 0.67 to 0.95 when computed using a cumulative data set.

MATERIALS AND METHODS

CHAPTER 3 MATERIALS AND METHODS

The present investigations on "**Evaluation and Characterization of Arka Sahan custard apple Progenies for Self fruitfulness**" were carried out during the year 2020-2023 at the Division of Fruit Crops, ICAR-Indian Institute of Horticultural Research (IIHR), Bengaluru-560089, Karnataka. The details of the materials used and methodology adopted during the investigations are given below;

3.1 Location

Field and laboratory experiments were carried out at the Indian Institute of Horticultural Research, Hesaraghatta Lake Post, Bengaluru, situated at 13º71 north latitude and 72º29 east longitude and an altitude of 890 m above mean sea level. The soil is red sandy loam with a pH of 5.2-6.4.

3.2 Weather and climate

Hesaraghatta has a moderately warm climate with mild summer months. The maximum mean temperature varied between 26.83 °C and 35.49 °C with an average temperature of 30.83 °C, while the minimum mean temperature varied between 9.50 °C and 21.72 °C with an average temperature of 18.13 °C during the period of study. The average relative humidity, average wind speed, and total rainfall obtained during the study period are detailed in Annexure I.

3.3 Parental Materials

The ICAR-IIHR developed interspecies hybrid Arka Sahan as a female parent, was crossed with Balanagar variety as pollen parent of custard apple to improve the quality with improved fruit set. The progenies developed by crossing were used for the study, and 1300 progenies were utilized for the evaluation.

Evaluation year : 2020-2023 (3 year)

Spacing : 5 x 5 m

Arka Sahan: It is an interspecific hybrid resulting from the cross between Atemoya cv. Island Gem (*Annona atemoya* Hort.) and Mammoth (*A. squamosa* L.). The fruits of Arka Sahan are typically harvested from September to October. On average, the fruit weighs around 400-450g and takes approximately 6-7 days to ripen. The skin of the fruit has a waxy bloom, appearing light green, and has a moderate thickness of 0.5 cm. The pulp of Arka Sahan is creamy white, juicy, and emits a mild pleasant aroma. It contains fewer seeds, approximately 9 per 100g of pulp. The edible pulp is notable for its sweetness, with a total sugar content of 22.8% and a measurement of over 30°B, while Mammoth registers 24°B. In terms of nutritional composition, Arka Sahan contains 2.49g of crude protein, 42.29mg of phosphorus, and 225mg of calcium per 100g of pulp, in comparison to Mammoth's values of 1.33g, 17.05mg, and 159mg, respectively. Arka Sahan exhibits an average yield of up to 12 tons per hectare.

Balanagar: The tree grows up to 3 m in height. Fruits are spherical, pyramidal, or cordate in shape; medium to big. The average fruit weight is 200 g but recorded up to 640 g; rarely 8.3 cm long and 3.5 cm in diameter. Areoles are tuberculate. Very rough, pitted, forming deep furrows; rind greenish, mesocarp white with coarse and medium granules, pulp white, buttery sweet, with moderate to plenty of juice, flavour excellent; seeds 40–80. Highly productive, fruits remain green when ripe; and rich in reducing sugars and proteins.

3.4.1 Observations

3.3.1 To evaluate the progenies of Arka Sahan x Balanagar for growth, yield, quality, and self-fruitfulness (n=1113)

3.3.1.1 Growth parameters

In a comprehensive research study, a total of 1113 Arka Sahan Custard apple progenies were subjected to rigorous evaluation for various plant morphological traits. This investigation aimed to gain valuable insights into the genetic diversity, variability, potential improvements and self fruitfulness in Custard apple varieties, specifically those falling under the Arka Sahan hybrid.

The evaluated morphological traits encompassed a wide spectrum, including: spreading habit, leaf shape, plant height, leaf length, leaf width and Petiole length.

The meticulous evaluation of 1113 Arka Sahan Custard apple progenies for morphological traits underscores the dedication to advancing horticultural knowledge and improving fruit varieties. The resulting data contributes to the broader understanding of genetic diversity within this cultivar and can guide future breeding efforts and cultivar selections for enhanced horticultural practices and consumer satisfaction.

The morphological observations based on descriptors by Protection of Plant Varieties and Farmers Rights Authority (PPV and FRA), Government of India, New Delhi recorded for the progenies.

3.3.1.1.1 Plant height (m)

The height of the plants was measured by using a standard wooden scale, starting from the base near the soil surface up to the highest point of the crown and expressed in meters.

3.3.1.1.2 Spreading habit

The spreading habit of the plants was recorded based on the predefined shapes provided in the descriptors for custard apple. The plants were scored as either "erect" or "spreading".

3.3.1.1.3 Leaf length (cm)

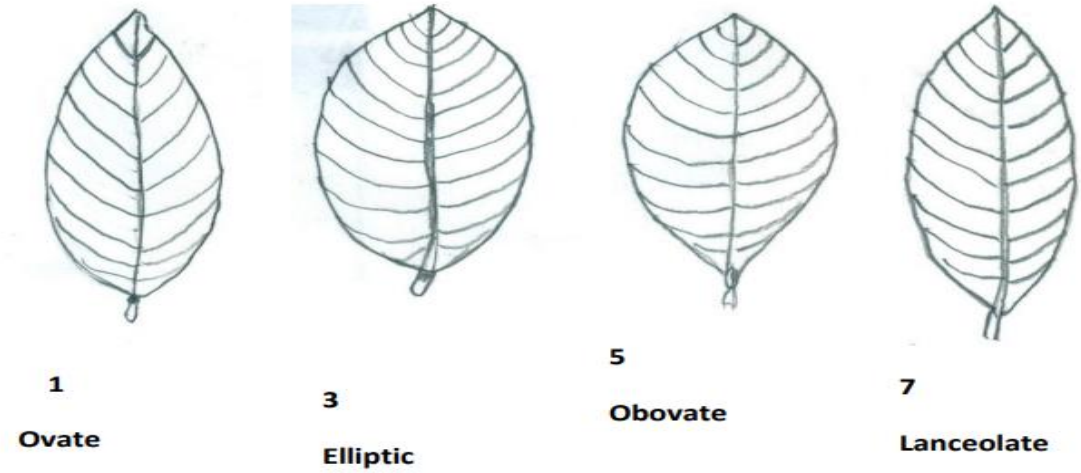
To determine leaf length, ten leaves were selected excluding the petiole, and their average length was recorded and expressed in centimeters. Measurements were taken from the 3^{rd} and 4^{th} positions from the tip of the shoot.

3.3.1.1.4 Leaf width (cm)

For leaf width, the average width of ten leaves was measured at the widest part of the leaf and expressed in centimeters. Measurements were taken from the 3rd and 4th positions from the tip of the shoot.

3.3.1.1.5 Leaf shape

Leaf shape was recorded based on the predefined shapes provided in the descriptors for custard apple. The shapes observed and scored included "ovate," "elliptic," "obovate," and "lanceolate."



3.3.1.1.5 Petiole length (cm)

Petiole length was measured using a measuring scale, starting from the stem to the base of the leaf blade and expresed in centimeter.

3.3.1.2 Fruits and yield parameter (n=222)

Initially, a pool of 1113 progenies underwent a three-year assessment focusing on precocity, regular bearingand self-fruitfulness. Following this initial screening, a subset of 222 progenies were selected for fruit yield and quality attributes. These chosen progenies were then earmarked for a more comprehensive evaluation of their fruit and yield traits.

3.3.1.2.1 Number of fruits per tree

The number of fruits per tree was counted by counting the total of harvested fruits for each tree at every harvest. The number of fruits obtained at each harvest was noted, and the cumulative total of fruits per plant was calculated.

3.3.1.2.2 Yield/tree (kg)

The total number of fruits per tree was counted for each harvest, and the average weight of fruits per plant was calculated and then multiplied by the number of fruits per tree by the average fruit weight.

3.3.1.2.3 Estimated yield (t/ha)

The estimated yield is determined by multiplying the yield per tree with the number of trees per hectare (400) and expressed in tones per hectare.

3.3.1.2.4 Average fruit weight (g)

Using an electronic balance, the weight of five fruits was measured, and the average weight was calculated and expessed in gram.

3.3.1.3 Proximate analysis of Fruits (n=56)

Among the group of 222 progenies displaying exceptional and consistent self-fruitfulness, a subset of 56 progenies exhibited remarkable qualities. These selected progenies not only demonstrated stability but also showcased remarkable traits in terms of fruit physical and quality. Notably, several of these trees bore a significant quantity of fruits, exceeding 30 in number, each weighing more than 200 grams and containing a high total soluble solids content of over 24° Brix total soluble solids (TSS).

3.3.1.3.1 Fruit length (cm)

With the aid of a vernier calliper, the length of the fruit was measured by starting from the fruit base and extending to the top of the groove at the end of the calyx and expressed in centimeter.

3.3.1.3.2 Fruit width (cm)

Fruit width was measured at the broadest part of the fruit with the help of a Vernier caliper and expressed in centimeter.

3.3.1.3.3 Pedicel length (cm)

Pedicel length was measured from attachment to the stem and to the fruit with the help of a measuring scale and expressed in centimeter.

3.3.1.3.4 Pulp weight (g)

Five fruits were randomly selected from each tree after ripening, and their weights were recorded using a Citizen Model I weighing balance model CG302L. The weights were measured after scooping out the pulp and separating it from the seeds and expressed in grams.

3.3.1.3.5 Peel weight (g)

Randomly five fruits were selected after ripening from each tree, and their separation of peel from the pulp weight was recorded by using weighing balance (Citizen Model I model CG302L) and expressed in grams.

3.3.1.3.6 Weight of pedicel (g)

Randomly five fruits were selected after ripening from each tree, and after removing of pedicel from the fruit the weight was recorded by using weighing balance (Citizen Model I model CG302L) and expressed in grams.

3.3.1.3.7 Number of flakes with seed

The number of flakes with seeds present in fruits was separated and counted manually.

3.3.1.3.8 Number of flakes without seed

The number of flakes without seeds present in the fruit was separated and counted manually.

3.3.1.3.9 Weight of seeds per fruit (g)

Randomly five fruits were selected at the time of the ripening stage from each tree, and after the extraction of seeds from fruits, the seed weight was recorded by using weighing balance (Citizen Model I model CG302L).

3.3.1.3.10 Pulp percentage

The pulp percentage of fruit was obtained from the following formula:

$$\text{Pulp (\%)} = \frac{\text{Pulp weight}}{\text{Total weight of fruit}} \times 100$$

3.3.1.3.11 Seed percentage

The seed percentage of fruit was obtained from the following formula:

$$\text{Seed content (\%)} = \frac{\text{Seed weight}}{\text{Total weight of fruit}} \times 100$$

3.3.1.3.12 Peel percentage

The peel percentage of fruit was obtained from the following formula:

$$\text{Peel content (\%)} = \frac{\text{Peel weight}}{\text{Total weight of fruit}} \times 100$$

3.3.1.3.13 Pulp-Seed ratio

The pulp: seed ratio was calculated by dividing the weight of the pulp by the weight of the seed.

3.3.1.4 Fruit biochemical parameters

From the 222 progenies that exhibited remarkable and unwavering self-fruitfulness, a specific subset of 50 progenies was singled out for detailed biochemical analysis.

3.3.1.4.1 Total soluble solids (°Brix)

The total soluble solids (TSS) of the fruit pulp from all the self-fruitful trees were measured using a digital refractometer (DBX-55), which utilizes the principle of total refraction. The TSS measurements were expressed in Brix units.

3.3.1.4.2 Reducing and non-reducing sugars (%)

Determination of Reducing Sugars was done by using the Nelson-Somogyi Method a quantitative method of determination of reducing sugars (Somogyi, 1952, Krishnaveni *et al.*, 1984).

Principle: The reducing sugars when heated with alkaline copper tartrate reduce the copper from the cupric to cuprous state and thus cuprous oxide is formed. When cuprous oxide is treated with arsenomolybdic acid, the reduction of molybdic acid to molybdenum blue takes place. The blue colour developed is compared with a set of standards in a colourimeter at 620 nm.

Materials

Alkaline Copper Tartrate

(i) To prepare a solution, combine 2.5 g of anhydrous sodium carbonate, 2 g of sodium bicarbonate, 2.5 g of potassium sodium tartrate, and 20 g of anhydrous sodium sulfate in 80 ml of water. Then, make up the volume to 100 ml.

(ii) For another solution, dissolve 15 g of copper sulfate in a small volume of distilled water. Add one drop of sulfuric acid and make up the volume to 100 ml. Before use, mix 4 ml of solution B with 96 ml of solution A.

(iii) To prepare the arsenomolybdate reagent, dissolve 2.5 g of ammonium molybdate in 45 ml of sterile distilled water. Carefully add 2.5 ml of sulfuric acid and mix thoroughly. Subsequently, add 0.3 g of disodium hydrogen arsenate dissolved in 25 ml of water. Mix well and incubate for 24-48 hours at 37°C.

(iv) For the standard glucose solution, prepare a stock solution containing 100 mg of glucose in 100 ml of distilled water.

Procedure

1. Weigh 2g of the sample and extract the sugars with hot 80% ethanol twice (5 ml each time).
2. Collect the supernatant and make up the volume to 25 ml.
3. Evaporate known quantity by keeping it in a water bath at 80°C.
4. Add 10 ml water and dissolve the sugars.
5. 5 ml for reducing sugars and the remaining 5 ml for total sugars.
6. Pipette out aliquots of 0.1 ml to test tubes and add 0.9 ml water.
7. Add 1 mL of alkaline copper tartrate reagent to each tube.
8. Place the tubes in boiling water for 10 minutes.
9. Cool the tubes and add 1 ml of arsenomolybolic acid reagent to all the tubes.
10. Make up the volume in each tube to 10 ml with water.
11. Read the absorbance of the blue colour at 620 nm after 10 min.
12. From the graph drawn, calculate the amount of reducing sugars present in the sample.
13. For Total sugars, add 1N HCl to the sample and keep it overnight.
14. Next day neutralize it by adding 2-3 drops of Phenolphthalein indicator and 40% NaOH until it turns to pink colour. Make up the volume to 10 ml with distilled water.
15. Estimate Total sugars using the same procedure given in reducing sugars.
16. Calculate the number of Total sugars present in the sample.

Calculation:

$$\text{Reducing Sugars}\left(\frac{g}{100g}\right) = \frac{OD620nm \times \text{Std. value } (\mu g/OD) \times \text{Total volume} \times \text{Total Vol. of extract} \times 100}{\text{Assay volume} \times \text{Simple taken for drying} \times \text{Wt. of the sample (g)} \times 1000 \times 1000}$$

$$\text{Total Sugars}\left(\frac{g}{100g}\right) = \frac{OD620nm \times \text{Std. value } \left(\mu \frac{g}{OD}\right) \times \text{Total volume} \times \text{Total Vol. of extract} \times 100}{\text{Assay volume} \times \text{Sample taken for drying} \times \text{Wt. of the sample (g)} \times 1000 \times 1000 \times 2}$$

Non reducing sugars (%) =Total sugars –reducing sugars

3.3.1.4.3 Total Antioxidant activity (mg AEAC/100g)

The DPPH (Diphenyl-1-picryl hydroxyl) radical scavenging ability assay, developed by Kang and Saltveit in 2002, is used to assess antioxidant activities in a relatively short time. The assay is based on the reduction of DPPH radicals in methanol by antioxidants, resulting in a reduction in absorbance at 517 nm.

The principle of the assay involves the reduction of the stable DPPH radical by the antioxidant (AH) present in the sample being tested.

Reagents

80% methanol

0.2mM DPPH: Dissolve 8 mg of 1, 1-Diphenyl-2-picryl hydroxyl in 100 ml of ethanol

10mM acetate buffer, pH 5.5

Ascorbic acid standards (20 – 100 µg/ml)

Procedure

Extract the sample (5g) with 50 ml of 80% methanol. Take 0.2 ml of extract in a test tube; add 0.3 ml of acetate buffer followed by 2.5 ml of DPPH solution, and mix. Read the absorbance of the solution spectrophotometrically at 517 nm after 30 minutes of incubation (A_1). Read the absorbance of DPPH solution without a sample (A_2). Calculate the difference in the absorbance of DPPH solution with and without a sample ($A_2 – A_1$). The decrease in absorbance with sample addition is used for the calculation of antioxidant activity. Develop a standard curve using different concentrations of ascorbic acid (20-100 µg/ml). Express the results as ascorbic acid equivalent antioxidant capacity.

Calculation

Calculate the difference in absorbance of DPPH solution with and without ascorbic acid (b_1-a_1). Divide the concentration of the ascorbic acid by the difference in absorbance to arrive at the amount of ascorbic acid per unit absorbance (µg/OD) **-** **(**a)

Calculate the antioxidant concentration in the sample extract (µg/ml) by multiplying the

$$\underset{capacity}{Antioxidant}\left(mg\,\frac{AEAC}{100g}\right)=\frac{\text{absorbance of sample with (a)– (b)}\times\text{Total volume}\times 100}{\text{Assay volume}\times\text{Wt of sample (g)}\times 1000}$$

3.3.1.4.4 Total phenols

Total phenol content is estimated by a spectrophotometric method using Folin Ciocalteu Reagent (FCR) (Singleton and Rossi, 1965).

Principle

Phenols react with the oxidizing agent phosphomolybdate in the Folin-Ciocalteau reagent and form a blue-coloured complex, molybdenum blue which is measured at 700nm.

Reagents required

80% Methanol

Folin- Ciocalteau's Phenol Reagent (1N)

20% Sodium Carbonate (Na_2CO_3)

Standard phenol (Gallic acid) solution (20-100 µg/ml) prepared in 80% methanol

Procedure

Homogenize 5g of the sample with 20 ml of methanol (80%) using a pestle and mortar, repeating the process 2-3 times. Combine the extracts obtained and adjust the volume to 50 ml. Next, take 0.5 ml of the extract and transfer it into test tubes. Add 0.2 ml of Folin-Ciocalteau's Phenol Reagent, followed by 3.3 ml of distilled water. Mix the contents thoroughly. After 2 minutes, introduce 1 ml of sodium carbonate solution and mix again. Allow the mixture to stand at room temperature for 30 minutes. Finally, measure the intensity of the blue colour using a spectrophotometer at a wavelength of 700 nm. To establish a standard curve for phenols, employ gallic acid (GA) as the standard compound.

Calculation

$$\text{Total phenol content (mg Gallic acid equivalents/100g)} = \frac{\text{OD@700nm} \times \text{Standard Value (µg/OD)} \times \text{Total volume of extract} \times 100}{\text{Assay volume} \times \text{Weight of the tissue (g)} \times 1000}$$

3.3.1.4.5 Total flavonoids

Flavonoids develop a brick-red colour with $AlCl_3$ and $NaNO_2$ at alkaline pH. The absorbance of the complex is read at 510 nm (Chun et. al, 2003).

Reagents required

80% methanol

10% Aluminium chloride ($AlCl_3$)

5% Sodium nitrite ($NaNO_2$)

4N Sodium hydroxide (NaOH)

Standard quercetin in 80% methanol (20 - 100µg/ml)

Procedure

Homogenize 5g of the sample with 20 ml of methanol (80%) in a pestle and mortar 2-3 times. Pool the extracts and make up the volume to 50 ml. Take 1.0 ml of extract in tubes, and add 0.3 ml of 5% $NaNO_2$. Wait for 2 min and add 0.3 ml of 10% $AlCl_3$. After another 2 min, add 3.4 ml of NaOH and Allow to stand at room temperature for 10 minutes. Read the absorbance at 510 nm against blank. Use catechin or quercetin as standard.

Calculation

$$\text{Total flavonoid content (mg catechin equivalents/100g)} = \frac{OD_{510} \times \text{Std. value (mg/OD)} \times \text{Total Vol. of extract} \times 100}{\text{Assay volume} \times \text{Wt. of sample (g)}}$$

3.3.1.4.6 Titrable acidity

The acidity of the 10 g pulp samples was determined by diluting an aliquot of the sample with distilled water and titrating with 0.1N NaOH using phenolphthalein as an

indicator. The end point appeared as light-pink colour. The calculated acidity was expressed as percent anhydrous citric acid (Ranganna, 1986).

$$\text{Total acidity (\%)} = \frac{\text{Titrate value} \times \text{Normality of alkali} \times \text{Volume made up} \times \text{Equivalent weight of acid} \times 100}{\text{Volume of sample taken for estimation} \times 10 \text{ ml} \times 1000}$$

3.3.1.5 Statistical analysis of diversity studies on progenies of Arka Sahan Custard apple

Analysis of variance and components of genetic variability such as mean, range, genotypic and phenotypic coefficient of variance (GCV and PCV respectively), heritability and genetic advance as per cent mean (GAM) were estimated using standard procedures. Multivariate analysis (cluster analysis), correlations and principal component analysis were performed on the data obtained, as detailed here.

3.3.1.5.1 Analysis of variance

Analysis of variance for each trait was estimated by using the SPSS software package Version17.0. Analysis of variance for each character was carried out by using a Randomized Block Design. The significance test was carried out by referring to the 'F' table value given by Fisher and Yates (1963).

3.3.1.5.2 Coefficient of variation

Genotypic and phenotypic coefficients of variation were computed according to Burton and Devane (1953) based on the estimate of genotypic and phenotypic variance as follows:

$$GCV = \frac{\sqrt{\text{GV}}}{\bar{X}} X\ 100$$

$$PCV = \frac{\sqrt{\text{PV}}}{\bar{X}} X\ 100$$

Where, GCV = Genotypic coefficient of variation

PCV = Phenotypic coefficient of variation

GV = Genotypic variance

PV = Phenotypic variance

$\bar{X}$ = General mean of character

Further, the PCV and GCV were classified as suggested by Sivasubramanian and Madhava (1973):

0 – 10%: Low

10 – 20%: Moderate

20% and above: High

3.3.1.5.3 Heritability

Heritability in the broad sense refers to the proportion of genetic variance to the total observed variance in the population. It has been estimated as per the formula given by Lush (1940).

$$h^2(b) = \frac{\text{Genotypic variance } (\sigma 2\ g)}{\text{Phenotypic variance } (\sigma 2\ p)} \times 100$$

Where, σ2 g and σ2 p are the genotypic and phenotypic variances.

Further, the range of heritability in a broad sense was classified as suggested by Johnson *et al.,* (1955) as Less than

30% : Low

30 – 60% : Moderate

More than 60% : High

3.3.1.5.4 Genetic advance as per cent mean (GAM)

Genetic advance as per cent mean was worked out for each character adopting the formula given by Johnson *et al*., (1955)

$$\text{GAM} = \frac{\text{GA}}{\bar{X}} \text{ x } 100$$

Where, Genetic advance (GA) = k x σ2 p x h2

K: Selection differential which is equal to 2.06 at 5% intensity of selection

σ^2 p: Phenotypic standard deviation

h^2: Estimated heritability and

x̄: General mean

The range of genetic advance as per cent mean was classified according to Johnson *et al.*, (1955).

Low: Less than 10%

Moderate: 10 – 20%

High: More than 20%

3.3.1.5.5 Genetic divergence analysis

The fruit anatomical data data collected from fruits of selected Arka Sahan Custard apple progenies were assessed for genetic distance and the similarity matrix was used for sub-cluster development by using the SPSS software. Principal component analysis was carried out as per the procedure described by Banfield (1978) using the SPSS software package Version 17.0. It is defined as a method of data reduction to clarify the relationships between two or more characters and to divide the total variance of the original characters into a limited number of uncorrelated new variables.

3.3.1.5.6 Correlation coefficient analysis

To determine the degree of association among the characters, the correlation coefficients were calculated. Yield per tree with fruit traits and fruit set with floral traits were determined by using the variance and covariance components as suggested by Al-Jibouri *et al.*, (1958).

3.4.2 To study the floral biology in self-fruitful and unfruitful Arka Sahan progenies

A total of 70 progenies of Arka Sahan were chosen for the study, comprising 50 self-fruitful progenies and 20 unfruitful ones. The selection of these progenies was based on the criteria of the number of fruits produced per tree.

3.4.2.1 Phenological study

3.4.2.1.1 Flowering time

The flowering time of a plant was noted by observing the duration in which it produced flowers.

3.4.2.1.2 Flower bud diameter (mm)

The flower bud diameter was measured at the broadest part of the flower bud with the help of a Vernier calliper and expressed in millimeter.

3.4.2.1.3 Flower length (cm)

The length of the flower was measured by measuring from the base of the flower to its tip by using a Vernier calliper and expressed in centimeter.

3.4.2.1.4 Duration of flowering

The duration of flowering was calculated by determining the difference in days between the date of the first flower and the date of the last flower.

3.4.2.1.5 Pedicel length (cm)

Pedicel length was measured by utilizing a measuring scale and noting the distance between the points of attachment to both the stem and the flower and expressed in centimeter.

3.4.2.1.6 Petal colour

The outer colour of the petals was determined by referencing the Royal Horticultural Society (RHS) Colour Chart. This was done by comparing one or more of the petals to the colour cards on the chart until a matching colour were found.

3.4.2.1.7 Petal inner Colour

The inner colour of the petals was determined by referencing the Royal Horticultural Society (RHS) Color Chart. This was done by comparing one or more of the petals to the colour cards on the chart until a matching colour were found.

3.4.2.1.8 Petal lenght (cm)

The length of a petal was measured by using a measuring scale and noted from the base of the petal to its tip and expressed in centimeter.

3.4.2.1.9 Petal width (cm)

The width of the petal was measured by using a Vernier calliper to determine the distance between the two opposite edges of the petal at its widest point and expressed in centimeter.

3.4.2.1.10 Anthesis time

The anthesis time was recorded by continuously monitoring the flowers until their petals fully opened, starting from the point when the petals began to unfold or separate.

3.4.2.1.11 Anther dehiscence time

Anther dehiscence time is determined by observing the signs of the splitting or opening of the anther sacs, which results in the release of pollen.

3.4.2.1.12 Diameter of stigma (mm)

The diameter of the stigma was measured using a Vernier calliper by measuring the widest part of the stigma and expressed in millimeter.

3.4.2.1.13 Stigma receptivity

Stigma receptivity was observed by using the hanging drop method This method involves placing a drop of hydrogen peroxide on the stigma and observing the formation of bubbles. (Dafni, 1998 and Makwana, 2017).

3.4.2.1.14 Days required for first flowering (days)

The number of days required for flowering was recorded by observing the emergence of the first flower after pruning.

3.4.2.1.15 Initial angle of the petal opening

The initial angle of the petal opening was measured by placing the flower in its early stage of petal opening on a protractor. The baseline of the protractor was aligned along the line of petal separation, and the angle at which the petals initially started to open was recorded.

3.4.2.1.16 Final angle of petal opening

The final angle of the petal opening was measured by placing the flower in its fully opened stage on a protractor. The baseline of the protractor was aligned along the line of petal separation, and the angle at which the petals initially started to open was recorded.

3.4.2.1.17 Number of flowers per 10 cm shoots

The number of flowers per 10 cm shoots was recorded by counting the total number of flowers present within the 10 cm section of the selectively chosen representative shoot from the plant (Rouby *et al*., 2008)

3.4.2.1.18 Fruit set (%)

The natural fruit set percentage was calculated by counting the number of flowers and fruits on a sample of stems or branches.

$$\text{Natural fruit set percentage} = \frac{\text{Number of fruits}}{\text{Number of flowers}} \times 100$$

3.4.2.1.19 Fruit drop (%)

The fruit set percentage was then calculated by dividing the number of fruits by the number of flowers and multiplying by 100. (Ghosh, 2017).

$$\text{Fruit drop percentage} = \frac{\text{The number of fruits that drop}}{\text{Total number of fruits}} \text{x } 100$$

3.4.2.1.20 Time taken for fruit maturity (Days)

The time taken for the fruit set, measured in days, was recorded starting from the date when the fruit set occurred till the harvesting stage.

3.4.2.2 Pollen morphological study

3.4.2.2.1 Pollen viability using Alexander stain

Fresh pollen grains from flowers were collected separately in glass petri dishes and transferred separately to the microscopic slide. A drop of 1 % Alexander stain solution was placed in the centre of the slide and viewed under the light microscope after a few minutes. Pink–deep stain pollen grains were counted as viable ones while unstained were counted as non–viable ones. (Shivanna and Rangaswamy, 1992).

$$\text{Pollen viability (\%)} = \frac{\text{Number of viable pollen}}{\text{Total number of pollen}} \times 100$$

3.4.2.2.2 Pollen germination (%)

Media: For the preparation of 5 % sucrose and 100 ppm boric acid in 100 ml distilled water, weigh 5 gm sucrose and 10 mg boric acid and add to the distilled water then mix clearly. The solutions were prepared always fresh before the study.

3.4.2.2.3 In vitro pollen germination

The germination of fresh pollen grains was assessed with the hanging drop technique (Gaaliche *et al*., 2013). A drop of germination medium was placed on a cover slip and the pollens collected at the time of anther dehiscence time were dusted onto the drop. The cover slip was inverted and placed over a concave depression on a slide, using Vaseline to seal the coverslip and prevent desiccation. Five slides were prepared per plant material.

After three hours the slides were examined under a microscope and germinated slides were made permanent by transferring the cover slip to the plain slide and adding a drop of methylene blue stain by using fevikwik gum to seal the slides. After drying of gum, germination count was taken on each slide under a compound microscope at 10x

magnification. A mean value was calculated for each slide and the mean of five slides of each plant material was considered as the germination percentage.

$$\text{Pollen germination } (\%) = \frac{\text{Number of germinated pollen}}{\text{Total number of pollen}} \times 100$$

3.4.2.2.4 Pollen tube growth (µm) 0

Pollen tube growth was observed and measured by using 10 x magnifications in a Zeiss-axioplan microscope. An average of five different pollen tube growths was taken for each replication.

3.4.2.2.5 Length of the pollen (µm)

The polar length of the pollen grain was measured using ZEISS EVO 18 SEM at 10 µm magnification. The length of 10 pollen grains was measured.

3.4.2.2.6 Equatorial width of the pollen (µm)

The Equatorial width of the pollen grain was measured using ZEISS EVO 18 SEM at 10 µm magnification. The equatorial length of 10 pollen grains was measured.

3.3.3 Assessment of genetic relatedness between parents and progenies

From a population of 1,113 Arka Sahan Custard apple progenies, a total of 200 progenies were carefully chosen for the study. Among these 200 progenies, 100 of them were identified as self-fruitful, exhibiting the highest fruit-bearing potential, while the remaining 100 progenies were classified as zero-fruit-bearing trees. This selection process was carried out to ensure a representative sample for the research.

3.3.3.1 DNA isolation

About 2 grams of young fresh leaf samples were used in DNA extraction using the 4% CTAB method. The two grams of leaf sample were ground in liquid nitrogen using a mortar and pestle. The pulverized leaves were quickly transferred to liquid nitrogen. The 4% CTAB buffer (10 ml) containing 1% (v/v) mercaptoethanol and 1% PVP was quickly added to the macro centrifuge tube (20 ml) and stirred with a glass to mix. The content was

incubated at 65°C for 1 hr. with frequent shacking. An equal volume of chloroform: Isoamyl alcohol (24:1) was added and centrifuged at 13000 rpm and 4°C for 15 min to separate the phases. The upper phase supernatant was carefully decanted and transferred to a new tube. The above steps, beginning with the addition of chloroform: isoamyl alcohol (24:1) and ending with decanting of supernatant, were repeated twice. The supernatant was precipitated with 10ml of ethanol and 3 M sodium acetate and incubated at -20°C for overnight. The precipitated pellet was collected and washed twice with 75% ethanol. The pellets were air-dried and re-suspended in $T_{10}E_1$ buffer (Nagori *et al*., 2018).

3.3.3.2 DNA quality and quantity assessment

DNA concentration was quantified using a Spectrophotometer/Nanodrop and also by gel electrophoresis (0.8% agarose gel was used to check the quality of DNA). The purity and concentration of guava DNA were quantified using a spectrophotometer by calculating absorbance at 260nm, 280nm, and 260/280nm ratio. The 260nm/280nm calculated absorbance ranges from 1.6 to 1.8 and reflects high-quality DNA. A PAGE was prepared, and agarose gel electrophoresis was performed. The gel was documented under the UVI-pro gel documentation system after the gel run.

3.3.3.3 Dilution of DNA samples

A part of the DNA samples was diluted with an adequate amount of TE buffer to obtain a working concentration of 50 ng/µl and stored at 4 °C.

3.3.3.4 Selection of SSR primers

A total of 65 SSR primers were used to study the genetic relatedness among parents and progenies (Anuragi, 2016. Escribano *et al.,* 2009).

Sequences of 16 SSR primers used for the study

Sl. No.	Locus	Forward and Reverse (5^{I}-3^{I})
1	LMCH 1	F- CTCTTCAAAGGTACGACTTC R- TTGAGAAAAGGATAAGGATT
2	LMCH 2	F- CATTAACAGAGCATCAAAAT R- AGATTGAGAAGTCGTACCTT
3	LMCH 3	F- TCTGTGAAAATACTCTCGTA R- TCTCCACTGAATAATCTTTAAT
4	LMCH 4	F- ATTAGAACAAGGACGAGAAT R- CCTGTGTCTTTCATGGAC
5	LMCH 5	F- CCCACTCTTCTACCCTCAAC R- CAAGTCCCTGTAAGAATCAGA
6	LMCH 6	F- GGCATCCTATNITCAGGTTT R- TTAAACAT TT TGGACAGACC
7	LMCH 7	F- ATCACCAACACTGAATCT TA R- AATTTTTACCTGTAGACGTG
8	LMCH 8	F- AATTACGCAGATCACAGTAGC R- CATCTTGCCTTGCTCTCTAC
9	LMCH 9	F- TCAAACACGTATAGAAAACC R- TATGTGAAAGATCAAAAAGAG
10	LMCH 10	F- TTCT TGTTGGGAAGTATAGA R- GAAATCAATGTAGGTGTGAC
11	LMCH 11	F- TACCTCTCGCTTCTCTTCCT R- GATGATTAGACACAAGTGGATG
12	LMCH 13	F- ATACGACTAGCGGAGCAGAC R- GAGAATGTCGAGGGAGATGT
13	LMCH 16	F- TGAAAAATAACAAGAATGTAA R- GGATAAACAAAGCAGTAAATC
14	LMCH29	F- GTACCATCTTTTAGGAAATC R-TGCAATCTATGTTAGTCAC
15	LMCH33	F- AAGAAATGGGAGTAAATAGTG R- ACGGTTGTGAATAGTTGAGT
16	LMCH34	F- ATTTGACGGTGTTAAGGTGGT R- TATGTAGGAAATGACCAGGCTA
17	LMCH36	F- ATAGAAGATTTACCCAGGAG R- GTAAGTAGCTGATTGTTGATCT
18	LMCH37	F- TATCGACAACATAGAAAAGTTA R- TAGTTAAATCACATCGTATGAC
19	LMCH38	F- GTTAAGAACCAACAAAAGAAAT R- CCCCTCTATTCCCTCTCTAT
20	LMCH39	F- AATTTGTATGGTGTTGACAG R- AGTTGTAGGTGGTTTAAGTTC
21	LMCH40	F- ACTCAGCAAGATAAAGAATAGGG R- GAGTGCCGCTAGTCAAGATT

Sl. No.	Locus	Forward and Reverse (5^{I}-3^{I})
22	LMCH42	F- TTTATCATTACGAGAGTTATCA R- AAAGTTGTCCTTTTACTCCT
23	LMCH43	F- CTAGTTCCAAGACGTGAGAGAT R- ATAGGAATAAGGGACTGTTGAG
24	LMCH48	F- TTAGAGTGAAAAGCGGCAAG R- TCAAGCTACAGAAAGTCTACCG
25	LMCH53	F- GATGACGATGATAAGAATTT R- GTGCTCAGTTCTACACTAACT
26	LMCH54	F- AGTTAGTGTAGAACTGAGCAC R- GAGGAAGAAAAATAGAGGAC
27	LMCH57	F- TTTTTGGGAGCTTTGCTGTT R- GAGGTCCACGTAATGAATGG
28	LMCH63	F- TTCCCCAAAATAATGAAATA R- ATGAAGAACCGAATACAAAA
29	LMCH68	F- GTTGCAAGTGGCGATAACAATA R-ATCCCTCTCGTTGACTCGTTTA
30	LMCH69	F- AGCTTTAGCCATGAATTAGA R-GAAAGGCTGACGAGATATAA
31	LMCH70	F- GAAGTTTTAGAGGCGATTCC R-TTTTGCCACTTTACTGTCAC
32	LMCH71	F- AGATAACACCCGCCCACTAT R-ACAACTTTTCTCCCAACCTATC
33	LMCH72	F- AATATGGACTTGTTGTAGTCTT R-ATATACGTTTGTTCCTGTTCT
34	LMCH73	F- CCAGTCCACTTATGCCTGTG R-ATCCACGTAAATAATGCAACAA
35	LMCH78	F- ATTTGATTGATTGATTTCCTA R-CTTTTGCTTTCTTTCACATC
36	LMCH79	F- GAAGCAAGTAGACACGTAGTA R-AGGGTTGGTATTTCTTTATAGT
37	LMCH80	F- AAAACAGAGACTAAAATGAAAT R- GAAGATATGCAAGGTATAAATC
38	LMCH83	F- CTCTCGTTGACTCGTTTACT R- GGTCTCTAGCCTTTACAATC
39	LMCH87	F- AGTTAAGACACGAGATGATAAA R-CAAGTAAAGACTGAAAGGTTG
40	LMCH88	F- GGGAGTTATTAGAGTGTTATTG R- AAATTAAGGATTGACTATTTCA
41	LMCH89	F- AATACAAATGGAGACGAATA R- GTGTCTAATACCATACATACCA
42	LMCH90	F- AAGAGCATTCTTGTGATCCT R- AAGTCTCAGTAGGGTTGATTT
43	LMCH91	F- CCTTGAGAAAGTGTCATCTAT R- ATAATCCTAGACCATAAAATTC

Sl. No.	Locus	Forward and Reverse (5^{I}-3^{I})
44	LMCH92	F- ATGTTGAAAAGAGCGTATAA R- GAAAAGATAGGAAAACTTATTG
45	LMCH93	F- GTTGACCTTGTTCTCGATCC R- CTCCCTCATGTTTTGCTTTT
46	LMCH96	F- AGAAGCTGGGAAACAAAACA R- ATTCTGGCTTTTAATTGAGGA
47	LMCH98	F- ATACAAGAGTGATATTGATTCG R- GTCTCAGCTACTTCTCCTGA
48	LMCH102	F- GCTAACCATCCATTTACATA R- ATAACATTCTTTATCACCATCT
49	LMCH103	F- CACAATAATCAGAAAAACATCA R- GTGTCTCGTATCCCTCCATA
50	LMCH106	F- AACAAATGACAGGAGAGC R- ATAATGTATATGACGCTGCT
51	LMCH108	F- TTAGCCTCAGCCATTACTTA R- ACTCTTCAAACGATGAAAAC
52	LMCH109	F- TATAAAATGGGAAAGCGATCT R- CCTCAAAGAGCAATAATCAGC
53	LMCH112	F- TAACCCAGGATCTACAATAAT R- TTGCATACATTTTCCTATTT
54	LMCH114	F- AAAATGTAGTGTGAAAGATGAC R- GTCCATTCAGTTTTAAGTGC
55	LMCH115	F- TATAATCCATCAACACAAATAA R- TTAGATACACAGAACATACAGC
56	LMCH119	F- CAGAAAATTAGCAGAGGACTCA R- GTGGGTTGGGTTTTTAGGTC
57	LMCH122	F- AGCAAAGATAAAGAGAAGATAA R- ATCCAAGCCTATTAACAACT
58	LMCH127	F- TTCTCAAGTCAGGTTGAAAT R- AATAGAAGTTTAAGGAGAGGTT
59	LMCH128	F- CTTGTTAAAATGGCTGTTACT R- GCATTGAGCTGACATAACTC
60	LMCH131	F- AGAAGCACCCAGATAGTCAC R- TTGTAGCAATCTCACTTTATCA
61	LMCH134	F- TTCTCTCAATCCGGTACA R- GAAGAAAATGGTAGGGATG
62	LMCH137	F- ACTCGATTATGATTACAAATTA R- AAAGTATCCCCACATAGACT
63	LMCH139	F- CTATCCATCTACGCTTCAAAAT R- CTGAGTCGGTTAGACATTGAGA
64	LMCH142	F- TATATGCCTCAACTGAAATC R- GGAATGACCTTAAAAACTCT
65	LMCH144	F- GTTTGGAAGAGTCGCAGGAT R- ACTGTAAAACGCAGACCAAGAT

3.3.3.5 Optimization of PCR Protocol

In a reaction volume of 16 µl, the DNA amplification process was conducted. The reaction mixture comprised several components, including a 10 mM dNTP mix, 30 ng of primers, 30 ng of DNA, 5 units/µl of Taq DNA polymerase, 15X PCR buffer, and sterile water. The amplification reaction was performed using a Mastercycler® nexus - PCR Cycler by Eppendorf India. The amplification process commenced with a hot start at 94°C for 3 minutes. This was followed by 35 cycles, with each cycle consisting of denaturation at 93°C for 5 minutes, annealing at 40°C for 1 minute, and extension at 72°C for 1 minute and 30 seconds. Finally, a final extension step was carried out at 72°C for 10 minutes.

3.3.3.6 Polyacrylamide gel electrophoresis (PAGE)

Component	Quantity
Acrylamide/ Bisacrylamide 29:1 (w/w)	6 ml
5X TBE	8 ml
Distilled water	40 ml
TEMED (N, N.N‟, N‟- Tetramethylenediamine)	640 µl
10 % APS (Ammonium persulphate)	525 µl
Voltage	75-80 ampere
Time	2.5-3 hr
Loading	3 µl

3.3.3.7 PAGE procedure:

- Prepare the gel: Prepare a polyacrylamide gel by mixing acrylamide, bisacrylamide (cross-linker), and a buffer solution.
- Cast the gel: Pour the gel mixture into a gel cassette or gel mould and insert a comb at the top to create sample wells. Allow the gel to polymerize and form a solid matrix.

- Prepare the samples: Mix your protein or nucleic acid samples with a loading buffer containing denaturing agents (e.g., SDS for protein samples) and a tracking dye.
- Load the samples: Remove the comb from the gel cassette and carefully load the PCR product, one-tenth volume (3µl) of 6x loading dye your prepared samples into the wells using a micropipette.
- Run the gel: Place the gel cassette into an electrophoresis chamber filled with a running buffer. Apply an electric field across the gel, with the negatively charged samples migrating toward the positive electrode. The size and charge of the molecules determine their migration rate through the gel.
- Stain the gel: Once the electrophoresis is complete, visualize the separated molecules by staining the gel. Ethidium bromide staining reveals the bands corresponding to nucleic acids.
- Image and analyze: Capture an image of the stained gel using an imaging system such as a gel documentation system

3.3.3.8 Molecular data analysis

Band scoring involves visually examining the gel, recording the presence or absence of specific bands, and comparing the band sizes among samples to analyze and score the bands corresponding to the polymorphic sites of interest in parents and the selected progenies among the population.

RESULTS

CHAPTER 4 RESULTS

The present investigation entitled '**Evaluation and Characterization of Arka Sahan Custard apple Progenies for Self fruitfulness**' was carried out during 2020-2023 at the Division of Fruit Crops, ICAR-Indian Institute of Horticultural Research (IIHR), Bengaluru. The results obtained from the course of the study are presented in this chapter.

4.1 To evaluate the progenies of Arka Sahan x Balanagar for growth, yield, quality, and self-fruitfulness

4.1.1 Growth parameters (n=1113)

Arka Sahan and Balanagar progenies revealed a considerably higher range of variations for various morphological traits. The results on various morphological traits are presented in Table 4.1.1.

4.1.1.1 Plant height (cm)

Considerable variation was observed in the plant height of 1113 progenies of Arka Sahan and Balanagar Custard apple (Table 4.1.1). Plant height ranged from 0.8 to 4.2 m with average plant height of 2.71 m. The maximum (4.20 m) plant height was recorded in progeny 45\6 and 51\9 followed by 13\7 (4.1 m) and minimum (0.8 m) in 38\17.

4.1.1.2 Growth habit

The observations on growth habit are presented in Table 4.1.1 which clearly indicates the distribution of spreading and erect habits among the progenies of Arka Sahan and Balanagar cross(Table 4.1.1). Out of a total of 1113 progenies observed, 524 progenies showed an erect habit, while 589 progenies exhibited a spreading habit **(**Plate 2).

4.1.1.3 Leaf shape

The observations on leaf shape are presented in Table 4.1.1 showed the leaf shape of Arka Sahan and Balanagar progenies of custard apple. Out of a total of 1113 progenies observed, 69 progenies showed an Elliptic pattern, 119 progenies showed an ovate pattern and 925 progenies showed lanceolate pattern (Plate 2b**)**.

4.1.1.4 Leaf length (cm)

Considerable variation was observed in the leaf length of Arka Sahan and Balanagar progenies of custard apple (Table 4.1.1). Leaf length ranged from 6.9 to 28.7 cm. Among the progenies, the average leaf length was recorded at 15.12 cm. The maximum (28.7 cm) leaf length was recorded in progeny 28\13 followed by 30\11 (28.3 cm) and minimum (6.9 cm) in 31\16.

4.1.1.5 Leaf width (cm)

Considerable variation was observed concerning the leaf width of Arka Sahan and Balanagar progenies of custard apple (Table 4.1.1). Leaf width ranged from 3.3 to 9.9 cm. Among the progenies, the average leaf width was recorded at 6.55 cm. The maximum (9.9 cm) leaf width was recorded in progeny 20\17 followed by 45\8 and 47\23 (9.8 cm) and minimum (3.3 cm) in 24\4 24\20 31\16 and 37\17.

4.1.1.6 Petiole length (cm)

Considerable variation was observed in the petiole length of Arka Sahan and Balanagar progenies of custard apple (Table 4.1.1). Petiole length ranged from 0.5 to 2.5 cm. Among the progenies, the average petiole length was recorded at 1.5 cm. The maximum (2.5 cm) petiole length was recorded in progeny 36\6 and 46\6 followed by 2.4 cm was observed in 2\16, 38\12 and 50\5 minimum (0.5 cm) in progeny 37\16.

Plate 4.1 General view of the experimental plot

Table 4.1.1 Morphological characteristics of Arka sahan Custard apple progenies

Sl. No.	Progeny	Spreading habit	Leaf shape	Plant height (m)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)
1	1\1	Erect	Ovate	2.8	13.7	5.6	2.1
2	1\2	Spreading	Elliptic	2.2	14.9	5.9	1.5
3	1\4	Spreading	Ovate	2.5	14.2	5.7	2.1
4	1\5	Erect	Ovate	1.8	16.1	7.8	2.1
5	1\6	Erect	Elliptic	2.7	11.6	5.1	1.6
6	1\7	Erect	Elliptic	2.9	13.8	5.9	1.7
7	1\8	Erect	Ovate	2.6	16.2	7.2	1.0
8	1\9	Spreading	Ovate	2.2	13.1	6.2	1.4
9	1\10	Erect	Ovate	2.2	15.5	5.5	1.3
10	1\11	Erect	Ovate	2.6	12.9	6.0	1.0
11	1\14	Erect	Ovate	2.5	12.9	5.4	1.9
12	1\16	Erect	Ovate	1.9	16.0	6.7	1.4
13	1\17	Erect	Ovate	1.8	13.4	5.8	2.1
14	1\20	Erect	Elliptic	2.4	11.8	5.2	1.8
15	1\21	Spreading	Ovate	1.7	11.9	5.5	1.4
16	1\22	Erect	Elliptic	1.8	14.5	6.1	1.5
17	1\23	Spreading	Ovate	3.1	13.4	5.3	1.2
18	1\24	Erect	Ovate	1.8	12.9	5.7	1.2
19	2\1	Spreading	Ovate	2.8	15.4	5.7	1.6
20	2\2	Erect	Ovate	2.5	13.5	6.3	1.5
21	2\3	Spreading	Ovate	3.1	15.0	7.2	2.1
22	2\4	Erect	Elliptic	3.1	15.1	8.1	1.6
23	2\5	Erect	Ovate	2.4	12.7	5.4	1.8
24	2\6	Spreading	Ovate	2.4	16.2	7.7	1.5
25	2\7	Erect	Ovate	2.4	15.4	7.4	1.4
26	2\8	Erect	Ovate	2.8	15.2	6.7	1.1
27	2\9	Spreading	Ovate	2.3	14.6	5.5	1.4
28	2\10	Erect	Ovate	2.2	15.7	6.8	1.7
29	2\11	Erect	Ovate	2.1	14.7	7.7	1.1
30	2\12	Erect	Ovate	2.3	12.0	5.2	1.7
31	2\13	Spreading	Ovate	2.3	14.7	6.8	1.5
32	2\14	Erect	Ovate	3.2	14.4	6.3	1.4
33	2\15	Spreading	Elliptic	2.6	14.6	5.4	1.4
34	2\16	Erect	Ovate	3.1	14.9	6.6	2.4
35	2\17	Erect	Ovate	2.4	13.7	7.8	1.5
36	2\18	Erect	Elliptic	2.5	16.1	8.4	1.0
37	2\19	Erect	Ovate	2.6	15.1	7.3	1.4
38	2\20	Erect	Elliptic	2.1	13.6	6.1	1.4
39	2\21	Erect	Ovate	2.1	15.4	6.7	1.1

Sl. No.	Progeny	Spreading habit	Leaf shape	Plant height (m)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)
40	2\22	Spreading	Ovate	2.2	11.9	5.7	1.0
41	2\23	Spreading	Ovate	2.6	16.0	6.2	1.2
42	2\24	Erect	Ovate	2.5	14.3	6.1	1.8
43	3\1	Erect	Ovate	2.9	15.1	5.6	1.8
44	3\2	Spreading	Ovate	2.8	12.8	4.8	1.2
45	3\3	Erect	Ovate	2.7	14.9	5.9	1.4
46	3\4	Erect	Elliptic	2.5	14.2	8.3	1.9
47	3\5	Erect	Ovate	2.7	17.1	8.2	1.7
48	3\6	Spreading	Ovate	2.7	14.4	7.5	1.3
49	3\7	Erect	Elliptic	2.5	12.7	6.7	2.3
50	3\8	Erect	Elliptic	2.4	12.1	5.7	1.5
51	3\9	Erect	Ovate	2.4	14.2	6.1	1.4
52	3\10	Spreading	Ovate	2.2	13.3	5.2	1.1
53	3\12	Erect	Ovate	2.8	13.7	4.9	1.1
54	3\13	Spreading	Ovate	3.2	14.2	6.3	1.4
55	3\14	Spreading	Ovate	3.1	15.3	7.1	1.7
56	3\15	Spreading	Ovate	2.3	12.8	8.2	1.7
57	3\16	Spreading	Ovate	2.4	14.1	5.4	1.9
58	3\17	Spreading	Ovate	2.9	15.0	6.9	1.5
59	3\18	Erect	Ovate	2.7	15.1	6.3	1.7
60	3\19	Erect	Ovate	2.3	15.2	5.9	1.4
61	3\20	Erect	Elliptic	2.4	13.0	8.3	1.6
62	3\21	Erect	Ovate	1.9	13.9	6.5	1.5
63	3\22	Spreading	Ovate	3.0	15.2	6.1	2.0
64	3\23	Spreading	Ovate	2.1	15.9	7.4	1.4
65	3\24	Erect	Ovate	2.5	15.2	5.9	1.5
66	4\1	Spreading	Ovate	2.6	12.3	5.0	2.0
67	4\2	Erect	Ovate	3.1	14.5	5.2	2.0
68	4\3	Erect	Ovate	3.1	15.6	8.8	1.6
69	4\4	Erect	Ovate	2.2	14.4	5.9	1.5
70	4\5	Spreading	Ovate	2.5	13.3	6.9	1.4
71	4\6	Spreading	Ovate	2.6	13.7	5.8	1.6
72	4\7	Spreading	Ovate	2.1	13.5	6.2	1.8
73	4\8	Erect	Ovate	2.5	12.3	5.0	1.3
74	4\9	Spreading	Ovate	1.9	12.7	4.6	1.2
75	4\10	Spreading	Ovate	2.1	15.0	6.4	1.4
76	4\11	Spreading	Ovate	2.9	15.3	7.7	1.9
77	4\12	Spreading	Ovate	2.4	14.0	5.7	1.5
78	4\13	Erect	Ovate	2.5	16.7	8.2	1.9
79	4\14	Spreading	Ovate	2.9	12.9	6.2	1.4

Sl. No.	Progeny	Spreading habit	Leaf shape	Plant height (m)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)
80	4\15	Erect	Elliptic	2.8	12.1	6.9	1.6
81	4\16	Spreading	Ovate	3.4	16.0	7.0	1.8
82	4\17	Spreading	Ovate	2.6	18.3	8.1	1.6
83	4\18	Erect	Ovate	2.5	17.2	8.7	1.6
84	4\19	Erect	Ovate	2.4	14.8	6.3	1.3
85	4\20	Erect	Ovate	3.5	12.2	5.4	1.3
86	4\21	Erect	Ovate	2.6	15.3	7.3	1.5
87	4\22	Erect	Ovate	3.1	11.8	4.1	1.3
88	4\23	Erect	Ovate	3.5	15.6	7.0	1.1
89	4\24	Erect	Ovate	3.4	15.6	7.4	1.6
90	5\1	Erect	Elliptic	2.5	15.7	7.9	1.9
91	5\2	Spreading	Lanceolate	2.5	15.5	5.9	1.5
92	5\3	Erect	Elliptic	3.3	13.7	6.1	1.6
93	5\4	Spreading	Lanceolate	2.9	13.1	4.7	1.7
94	5\5	Spreading	Ovate	2.5	17.6	7.8	1.5
95	5\6	Spreading	Lanceolate	2.2	14.6	4.9	2.0
96	5\7	Spreading	Ovate	2.7	13.4	6.1	1.5
97	5\8	Spreading	Lanceolate	2.5	12.8	4.9	1.1
98	5\9	Erect	Elliptic	2.4	16.5	8.7	2.1
99	5\10	Erect	Elli\tic	3.1	15.1	6.3	1.6
100	5\11	Spreading	Ovate	2.5	12.2	5.0	1.0
101	5\12	Erect	Ovate	2.3	14.6	7.1	1.4
102	5\13	Spreading	Elliptic	2.5	16.9	9.4	1.9
103	5\14	Spreading	Lanceolate	2.6	13.2	5.1	1.1
104	5\16	Spreading	Ovate	2.4	15.6	7.9	1.8
105	5\17	Spreading	Lanceolate	3.2	14.7	5.5	1.4
106	5\20	Spreading	Lanceolate	2.5	13.8	5.6	1.4
107	5\21	Erect	Elliptic	2.7	15.5	7.3	1.4
108	5\22	Erect	Ovate	2.6	12.2	7.0	1.4
109	5\23	Erect	Obovate	3.4	11.1	5.1	1.6
110	5\24	Erect	Lanceolate	2.7	11.6	4.0	1.6
111	6\1	Spreading	Ovate	2.8	15.6	7.8	1.6
112	6\2	Spreading	Ovate	2.6	12.4	7.6	2.1
113	6\3	Spreading	Lanceolate	3.0	14.8	7.2	1.5
114	6\4	Spreading	Ovate	2.4	11.6	4.9	1.2
115	6\5	Spreading	Lanceolate	2.4	15.0	5.3	1.4
116	6\6	Erect	Ovate	2.5	14.2	5.7	1.6
117	6\7	Spreading	Lanceolate	2.3	15.4	8.7	1.5
118	6\8	Erect	Elliptic	2.9	15.2	7.7	1.6
119	6\9	Spreading	Lanceolate	2.3	17.3	6.2	1.5

Sl. No.	Progeny	Spreading habit	Leaf shape	Plant height (m)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)
120	6\10	Spreading	Lanceolate	2.4	14.0	4.9	1.3
121	6\11	Spreading	Ovate	2.7	13.8	6.0	1.8
122	6\12	Spreading	Lanceolate	2.6	14.2	5.6	1.3
123	6\14	Spreading	Lanceolate	2.5	14.5	5.3	2.1
124	6\15	Spreading	Lanceolate	1.0	15.7	7.2	1.7
125	6\16	Erect	Ovate	2.8	15.1	6.0	1.8
126	6\17	Spreading	Ovate	2.7	10.7	3.8	1.2
127	6\18	Spreading	Ovate	2.8	13.5	6.1	1.4
128	6\19	Erect	Ovate	2.9	14.7	5.8	2.0
129	6\20	Spreading	Ovate	3.0	16.8	8.1	1.6
130	6\21	Erect	Elliptic	2.7	16.1	9.0	1.5
131	6\22	Erect	Lanceolate	2.2	15.7	8.2	1.7
132	6\23	Spreading	Lanceolate	3.5	15.8	7.4	1.9
133	6\24	Spreading	Lanceolate	2.7	15.1	5.9	1.8
134	7\1	Erect	Lanceolate	2.7	12.0	6.3	1.3
135	7\2	Spreading	Ovate	2.9	15.0	7.3	1.8
136	7\3	Erect	Lanceolate	2.3	15.9	7.9	1.1
137	7\4	Spreading	Lanceolate	2.7	14.4	6.4	1.7
138	7\5	Spreading	Lanceolate	2.7	15.1	7.0	1.4
139	7\6	Spreading	Lanceolate	2.6	11.0	4.1	1.4
140	7\7	Erect	Elliptic	2.5	12.4	6.3	1.0
141	7\8	Erect	Elliptic	2.8	13.8	6.1	1.6
142	7\9	Erect	Ovate	2.7	13.0	6.0	1.6
143	7\10	Spreading	Lanceolate	2.3	13.1	5.2	1.1
144	7\11	Erect	Ovate	2.5	16.0	9.0	1.9
145	7\12	Spreading	Lanceolate	2.1	14.6	5.2	1.1
146	7\13	Spreading	Obovate	2.4	14.7	7.6	1.4
147	7\14	Spreading	Lanceolate	2.6	14.8	6.1	0.8
148	7\15	Erect	Lanceolate	2.7	13.7	5.9	1.7
149	7\16	Erect	Lanceolate	2.6	14.4	5.9	1.4
150	7\17	Spreading	Lanceolate	2.8	12.6	4.5	2.1
151	7\18	Spreading	Ovate	2.7	18.1	5.1	1.4
152	7\19	Erect	Ovate	2.8	12.7	9.0	1.4
153	7\20	Spreading	Lanceolate	2.9	18.1	4.8	1.8
154	7\21	Spreading	Lanceolate	2.4	15.4	6.1	1.8
155	7\22	Erect	Ovate	2.7	15.8	5.4	1.6
156	7\23	Spreading	Lanceolate	2.5	14.8	5.2	1.4
157	7\24	Spreading	Lanceolate	2.9	14.3	5.7	1.7
158	7\25	Erect	Lanceolate	2.9	14.0	5.3	1.4
159	8\1	Spreading	Lanceolate	2.8	14.1	5.8	1.6

Sl. No.	Progeny	Spreading habit	Leaf shape	Plant height (m)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)
160	8\2	Erect	Lanceolate	2.8	15.9	6.5	1.5
161	8\3	Erect	Elli\tic	2.6	15.7	7.1	1.3
162	8\4	Spreading	Lanceolate	2.3	14.9	6.6	1.3
163	8\5	Erect	Lanceolate	2.3	13.0	5.1	1.6
164	8\6	Spreading	Lanceolate	2.1	13.2	5.4	1.2
165	8\7	Spreading	Lanceolate	2.4	14.9	6.2	1.7
166	8\8	Spreading	Lanceolate	2.5	12.0	5.0	1.7
167	8\9	Spreading	Ovate	2.3	12.6	5.0	1.8
168	8\10	Erect	Ovate	2.5	15.2	5.6	1.8
169	8\11	Erect	Ovate	2.0	13.8	6.2	1.3
170	8\12	Erect	Ovate	2.3	14.9	6.3	0.8
171	8\13	Spreading	Ovate	2.2	14.0	6.7	1.9
172	8\14	Erect	Ovate	2.4	14.0	5.7	1.8
173	8\15	Erect	Lanceolate	2.6	14.1	5.4	1.3
174	8\16	Spreading	Lanceolate	2.8	13.0	5.8	1.8
175	8\17	Spreading	Lanceolate	2.5	14.1	5.6	1.3
176	8\18	Spreading	Elliptic	1.7	13.8	4.9	1.6
177	8\19	Erect	Elliptic	2.7	10.6	7.8	1.1
178	8\20	Spreading	Ovate	2.7	14.1	5.1	1.3
179	8\21	Spreading	Lanceolate	2.4	12.3	5.6	1.2
180	8\22	Spreading	Lanceolate	2.8	14.7	4.7	1.2
181	8\23	Erect	Lanceolate	2.5	14.0	4.6	1.5
182	8\24	Spreading	Lanceolate	2.6	15.3	5.3	2.1
183	8\25	Erect	Lanceolate	3.1	16.1	6.1	1.7
184	9\1	Spreading	Lanceolate	2.3	14.3	6.4	2.0
185	9\2	Erect	Ovate	2.7	11.6	6.3	1.6
186	9\3	Erect	Ovate	2.6	15.4	7.4	1.6
187	9\4	Erect	Lanceolate	2.4	13.8	5.6	1.8
188	9\6	Spreading	Elliptic	2.9	14.4	5.8	2.1
189	9\7	Erect	Elliptic	2.7	12.4	6.0	1.4
190	9\8	Spreading	Lanceolate	2.2	14.6	5.4	1.3
191	9\10	Spreading	Lanceolate	2.6	15.8	6.4	1.4
192	9\11	Spreading	Lanceolate	2.5	15.0	4.9	1.7
193	9\12	Erect	Lanceolate	2.6	15.0	5.3	1.7
194	9\13	Spreading	Ovate	2.7	13.4	5.1	1.7
195	9\14	Erect	Ovate	2.5	13.6	5.9	1.8
196	9\15	Erect	Ovate	2.2	10.8	4.9	1.7
197	9\16	Spreading	Ovate	2.9	13.3	5.1	1.2
198	9\17	Spreading	Ovate	2.7	14.9	6.9	1.8
199	9\18	Erect	Elliptic	2.2	13.9	7.3	1.6

Sl. No.	Progeny	Spreading habit	Leaf shape	Plant height (m)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)
200	9\19	Spreading	Lanceolate	3.3	12.7	5.4	1.6
201	9\20	Spreading	Lanceolate	2.7	15.4	7.4	1.6
202	9\21	Erect	Lanceolate	3.0	15.6	5.3	1.7
203	9\22	Spreading	Lanceolate	2.8	13.2	6.2	1.0
204	9\23	Erect	Lanceolate	2.5	13.9	6.9	1.5
205	9\24	Erect	Lanceolate	2.9	12.5	5.4	1.4
206	10\1	Spreading	Lanceolate	2.7	12.5	5.4	1.7
207	10\2	Erect	Elliptic	2.1	13.7	5.9	1.8
208	10\3	Spreading	Lanceolate	2.6	14.4	5.8	2.1
209	10\4	Erect	Lanceolate	2.5	16.0	6.3	1.7
210	10\5	Spreading	Lanceolate	2.5	16.1	5.9	1.7
211	10\6	Spreading	Ovate	3.1	13.6	5.3	1.7
212	10\7	Erect	Ovate	1.9	13.8	5.3	1.4
213	10\8	Erect	Lanceolate	1.5	16.8	6.6	1.6
214	10\9	Spreading	Lanceolate	2.4	14.0	5.6	1.5
215	10\10	Spreading	Lanceolate	2.0	15.4	7.4	1.6
216	10\11	Spreading	Lanceolate	2.5	9.1	4.3	1.6
217	10\12	Erect	Lanceolate	2.2	12.0	5.5	1.3
218	10\13	Spreading	Lanceolate	2.5	12.3	5.0	1.8
219	10\14	Erect	Lanceolate	2.2	15.0	6.1	1.4
220	10\15	Erect	Ovate	1.9	14.3	6.5	1.5
221	10\16	Spreading	Ovate	2.9	15.1	7.1	1.5
222	10\17	Spreading	Lanceolate	2.6	14.7	7.1	1.8
223	10\18	Spreading	Lanceolate	2.4	10.4	4.6	1.5
224	10\19	Spreading	Elliptic	2.7	10.4	5.9	1.2
225	10\20	Erect	Ovate	2.9	14.6	6.4	1.6
226	10\21	Spreading	Lanceolate	2.8	14.3	6.9	1.3
227	10\22	Erect	Lanceolate	2.0	12.3	4.7	1.2
228	10\23	Erect	Lanceolate	2.8	13.9	6.0	1.6
229	10\24	Spreading	Lanceolate	2.5	17.5	8.4	1.5
230	11\1	Erect	Lanceolate	2.8	14.2	8.1	1.7
231	11\2	Erect	Ovate	2.4	14.1	8.1	1.8
232	11\3	Spreading	Lanceolate	2.5	13.5	6.4	2.1
233	11\4	Spreading	Lanceolate	2.1	10.5	5.1	1.7
234	11\5	Erect	Ovate	2.8	16.0	8.5	1.7
235	11\6	Erect	Lanceolate	2.6	12.1	5.2	1.7
236	11\7	Erect	Lanceolate	2.5	13.1	5.5	1.4
237	11\8	Spreading	Lanceolate	2.1	14.9	5.6	1.6
238	11\9	Erect	Lanceolate	2.6	13.5	6.4	1.5
239	11\10	Erect	Ovate	2.6	12.7	4.7	1.6

Sl. No.	Progeny	Spreading habit	Leaf shape	Plant height (m)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)
240	11\11	Erect	Ovate	2.7	15.3	6.3	1.6
241	11\12	Spreading	Elliptic	2.5	15.5	5.4	1.3
242	11\13	Spreading	Elliptic	2.6	13.7	5.5	1.8
243	11\14	Spreading	Ovate	2.9	13.7	5.9	1.4
244	11\15	Erect	Elliptic	2.2	12.5	6.0	1.5
245	11\16	Spreading	Lanceolate	2.4	11.2	4.0	1.5
246	11\17	Erect	Lanceolate	1.8	16.5	7.5	1.8
247	11\18	Erect	Lanceolate	2.5	15.4	7.0	1.5
248	11\19	Erect	Lanceolate	2.7	15.4	7.4	1.2
249	11\20	Erect	Ovate	2.5	14.7	4.9	1.6
250	11\21	Spreading	Ovate	2.5	13.2	6.2	1.3
251	11\22	Erect	Ovate	2.9	17.0	7.9	1.2
252	11\23	Spreading	Ovate	3.1	11.8	4.4	1.6
253	11\24	Spreading	Lanceolate	2.9	14.3	5.5	1.5
254	12\1	Spreading	Elliptic	3.0	14.0	8.4	1.5
255	12\2	Erect	Lanceolate	2.3	15.2	8.8	1.3
256	12\3	Spreading	Lanceolate	2.9	13.3	5.6	1.4
257	12\4	Erect	Lanceolate	2.4	13.2	6.1	1.4
258	12\5	Erect	Lanceolate	2.6	16.2	7.0	1.8
259	12\6	Spreading	Ovate	3.1	13.9	7.0	1.5
260	12\7	Spreading	Lanceolate	2.7	14.9	6.7	1.4
261	12\8	Spreading	Lanceolate	2.5	14.3	6.5	1.7
262	12\9	Sreading	Lanceolate	2.9	13.6	5.1	1.5
263	12\10	Erect	Lanceolate	2.3	13.3	6.6	2.0
264	12\12	Spreading	Ovate	1.4	13.9	7.1	1.5
265	12\13	Spreading	Lanceolate	2.5	11.4	6.9	1.3
266	12\14	Erect	Lanceolate	1.7	16.4	5.9	1.4
267	12\17	Erect	Lanceolate	1.4	15.0	5.2	1.4
268	12\18	Spreading	Lanceolate	2.8	14.1	6.5	1.5
269	12\19	Spreading	Lanceolate	2.2	13.8	5.2	1.6
270	12\20	Spreading	Ovate	2.8	14.5	5.6	1.6
271	12\21	Spreading	Lanceolate	2.0	15.9	6.2	1.4
272	12\22	Spreading	Lanceolate	2.7	13.5	5.7	1.6
273	12\23	Erect	Ovate	2.0	16.2	7.5	1.4
274	12\24	Erect	Ovate	2.8	14.6	7.6	1.8
275	13\1	Erect	Ovate	3.2	15.0	5.7	1.8
276	13\2	Erect	Ovate	2.6	12.7	5.9	1.6
277	13\3	Erect	Elliptic	2.7	12.6	7.3	1.5
278	13\5	Spreading	Lanceolate	2.4	13.6	5.7	1.5
279	13\6	Spreading	Lanceolate	2.5	15.2	5.9	1.7

Sl. No.	Progeny	Spreading habit	Leaf shape	Plant height (m)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)
280	13\7	Spreading	Ovate	2.5	14.3	6.1	1.5
281	13\8	Erect	Lanceolate	2.2	14.3	7.7	1.0
282	13\9	Erect	Lanceolate	2.6	13.8	5.8	1.5
283	13\10	Erect	Ovate	2.3	13.9	6.6	1.8
284	13\11	Erect	Lanceolate	2.2	13.7	5.6	1.3
285	13\12	Spreading	Lanceolate	2.5	14.7	5.6	1.8
286	13\13	Spreading	Lanceolate	2.5	13.1	5.7	1.8
287	13\14	Erect	Elliptic	2.6	16.0	7.6	1.5
288	13\15	Spreading	Lanceolate	2.3	9.4	4.4	1.3
289	13\17	Erect	Lanceolate	2.6	14.2	6.6	1.3
290	13\18	Erect	Lanceolate	2.9	12.7	5.7	1.7
291	13\19	Erect	Lanceolate	2.9	10.4	5.9	1.6
292	13\20	Erect	Lanceolate	2.6	15.8	6.7	1.8
293	13\21	Erect	Lanceolate	2.6	15.5	6.5	2.0
294	13\22	Erect	Lanceolate	2.5	16.6	7.3	1.5
295	13\23	Erect	Lanceolate	2.7	18.0	8.4	1.9
296	13\24	Erect	Lanceolate	2.4	17.8	8.8	1.7
297	14\1	Erect	Lanceolate	2.8	11.6	5.6	2.0
298	14\2	Erect	Ovate	2.2	11.7	4.8	2.1
299	14\3	Erect	Ovate	2.6	9.1	5.3	1.7
300	14\4	Spreading	Ovate	2.2	13.9	5.7	1.7
301	14\5	Spreading	Lanceolate	2.9	15.8	7.1	1.8
302	14\6	Spreading	Lanceolate	2.3	18.0	6.6	2.1
303	14\7	Erect	Ovate	2.0	17.4	7.1	1.5
304	14\8	Erect	Lanceolate	2.3	17.0	6.0	2.1
305	14\9	Erect	Lanceolate	2.5	15.5	5.9	1.5
306	14\10	Erect	Lanceolate	2.8	12.5	5.2	1.2
307	14\11	Erect	Lanceolate	2.6	16.6	6.6	1.4
308	14\12	Erect	Lanceolate	1.8	14.1	6.4	1.1
309	14\13	Spreading	Lanceolate	2.2	13.8	6.5	2.1
310	14\14	Spreading	Lanceolate	2.3	15.6	6.5	1.5
311	14\15	Erect	Ovate	2.3	14.4	6.6	1.4
312	14\16	Spreading	Lanceolate	2.5	12.0	4.3	1.5
313	14\17	Spreading	Lanceolate	2.9	13.1	5.5	1.5
314	14\18	Spreading	Lanceolate	2.4	12.9	5.2	1.5
315	14\19	Erect	Ovate	2.5	14.3	7.2	1.7
316	14\20	Erect	Ovate	2.9	14.4	4.9	1.2
317	14\21	Spreading	Lanceolate	2.6	14.3	5.0	2.0
318	14\22	Spreading	Lanceolate	2.9	16.4	8.0	1.8
319	14\23	Erect	Lanceolate	2.5	11.4	4.3	1.7

Sl. No.	Progeny	Spreading habit	Leaf shape	Plant height (m)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)
320	14\24	Erect	Lanceolate	2.6	14.7	7.4	1.7
321	15\1	Erect	Lanceolate	2.5	15.8	7.0	2.0
322	15\2	Erect	Lanceolate	2.2	16.0	7.9	1.5
323	15\3	Spreading	Lanceolate	3.2	10.6	4.3	1.2
324	15\4	Spreading	Lanceolate	2.3	15.0	6.2	1.6
325	15\5	Spreading	Lanceolate	2.4	13.9	5.2	1.4
326	15\6	Spreading	Lanceolate	2.6	14.0	5.7	1.9
327	15\7	Erect	Lanceolate	1.3	11.4	4.8	1.5
328	15\8	Spreading	Lanceolate	2.0	15.6	5.7	1.5
329	15\9	Spreading	Lanceolate	2.0	13.7	5.0	1.3
330	15\10	Spreading	Lanceolate	2.7	13.9	5.9	1.5
331	15\11	Erect	Lanceolate	2.8	13.5	5.5	1.3
332	15\13	Spreading	Lanceolate	2.5	13.8	5.7	1.6
333	15\14	Spreading	Ovate	2.6	11.7	4.4	1.0
334	15\15	Spreading	Ovate	2.4	15.2	7.4	1.8
335	15\16	Erect	Lanceolate	2.4	13.6	6.0	1.8
336	15\17	Spreading	Ovate	3.0	11.5	4.6	1.6
337	15\18	Spreading	Lanceolate	2.2	14.0	6.5	1.7
338	15\19	Spreading	Lanceolate	2.5	15.7	5.5	1.7
339	15\20	Erect	Ovate	2.3	14.5	6.5	2.1
340	15\21	Spreading	Ovate	2.3	16.4	7.1	1.5
341	15\22	Erect	Lanceolate	2.1	14.2	6.6	1.5
342	15\23	Erect	Lanceolate	2.9	17.6	8.4	1.4
343	15\24	Erect	Lanceolate	2.4	15.7	6.3	1.5
344	16\1	Erect	Lanceolate	2.3	11.6	3.8	0.8
345	16\2	Spreading	Lanceolate	1.9	11.9	5.4	1.2
346	16\3	Spreading	Elliptic	2.2	13.7	7.6	1.8
347	16\4	Spreading	Lanceolate	2.4	13.2	4.5	1.7
348	16\5	Spreading	Lanceolate	2.4	14.1	5.4	1.6
349	16\6	Spreading	Lanceolate	2.0	9.5	3.9	1.4
350	16\7	Erect	Lanceolate	2.5	14.7	6.9	1.5
351	16\8	Spreading	Lanceolate	2.9	16.0	6.8	1.8
352	16\10	Spreading	Lanceolate	3.1	15.1	6.5	1.1
353	16\11	Erect	Lanceolate	2.4	12.8	5.8	1.2
354	16\12	Erect	Lanceolate	2.8	11.4	4.7	1.3
355	16\13	Erect	Lanceolate	2.8	12.9	6.1	1.6
356	16\14	Spreading	Lanceolate	2.9	17.6	7.0	1.5
357	16\15	Erect	Lanceolate	2.8	14.3	6.9	1.7
358	16\16	Erect	Ovate	2.4	15.4	6.0	1.6
359	16\17	Erect	Lanceolate	2.3	14.7	5.5	1.6

Sl. No.	Progeny	Spreading habit	Leaf shape	Plant height (m)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)
360	16\18	Erect	Lanceolate	2.6	16.3	8.1	1.4
361	16\20	Spreading	Lanceolate	2.0	15.0	7.3	1.0
362	16\21	Spreading	Lanceolate	2.2	13.3	4.9	2.1
363	16\22	Spreading	Lanceolate	2.1	18.2	6.9	1.5
364	16\23	Erect	Lanceolate	2.0	18.8	7.8	1.6
365	16\24	Spreading	Ovate	2.7	14.9	5.1	1.4
366	17\1	Spreading	Lanceolate	2.3	11.0	4.3	1.4
367	17\2	Spreading	Ovate	2.1	13.9	5.1	1.9
368	17\3	Spreading	Lanceolate	1.7	15.7	5.9	1.5
369	17\4	Erect	Lanceolate	2.6	14.2	6.5	1.7
370	17\5	Spreading	Lanceolate	2.8	14.2	6.4	1.9
371	17\6	Spreading	Lanceolate	2.1	15.2	6.8	1.8
372	17\8	Erect	Ovate	2.5	15.1	6.3	1.2
373	17\9	Erect	Elliptic	2.9	13.1	6.2	1.5
374	17\10	Spreading	Lanceolate	3.1	15.7	7.5	1.8
375	17\11	Erect	Lanceolate	2.4	16.0	6.1	1.7
376	17\13	Erect	Lanceolate	2.6	15.8	8.0	2.1
377	17\14	Erect	Lanceolate	2.2	14.9	5.8	1.7
378	17\15	Erect	Lanceolate	2.2	11.2	5.5	1.4
379	17\16	Erect	Lanceolate	2.4	20.3	9.0	1.8
380	17\17	Erect	Lanceolate	2.3	18.4	8.0	1.6
381	17\18	Erect	Ovate	2.5	11.8	4.5	1.7
382	17\19	Spreading	Lanceolate	2.4	15.2	6.4	1.3
383	17\20	Spreading	Ovate	2.2	14.8	5.9	1.7
384	17\21	Erect	Elliptic	1.6	12.2	5.9	1.4
385	17\22	Spreading	Lanceolate	2.9	15.5	5.7	1.8
386	17\23	Spreading	Lanceolate	3.0	15.3	6.7	1.4
387	17\24	Spreading	Elliptic	1.7	17.4	9.0	1.5
388	18\1	Erect	Elliptic	2.7	12.4	5.6	1.2
389	18\2	Erect	Ovate	2.1	16.1	6.6	1.6
390	18\3	Erect	Lanceolate	2.4	16.4	6.9	1.5
391	18\4	Spreading	Lanceolate	1.7	16.9	7.7	1.4
392	18\5	Erect	Lanceolate	2.7	19.2	9.0	2.1
393	18\6	Spreading	Lanceolate	1.7	16.2	8.4	2.0
394	18\7	Spreading	Lanceolate	3.2	15.0	6.0	1.6
395	18\9	Spreading	Lanceolate	2.6	13.6	6.0	1.2
396	18\10	Spreading	Lanceolate	2.8	17.5	8.2	1.6
397	18\11	Erect	Ovate	2.4	13.2	6.1	1.5
398	18\12	Erect	Lanceolate	2.3	22.6	9.0	1.5
399	18\13	Spreading	Lanceolate	2.2	17.1	7.5	1.7

Sl. No.	Progeny	Spreading habit	Leaf shape	Plant height (m)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)
400	18\14	Spreading	Lanceolate	2.4	15.5	6.4	1.6
401	18\16	Spreading	Lanceolate	2.6	15.3	6.2	1.7
402	18\17	Erect	Lanceolate	2.8	16.1	7.0	1.4
403	18\18	Erect	Lanceolate	2.5	15.2	6.7	1.7
404	18\19	Erect	Lanceolate	2.0	17.5	8.4	1.6
405	18\20	Erect	Lanceolate	2.3	11.7	4.2	1.5
406	18\21	Spreading	Lanceolate	2.5	16.8	7.7	1.3
407	18\22	Spreading	Lanceolate	3.0	16.6	6.2	1.5
408	18\23	Erect	Ovate	2.6	15.1	6.6	1.8
409	18\24	Spreading	Lanceolate	2.4	13.0	4.9	1.7
410	19\1	Spreading	Lanceolate	2.5	9.8	4.0	2.1
411	19\2	Erect	Lanceolate	2.4	20.3	9.6	1.6
412	19\3	Spreading	Lanceolate	2.8	14.1	5.2	1.6
413	19\4	Spreading	Lanceolate	2.0	14.7	5.3	1.9
414	19\5	Spreading	Lanceolate	2.3	12.8	5.4	1.7
415	19\6	Spreading	Lanceolate	3.2	17.3	7.5	1.7
416	19\8	Spreading	Lanceolate	2.0	18.0	7.0	1.8
417	19\9	Spreading	Lanceolate	2.5	14.5	6.1	1.5
418	19\10	Spreading	Lanceolate	2.3	13.7	5.6	1.8
419	19\11	Erect	Lanceolate	2.6	15.5	6.8	1.8
420	19\12	Spreading	Lanceolate	2.3	15.8	6.6	1.4
421	19\13	Spreading	Lanceolate	1.7	17.2	7.5	2.0
422	19\14	Spreading	Lanceolate	2.3	18.5	7.2	1.6
423	19\15	Spreading	Elliptic	2.0	14.5	5.7	1.4
424	19\16	Spreading	Lanceolate	1.8	14.4	6.0	1.7
425	19\17	Spreading	Lanceolate	2.8	11.8	5.7	1.7
426	19\18	Erect	Lanceolate	3.0	14.1	6.4	1.6
427	19\19	Erect	Lanceolate	2.6	11.9	4.3	1.3
428	19\20	Spreading	Lanceolate	2.6	13.9	6.5	1.7
429	19\21	Spreading	Lanceolate	3.0	14.5	5.4	2.0
430	19\22	Erect	Lanceolate	2.7	16.2	7.5	1.8
431	19\24	Spreading	Lanceolate	2.8	18.8	8.1	1.6
432	20\1	Spreading	Ovate	2.5	16.4	7.9	1.8
433	20\2	Erect	Lanceolate	2.5	16.0	8.7	1.8
434	20\3	Erect	Lanceolate	2.7	14.1	6.0	1.4
435	20\4	Spreading	Lanceolate	2.6	15.6	7.8	1.7
436	20\5	Spreading	Lanceolate	2.8	12.7	4.7	1.4
437	20\6	Spreading	Lanceolate	2.2	13.4	6.3	1.6
438	20\7	Erect	Lanceolate	2.6	18.2	8.4	2.3
439	20\8	Spreading	Lanceolate	2.9	14.2	6.9	1.7

Sl. No.	Progeny	Spreading habit	Leaf shape	Plant height (m)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)
440	20\10	Erect	Elliptic	2.8	23.0	9.0	1.8
441	20\11	Erect	Elliptic	2.3	12.8	6.7	1.5
442	20\12	Spreading	Lanceolate	2.1	11.8	4.6	1.5
443	20\13	Spreading	Lanceolate	2.7	15.5	6.6	1.6
444	20\14	Erect	Lanceolate	2.5	20.0	8.8	2.1
445	20\15	Spreading	Elliptic	2.4	12.8	6.2	1.5
446	20\16	Spreading	Ovate	2.6	18.1	7.2	1.2
447	20\17	Erect	Lanceolate	2.3	19.6	9.9	1.6
448	20\18	Erect	Elliptic	2.2	12.3	5.7	1.5
449	20\20	Spreading	Lanceolate	2.3	12.5	6.7	1.8
450	20\21	Spreading	Lanceolate	2.6	16.3	7.0	2.0
451	20\22	Spreading	Lanceolate	2.5	15.6	5.4	1.4
452	20\23	Spreading	Ovate	3.1	10.3	5.5	1.8
453	20\24	Erect	Lanceolate	3.2	12.6	5.8	1.4
454	21\1	Erect	Ovate	2.6	17.7	7.1	2.0
455	21\2	Spreading	Lanceolate	2.0	16.0	7.2	1.7
456	21\3	Erect	Lanceolate	2.6	16.8	8.0	1.2
457	21\4	Erect	Lanceolate	2.7	16.3	7.0	1.7
458	21\5	Erect	Elliptic	2.1	12.8	6.5	1.6
459	21\6	Spreading	Lanceolate	2.8	15.7	6.4	1.5
460	21\7	Erect	Ovate	2.4	19.1	8.3	1.8
461	21\8	Erect	Lanceolate	2.9	16.6	7.0	2.0
462	21\9	Spreading	Lanceolate	2.2	15.6	6.3	1.6
463	21\11	Erect	Lanceolate	2.5	13.1	5.0	1.6
464	21\12	Spreading	Lanceolate	1.7	13.7	5.5	1.8
465	21\13	Erect	Lanceolate	2.1	17.4	6.8	1.6
466	21\14	Spreading	Lanceolate	2.5	15.2	6.5	1.5
467	21\15	Spreading	Lanceolate	2.1	16.2	6.6	1.5
468	21\16	Spreading	Lanceolate	2.7	12.0	5.6	1.1
469	21\17	Spreading	Lanceolate	2.5	16.0	6.7	1.4
470	21\18	Erect	Lanceolate	2.5	15.1	5.9	1.2
471	21\19	Spreading	Lanceolate	2.4	14.8	6.6	1.2
472	21\20	Erect	Lanceolate	3.1	12.4	5.5	2.1
473	21\21	Erect	Lanceolate	2.7	17.7	6.4	1.5
474	22\1	Erect	Lanceolate	2.5	13.8	6.3	1.4
475	22\2	Spreading	Lanceolate	2.2	18.4	8.6	2.0
476	22\3	Erect	Lanceolate	2.5	17.2	6.3	1.8
477	22\4	Erect	Lanceolate	2.4	14.0	6.3	1.8
478	22\5	Erect	Lanceolate	1.9	15.6	6.8	2.0
479	22\6	Spreading	Elliptic	2.5	14.6	6.8	1.5

Sl. No.	Progeny	Spreading habit	Leaf shape	Plant height (m)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)
480	22\7	Erect	Lanceolate	2.5	14.1	5.5	1.8
481	22\8	Spreading	Lanceolate	2.5	14.8	6.4	2.0
482	22\9	Spreading	Ovate	2.7	12.3	4.6	1.7
483	22\10	Spreading	Lanceolate	2.0	17.0	6.4	1.0
484	22\11	Erect	Lanceolate	2.6	15.1	6.7	1.4
485	22\12	Erect	Lanceolate	2.6	17.0	7.0	1.8
486	22\13	Erect	Lanceolate	2.4	14.9	6.2	1.4
487	22\14	Spreading	Ovate	2.6	12.6	5.3	1.5
488	22\15	Erect	Lanceolate	2.0	16.2	6.4	1.4
489	22\16	Erect	Lanceolate	2.9	16.3	6.8	1.7
490	22\17	Spreading	Lanceolate	2.3	16.9	7.0	1.8
491	22\18	Erect	Lanceolate	1.9	16.1	7.8	1.4
492	22\19	Spreading	Lanceolate	2.3	13.7	6.5	1.5
493	22\20	Erect	Lanceolate	2.6	17.5	6.1	1.0
494	22\21	Spreading	Lanceolate	2.9	19.6	7.5	1.7
495	23\1	Spreading	Lanceolate	1.6	10.3	4.1	1.5
496	23\2	Spreading	Lanceolate	2.2	14.2	4.7	1.1
497	23\3	Erect	Ovate	1.5	15.4	6.3	1.3
498	23\4	Erect	Lanceolate	1.3	12.4	5.0	1.5
499	23\5	Spreading	Ovate	2.2	13.2	5.4	1.4
500	23\6	Spreading	Lanceolate	2.5	13.0	4.4	1.4
501	23\8	Spreading	Lanceolate	2.4	11.1	5.3	1.4
502	23\9	Spreading	Lanceolate	2.2	13.1	4.7	2.2
503	23\10	Spreading	Lanceolate	2.7	14.3	6.7	1.1
504	23\11	Erect	Lanceolate	2.2	16.3	7.0	2.0
505	23\12	Spreading	Lanceolate	2.5	13.8	5.0	1.7
506	23\13	Spreading	Lanceolate	2.4	16.4	6.8	1.7
507	23\14	Erect	Lanceolate	2.4	17.7	7.8	1.3
508	23\15	Spreading	Lanceolate	2.3	12.4	5.4	1.4
509	23\16	Spreading	Lanceolate	2.5	15.6	6.7	1.5
510	23\17	Spreading	Lanceolate	2.4	14.3	5.1	1.6
511	23\18	Spreading	Lanceolate	2.6	16.7	7.0	1.1
512	23\19	Spreading	Lanceolate	2.5	14.9	8.4	1.3
513	23\20	Erect	Lanceolate	1.8	14.7	6.6	1.3
514	24\1	Spreading	Lanceolate	2.8	12.8	8.0	2.0
515	24\2	Erect	Lanceolate	2.4	16.1	5.2	1.7
516	24\3	Erect	Lanceolate	2.5	14.6	5.0	1.5
517	24\4	Spreading	Lanceolate	2.4	14.6	3.3	1.8
518	24\5	Erect	Lanceolate	2.1	14.1	7.7	2.0
519	24\6	Spreading	Lanceolate	2.4	14.8	5.2	2.0

Sl. No.	Progeny	Spreading habit	Leaf shape	Plant height (m)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)
520	24\7	Erect	Lanceolate	2.5	16.2	5.0	0.8
521	24\8	Spreading	Lanceolate	1.8	15.4	5.4	2.1
522	24\9	Spreading	Lanceolate	2.7	13.6	6.5	1.2
523	24\10	Spreading	Lanceolate	2.5	16.3	5.2	1.4
524	24\11	Spreading	Lanceolate	2.0	14.6	7.3	1.2
525	24\14	Erect	Ovate	2.3	16.8	6.5	1.6
526	24\16	Spreading	Lanceolate	2.4	15.3	5.7	2.0
527	24\17	Spreading	Lanceolate	1.5	15.9	7.8	1.4
528	24\20	Spreading	Lanceolate	1.9	14.6	3.3	2.0
529	24\21	Spreading	Lanceolate	2.5	16.5	5.2	1.7
530	24\22	Spreading	Lanceolate	2.5	16.7	5.4	2.2
531	24\23	Erect	Lanceolate	2.2	14.7	5.3	2.1
532	24\24	Spreading	Lanceolate	2.3	15.9	5.2	2.0
533	25\1	Spreading	Ovate	2.2	16.1	6.9	2.0
534	25\2	Erect	Lanceolate	2.8	14.5	7.1	1.4
535	25\3	Spreading	Elliptic	2.1	16.7	8.2	1.2
536	25\4	Spreading	Ovate	1.8	10.7	4.6	1.2
537	25\5	Spreading	Lanceolate	2.6	14.6	6.0	1.4
538	25\6	Spreading	Lanceolate	2.6	16.4	5.8	1.6
539	25\7	Spreading	Lanceolate	2.6	11.3	4.1	2.0
540	25\8	Spreading	Lanceolate	2.5	13.8	5.7	1.5
541	25\9	Erect	Ovate	2.4	14.7	6.1	1.3
542	25\10	Erect	Lanceolate	2.8	15.6	7.9	1.5
543	25\12	Spreading	Lanceolate	3.0	13.7	6.8	1.6
544	25\13	Spreading	Lanceolate	3.1	16.2	7.0	1.4
545	25\14	Erect	Lanceolate	2.9	19.7	9.1	1.7
546	25\15	Spreading	Lanceolate	3.2	19.5	8.9	1.9
547	26\1	Erect	Lanceolate	2.8	15.9	6.5	1.4
548	26\2	Spreading	Ovate	2.3	14.8	6.5	1.4
549	26\3	Spreading	Ovate	2.5	13.8	7.0	1.6
550	26\4	Spreading	Lanceolate	2.1	12.7	5.0	1.5
551	26\6	Spreading	Lanceolate	3.5	19.4	7.5	1.8
552	26\7	Spreading	Lanceolate	2.6	13.8	6.1	1.6
553	26\8	Spreading	Lanceolate	3.8	19.9	8.1	1.8
554	26\9	Spreading	Ovate	3.2	14.0	8.5	1.0
555	26\10	Spreading	Lanceolate	3.7	16.6	9.3	1.3
556	26\11	Spreading	Lanceolate	3.1	18.6	9.0	1.3
557	26\12	Spreading	Lanceolate	3.5	19.4	6.8	1.6
558	26\13	Erect	Lanceolate	3.2	14.6	8.4	2.2
559	26\14	Spreading	Lanceolate	3.3	18.6	7.9	1.8

Sl. No.	Progeny	Spreading habit	Leaf shape	Plant height (m)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)
560	26\15	Erect	Lanceolate	2.9	16.7	9.5	1.8
561	26\16	Spreading	Lanceolate	3.1	21.5	9.2	1.7
562	27\1	Erect	Lanceolate	2.8	18.0	8.5	1.1
563	27\2	Erect	Lanceolate	2.5	13.8	5.3	1.5
564	27\3	Erect	Lanceolate	3.1	14.9	7.9	1.8
565	27\4	Erect	Elliptic	2.9	17.3	8.6	1.6
566	27\5	Erect	Lanceolate	3.2	15.5	7.6	2.0
567	27\6	Spreading	Lanceolate	3.3	18.1	6.9	1.6
568	27\7	Spreading	Lanceolate	2.9	15.4	5.3	1.8
569	27\8	Erect	Lanceolate	3.1	19.0	8.8	1.3
570	27\9	Erect	Lanceolate	3.2	15.6	6.3	1.4
571	27\10	Spreading	Lanceolate	2.7	14.4	6.4	1.6
572	27\11	Erect	Lanceolate	3.1	14.8	6.8	1.4
573	27\12	Erect	Lanceolate	2.6	14.4	6.4	1.3
574	27\13	Spreading	Lanceolate	3.1	15.3	8.6	1.8
575	27\14	Spreading	Lanceolate	2.8	16.3	6.6	1.5
576	27\15	Sreading	Lanceolate	2.4	13.8	8.0	1.8
577	27\16	Erect	Lanceolate	3.0	15.0	7.1	1.7
578	28\1	Spreading	Lanceolate	2.8	16.7	6.6	1.5
579	28\2	Spreading	Lanceolate	3.2	14.4	7.3	1.9
580	28\4	Erect	Lanceolate	3.2	13.6	7.5	1.6
581	28\5	Spreading	Lanceolate	2.6	15.1	5.7	2.1
582	28\6	Spreading	Lanceolate	3.1	18.0	5.9	2.0
583	28\7	Spreading	Lanceolate	2.6	13.5	6.3	1.8
584	28\8	Spreading	Lanceolate	3.1	17.6	7.7	1.7
585	28\9	Spreading	Lanceolate	3.4	14.8	6.6	1.4
586	28\10	Spreading	Lanceolate	2.6	15.5	5.9	1.5
587	28\11	Spreading	Lanceolate	2.7	16.7	5.5	1.4
588	28\12	Erect	Lanceolate	2.8	15.8	8.1	2.0
589	28\13	Spreading	Lanceolate	2.5	28.7	6.2	1.5
590	28\14	Spreading	Lanceolate	2.9	18.2	6.0	1.7
591	28\15	Erect	Lanceolate	2.7	16.7	4.7	1.1
592	28\16	Spreading	Lanceolate	3.2	18.3	7.3	2.1
593	29\1	Spreading	Lanceolate	3.5	18.5	8.8	1.4
594	29\2	Spreading	Lanceolate	2.9	15.8	7.0	2.0
595	29\3	Spreading	Lanceolate	2.4	15.0	8.1	1.5
596	29\4	Erect	Lanceolate	3.2	12.6	7.0	1.7
597	29\5	Spreading	Lanceolate	2.4	12.0	4.6	1.7
598	29\6	Spreading	Lanceolate	3.1	16.1	6.6	1.9
599	29\9	Erect	Lanceolate	2.8	16.9	7.3	1.6

Sl. No.	Progeny	Spreading habit	Leaf shape	Plant height (m)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)
600	29\10	Erect	Lanceolate	3.6	17.0	6.6	1.5
601	29\11	Spreading	Lanceolate	3.9	15.5	6.3	1.2
602	29\12	Spreading	Lanceolate	2.6	13.1	4.9	1.3
603	29\13	Erect	Lanceolate	3.1	16.0	8.6	1.3
604	29\14	Spreading	Lanceolate	3.5	15.5	7.2	1.7
605	29\15	Erect	Lanceolate	3.0	13.6	6.6	1.4
606	29\16	Erect	Lanceolate	2.7	19.4	9.3	2.0
607	29\17	Erect	Lanceolate	3.0	14.3	7.5	1.4
608	30\1	Spreading	Lanceolate	2.7	11.3	4.6	1.4
609	30\2	Spreading	Lanceolate	2.2	13.1	6.2	1.5
610	30\3	Erect	Lanceolate	3.5	13.4	7.8	1.2
611	30\4	Spreading	Lanceolate	2.8	17.0	8.5	2.0
612	30\6	Spreading	Ovate	2.8	12.9	5.7	1.0
613	30\7	Spreading	Lanceolate	3.0	14.5	8.8	1.5
614	30\8	Spreading	Lanceolate	2.6	11.3	4.3	1.7
615	30\9	Erect	Lanceolate	3.0	18.5	8.7	1.7
616	30\10	Spreading	Lanceolate	2.8	13.2	5.9	1.3
617	30\11	Spreading	Lanceolate	2.6	28.3	4.7	1.7
618	30\12	Spreading	Lanceolate	4.0	13.7	6.7	1.8
619	30\13	Erect	Ovate	2.6	15.7	8.4	1.6
620	30\14	Erect	Lanceolate	2.7	14.4	6.3	1.7
621	30\15	Erect	Lanceolate	3.1	15.9	8.3	1.9
622	30\16	Erect	Lanceolate	3.1	14.4	7.0	1.2
623	30\17	Spreading	Lanceolate	2.8	18.2	8.7	1.7
624	31\1	Erect	Lanceolate	3.8	14.4	7.1	1.4
625	31\2	Erect	Elliptic	3.5	14.0	8.5	1.5
626	31\3	Spreading	Lanceolate	2.9	17.0	8.6	1.5
627	31\4	Spreading	Elliptic	3.3	15.6	8.7	1.4
628	31\5	Spreading	Lanceolate	1.8	12.6	6.4	1.5
629	31\6	Erect	Elliptic	3.4	17.3	9.1	1.7
630	31\7	Erect	Lanceolate	3.4	11.1	4.8	1.2
631	31\8	Erect	Lanceolate	3.3	12.0	4.8	1.6
632	31\9	Erect	Lanceolate	2.9	17.6	9.0	1.6
633	31\10	Spreading	Ovate	2.6	14.1	6.1	1.5
634	31\11	Spreading	Lanceolate	2.9	12.8	6.0	1.6
635	31\12	Erect	Lanceolate	2.9	14.3	5.0	1.3
636	31\13	Erect	Lanceolate	2.4	15.2	7.1	1.6
637	31\14	Erect	Lanceolate	1.4	10.5	3.9	1.2
638	31\15	Erect	Lanceolate	2.9	13.9	4.9	1.5
639	31\16	Erect	Lanceolate	2.5	6.9	3.3	1.7

Sl. No.	Progeny	Spreading habit	Leaf shape	Plant height (m)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)
640	31\17	Erect	Lanceolate	2.9	18.7	7.8	1.5
641	32\1	Spreading	Lanceolate	3.2	17.8	7.9	1.2
642	32\2	Spreading	Lanceolate	1.6	13.6	5.8	1.4
643	32\3	Spreading	Lanceolate	2.6	14.5	6.2	1.6
644	32\4	Erect	Lanceolate	3.2	14.8	6.1	1.3
645	32\5	Erect	Lanceolate	3.2	17.5	9.0	1.5
646	32\6	Spreading	Lanceolate	2.9	16.3	7.0	1.7
647	32\7	Erect	Lanceolate	2.8	14.1	5.8	1.2
648	32\8	Erect	Lanceolate	2.9	18.0	8.0	1.6
649	32\9	Spreading	Lanceolate	2.7	12.9	5.2	1.6
650	32\10	Erect	Lanceolate	3.0	14.4	6.1	1.5
651	32\11	Erect	Lanceolate	2.9	15.3	6.3	1.6
652	32\12	Spreading	Ovate	3.1	11.8	5.4	1.3
653	32\13	Spreading	Lanceolate	2.2	12.9	5.5	1.6
654	32\14	Spreading	Lanceolate	3.2	18.4	9.0	1.2
655	32\15	Spreading	Lanceolate	2.1	16.1	7.0	1.5
656	32\16	Erect	Lanceolate	2.5	16.3	8.4	1.7
657	32\17	Erect	Lanceolate	2.7	15.1	7.1	1.5
658	32\18	Erect	Lanceolate	2.9	14.1	6.5	1.6
659	33\1	Spreading	Lanceolate	3.0	13.4	4.3	1.5
660	33\2	Spreading	Lanceolate	2.5	15.0	6.3	1.6
661	33\3	Spreading	Lanceolate	2.0	15.3	7.1	1.6
662	33\4	Erect	Lanceolate	2.6	14.6	6.3	1.7
663	33\5	Erect	Lanceolate	3.2	15.2	6.4	1.1
664	33\6	Erect	Lanceolate	3.2	17.2	7.3	1.1
665	33\7	Erect	Lanceolate	3.4	13.2	8.1	0.7
666	33\8	Erect	Lanceolate	2.9	12.7	4.9	1.6
667	33\9	Spreading	Lanceolate	3.1	13.0	5.4	1.6
668	33\10	Erect	Lanceolate	2.9	15.0	7.8	1.6
669	33\11	Spreading	Lanceolate	3.1	15.6	5.2	1.3
670	33\12	Erect	Elliptic	3.7	17.0	7.9	2.1
671	33\13	Spreading	Lanceolate	2.5	14.2	4.9	1.5
672	33\14	Spreading	Lanceolate	2.7	13.9	6.4	1.6
673	33\15	Spreading	Lanceolate	2.9	9.6	4.5	1.1
674	33\16	Erect	Lanceolate	2.9	19.0	7.2	1.5
675	33\17	Erect	Lanceolate	3.4	17.8	7.9	1.4
676	33\18	Spreading	Lanceolate	3.3	14.8	7.2	1.6
677	34\1	Erect	Lanceolate	3.0	16.2	7.3	1.9
678	34\2	Erect	Lanceolate	2.6	14.9	7.8	1.6
679	34\3	Spreading	Lanceolate	1.3	12.4	4.9	1.1

Sl. No.	Progeny	Spreading habit	Leaf shape	Plant height (m)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)
680	34\4	Erect	Lanceolate	3.1	17.0	7.4	0.8
681	34\5	Erect	Lanceolate	3.2	15.4	6.9	1.5
682	34\6	Erect	Lanceolate	3.0	14.8	5.5	1.3
683	34\7	Spreading	Lanceolate	3.4	15.3	7.5	1.6
684	34\8	Erect	Lanceolate	2.9	16.3	6.7	1.7
685	34\9	Spreading	Lanceolate	3.2	13.4	5.7	1.5
686	34\10	Spreading	Lanceolate	2.8	17.1	7.3	1.2
687	34\11	Erect	Ovate	2.8	11.7	6.1	1.5
688	34\12	Spreading	Lanceolate	2.9	12.2	5.2	0.8
689	34\14	Erect	Lanceolate	2.9	14.3	5.5	1.6
690	34\16	Spreading	Lanceolate	1.9	12.4	4.6	1.5
691	34\17	Spreading	Lanceolate	3.4	14.1	6.8	1.6
692	34\18	Erect	Lanceolate	3.3	15.7	7.9	1.7
693	34\19	Spreading	Lanceolate	3.5	14.2	5.9	2.1
694	35\1	Spreading	Lanceolate	2.5	12.7	6.8	1.6
695	35\2	Spreading	Lanceolate	2.7	14.1	6.9	1.6
696	35\3	Spreading	Lanceolate	2.6	14.9	7.3	1.5
697	35\4	Erect	Lanceolate	2.5	17.7	7.9	1.9
698	35\5	Spreading	Lanceolate	2.6	10.8	5.5	2.3
699	35\6	Erect	Lanceolate	3.0	15.8	7.8	1.3
700	35\7	Spreading	Lanceolate	3.0	13.7	6.8	1.4
701	35\8	Spreading	Lanceolate	2.5	16.4	7.8	1.5
702	35\9	Erect	Lanceolate	2.7	14.8	6.6	1.2
703	35\10	Spreading	Lanceolate	3.2	14.6	6.6	1.9
704	35\11	Spreading	Lanceolate	2.7	13.7	6.6	1.7
705	35\12	Spreading	Lanceolate	2.5	16.6	7.5	1.3
706	35\13	Spreading	Lanceolate	2.9	14.8	5.3	1.6
707	35\14	Erect	Lanceolate	2.1	13.1	6.2	1.7
708	35\15	Spreading	Lanceolate	3.1	20.7	9.5	1.6
709	35\16	Erect	Lanceolate	3.5	20.5	7.0	1.8
710	35\17	Spreading	Lanceolate	3.0	13.8	5.3	1.4
711	35\18	Spreading	Lanceolate	3.3	14.4	6.9	1.6
712	35\19	Spreading	Lanceolate	2.5	10.1	4.0	1.1
713	36\1	Spreading	Lanceolate	3.8	15.0	6.8	1.6
714	36\2	Spreading	Lanceolate	2.4	12.9	7.1	1.7
715	36\3	Spreading	Lanceolate	3.4	12.9	6.6	1.8
716	36\4	Erect	Lanceolate	2.2	14.9	6.2	2.1
717	36\5	Erect	Lanceolate	2.9	15.0	7.3	2.0
718	36\6	Spreading	Lanceolate	3.2	17.1	7.5	2.5
719	36\7	Erect	Lanceolate	3.6	15.5	8.8	1.7

Sl. No.	Progeny	Spreading habit	Leaf shape	Plant height (m)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)
720	36\8	Spreading	Lanceolate	3.5	18.4	8.0	1.4
721	36\9	Erect	Lanceolate	3.2	15.9	7.5	1.5
722	36\10	Spreading	Lanceolate	1.8	14.0	6.8	1.5
723	36\11	Erect	Lanceolate	3.6	15.8	5.9	1.5
724	36\12	Erect	Lanceolate	2.7	14.7	7.0	1.3
725	36\13	Erect	Elliptic	2.9	19.6	9.4	1.5
726	36\14	Erect	Lanceolate	3.3	17.6	7.9	1.5
727	36\15	Erect	Lanceolate	2.7	16.0	8.4	1.5
728	36\16	Erect	Lanceolate	3.1	18.9	8.1	1.7
729	36\17	Spreading	Lanceolate	2.9	15.5	6.2	1.5
730	36\18	Erect	Lanceolate	2.8	12.5	6.0	1.3
731	36\19	Spreading	Lanceolate	2.8	16.9	6.7	1.4
732	37\1	Erect	Lanceolate	3.4	14.6	6.8	1.6
733	37\2	Spreading	Lanceolate	2.6	13.7	5.1	1.1
734	37\3	Spreading	Lanceolate	2.1	15.1	6.2	1.7
735	37\4	Erect	Lanceolate	2.9	14.8	7.7	2.1
736	37\5	Erect	Lanceolate	3.2	14.8	7.2	1.6
737	37\6	Spreading	Lanceolate	3.1	15.6	6.1	1.4
738	37\7	Erect	Lanceolate	4.1	15.7	7.2	1.6
739	37\8	Erect	Lanceolate	3.9	15.4	7.1	2.2
740	37\9	Erect	Lanceolate	3.2	15.3	6.9	1.2
741	37\10	Spreading	Lanceolate	2.7	14.8	6.3	1.3
742	37\11	Erect	Ovate	2.4	13.8	6.9	1.2
743	37\12	Erect	Lanceolate	3.2	16.0	9.0	1.7
744	37\14	Spreading	Lanceolate	2.6	14.8	5.2	1.4
745	37\15	Spreading	Lanceolate	2.9	16.4	6.6	1.5
746	37\16	Erect	Lanceolate	3.1	14.9	9.5	0.5
747	37\17	Spreading	Lanceolate	1.4	9.1	3.3	1.3
748	37\18	Spreading	Lanceolate	2.7	15.6	6.5	1.3
749	37\19	Erect	Lanceolate	3.2	14.7	9.2	1.5
750	37\20	Spreading	Lanceolate	2.6	15.0	6.3	1.4
751	38\1	Erect	Lanceolate	2.5	14.5	6.3	1.3
752	38\2	Spreading	Lanceolate	3.1	18.0	7.7	1.7
753	38\3	Erect	Lanceolate	2.9	16.3	8.1	1.8
754	38\4	Spreading	Lanceolate	3.0	17.5	7.1	1.7
755	38\5	Erect	Lanceolate	3.6	14.2	6.9	1.8
756	38\6	Spreading	Lanceolate	2.7	16.1	8.1	1.2
757	38\7	Erect	Lanceolate	3.2	16.0	7.9	1.0
758	38\8	Spreading	Lanceolate	3.6	17.6	8.1	1.8
759	38\9	Erect	Lanceolate	3.6	18.8	8.7	1.3

Sl. No.	Progeny	Spreading habit	Leaf shape	Plant height (m)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)
760	38\10	Erect	Lanceolate	2.9	18.7	8.2	1.8
761	38\11	Erect	Lanceolate	3.1	15.9	5.7	1.6
762	38\12	Spreading	Lanceolate	3.2	18.7	8.1	2.4
763	38\13	Erect	Lanceolate	2.9	19.7	9.3	1.8
764	38\14	Spreading	Lanceolate	3.4	14.5	7.6	1.8
765	38\15	Erect	Lanceolate	2.7	13.0	6.7	1.6
766	38\16	Erect	Lanceolate	3.3	19.3	8.6	2.1
767	38\17	Spreading	Lanceolate	0.8	12.8	6.3	1.3
768	38\18	Spreading	Lanceolate	2.7	14.9	6.2	1.3
769	38\19	Erect	Lanceolate	3.1	14.8	8.2	2.0
770	38\20	Erect	Lanceolate	2.6	16.2	7.2	1.3
771	39\1	Spreading	Lanceolate	2.9	16.2	7.6	1.4
772	39\2	Spreading	Lanceolate	3.0	15.2	6.5	1.8
773	39\3	Erect	Lanceolate	2.9	13.9	5.7	1.7
774	39\4	Erect	Lanceolate	2.7	14.7	7.0	1.3
775	39\5	Erect	Elliptic	2.3	12.1	4.9	1.4
776	39\6	Spreading	Lanceolate	2.6	14.6	9.0	1.1
777	39\7	Erect	Lanceolate	2.2	14.8	6.3	1.5
778	39\8	Spreading	Lanceolate	2.5	14.2	6.2	1.4
779	39\9	Spreading	Lanceolate	2.5	13.4	5.0	1.5
780	39\10	Sreading	Lanceolate	2.3	14.1	7.5	1.7
781	39\11	Erect	Lanceolate	2.8	14.6	5.3	1.0
782	39\12	Spreading	Lanceolate	3.2	15.3	5.7	2.1
783	39\13	Spreading	Lanceolate	3.2	17.0	9.1	1.9
784	39\14	Spreading	Lanceolate	3.4	15.9	7.7	1.6
785	39\15	Spreading	Lanceolate	3.4	17.3	8.1	2.2
786	39\16	Spreading	Lanceolate	3.2	13.2	5.8	1.0
787	39\18	Erect	Lanceolate	3.1	16.2	7.7	2.1
788	39\19	Erect	Lanceolate	3.2	14.2	8.5	1.7
789	39\20	Erect	Lanceolate	2.5	11.9	5.7	1.6
790	39\21	Spreading	Lanceolate	2.7	13.0	6.4	1.5
791	40\1	Spreading	Lanceolate	2.7	14.6	6.4	1.6
792	40\2	Erect	Lanceolate	2.9	14.8	6.6	1.6
793	40\3	Spreading	Lanceolate	2.8	14.5	5.3	1.6
794	40\5	Spreading	Ovate	2.7	14.7	5.5	1.7
795	40\6	Spreading	Lanceolate	3.0	16.5	7.2	1.6
796	40\7	Spreading	Lanceolate	2.4	15.0	7.7	1.4
797	40\8	Erect	Lanceolate	2.0	15.1	5.3	1.4
798	40\9	Spreading	Lanceolate	3.1	15.3	7.1	1.3
799	40\10	Spreading	Lanceolate	1.9	13.9	6.0	1.3

Sl. No.	Progeny	Spreading habit	Leaf shape	Plant height (m)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)
800	40\11	Erect	Lanceolate	2.8	12.3	7.9	1.5
801	40\12	Erect	Lanceolate	2.9	16.7	6.0	1.4
802	40\13	Erect	Lanceolate	3.2	15.9	7.8	1.6
803	40\14	Spreading	Lanceolate	3.2	13.7	5.9	1.5
804	40\15	Spreading	Lanceolate	2.3	10.7	4.5	1.2
805	40\16	Erect	Lanceolate	2.9	15.3	7.3	1.4
806	40\17	Erect	Lanceolate	3.5	20.5	8.1	1.8
807	40\18	Erect	Elliptic	3.8	20.9	9.7	1.6
808	40\19	Spreading	Lanceolate	3.2	16.7	7.4	1.6
809	40\20	Erect	Lanceolate	3.1	18.5	7.9	1.6
810	40\21	Spreading	Elliptic	2.7	18.0	5.8	1.3
811	41\1	Erect	Lanceolate	3.1	17.1	8.2	1.8
812	41\2	Spreading	Lanceolate	3.0	17.3	7.5	1.7
813	41\3	Erect	Lanceolate	3.3	16.3	7.6	1.6
814	41\4	Spreading	Lanceolate	3.2	17.1	6.6	1.6
815	41\5	Erect	Lanceolate	3.5	21.2	8.0	1.7
816	41\6	Spreading	Lanceolate	2.7	15.2	7.6	1.2
817	41\7	Spreading	Lanceolate	2.0	13.2	5.0	1.6
818	41\8	Erect	Lanceolate	3.0	13.6	6.3	1.7
819	41\9	Spreading	Lanceolate	2.9	14.0	5.3	1.7
820	41\10	Spreading	Lanceolate	2.7	16.9	7.6	1.4
821	41\11	Erect	Lanceolate	3.0	16.3	7.5	1.7
822	41\12	Erect	Lanceolate	3.3	14.5	8.8	1.7
823	41\13	Spreading	Lanceolate	2.9	14.4	5.7	1.5
824	41\14	Spreading	Lanceolate	3.1	16.3	7.1	1.8
825	41\15	Erect	Lanceolate	2.9	17.4	9.2	1.8
826	41\16	Erect	Lanceolate	2.6	10.9	3.7	1.4
827	41\17	Spreading	Lanceolate	2.8	16.7	7.4	1.8
828	41\18	Spreading	Lanceolate	2.4	14.0	4.9	1.6
829	41\19	Spreading	Lanceolate	2.7	13.4	4.9	2.1
830	41\20	Spreading	Lanceolate	3.5	14.1	7.0	1.7
831	41\21	Erect	Lanceolate	2.3	14.0	6.0	1.6
832	41\22	Erect	Lanceolate	2.5	15.0	7.1	1.7
833	42\1	Spreading	Lanceolate	3.3	14.5	6.7	1.6
834	42\2	Erect	Lanceolate	2.1	15.3	9.1	1.5
835	42\3	Spreading	Lanceolate	2.4	14.6	6.0	1.3
836	42\4	Erect	Lanceolate	2.7	17.6	7.9	1.4
837	42\5	Spreading	Lanceolate	2.4	15.8	6.9	1.7
838	42\6	Spreading	Lanceolate	2.5	15.4	6.2	1.6
839	42\7	Spreading	Lanceolate	3.3	15.8	7.0	1.5

Sl. No.	Progeny	Spreading habit	Leaf shape	Plant height (m)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)
840	42\8	Erect	Lanceolate	3.3	13.8	5.1	1.6
841	42\9	Erect	Lanceolate	3.5	19.5	7..2	1.0
842	42\10	Erect	Lanceolate	2.9	15.5	8.2	2.2
843	42\11	Erect	Lanceolate	2.7	15.7	6.4	1.7
844	42\12	Spreading	Lanceolate	2.7	17.1	7.0	2.1
845	42\13	Spreading	Lanceolate	2.9	16.0	6.0	1.4
846	42\14	Erect	Lanceolate	3.2	19.0	8.3	1.8
847	42\15	Spreading	Lanceolate	2.6	14.6	5.4	1.5
848	42\16	Erect	Lanceolate	3.2	12.8	5.2	1.3
849	42\17	Spreading	Lanceolate	3.2	10.3	4.8	1.6
850	42\18	Spreading	Lanceolate	2.4	14.0	6.3	1.7
851	42\19	Spreading	Ovate	3.4	22.4	9.1	2.1
852	42\20	Spreading	Lanceolate	2.9	14.9	7.2	1.9
853	42\21	Spreading	Lanceolate	3.2	14.7	7.7	2.1
854	42\22	Spreading	Lanceolate	3.0	14.6	5.4	1.5
855	42\23	Erect	Lanceolate	3.1	14.0	6.3	1.7
856	43\1	Spreading	Lanceolate	2.7	14.2	5.7	1.3
857	43\2	Erect	Lanceolate	2.6	19.3	9.5	1.8
858	43\3	Spreading	Lanceolate	2.4	15.4	6.4	1.6
859	43\4	Spreading	Lanceolate	3.2	11.9	4.7	1.6
860	43\5	Spreading	Lanceolate	2.8	14.4	5.7	2.1
861	43\6	Erect	Lanceolate	3.5	14.1	6.1	2.1
862	43\7	Erect	Lanceolate	3.2	16.3	7.5	1.8
863	43\8	Spreading	Lanceolate	3.1	16.8	8.2	2.0
864	43\9	Erect	Lanceolate	3.4	16.4	8.9	1.5
865	43\10	Spreading	Lanceolate	2.0	17.3	7.3	1.0
866	43\11	Spreading	Lanceolate	3.5	14.6	7.3	1.7
867	43\12	Spreading	Lanceolate	3.0	14.8	5.7	1.3
868	43\13	Erect	Lanceolate	2.6	17.1	8.2	1.0
869	43\14	Spreading	Lanceolate	3.2	10.4	5.2	1.6
870	43\15	Spreading	Lanceolate	2.9	12.4	5.6	1.6
871	43\16	Erect	Lanceolate	3.5	14.4	6.7	1.3
872	43\17	Erect	Lanceolate	3.5	13.5	5.6	1.3
873	43\18	Spreading	Lanceolate	3.3	15.3	7.1	1.7
874	43\19	Erect	Elliptic	2.9	18.7	8.3	2.0
875	43\20	Spreading	Lanceolate	2.7	12.1	4.9	1.7
876	43\21	Spreading	Lanceolate	2.4	13.5	5.9	1.4
877	43\22	Spreading	Lanceolate	2.9	14.6	6.3	1.8
878	44\1	Spreading	Lanceolate	2.0	16.7	6.9	1.8
879	44\2	Spreading	Lanceolate	3.0	12.3	5.3	1.6

Sl. No.	Progeny	Spreading habit	Leaf shape	Plant height (m)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)
880	44\3	Erect	Lanceolate	2.8	16.2	7.2	1.6
881	44\4	Erect	Lanceolate	3.3	17.0	7.7	1.7
882	44\5	Spreading	Lanceolate	1.6	15.0	7.3	1.3
883	44\6	Erect	Ovate	3.2	15.0	6.6	1.5
884	44\7	Spreading	Lanceolate	2.8	15.9	6.5	1.6
885	44\8	Erect	Lanceolate	3.2	18.6	8.6	1.7
886	44\9	Spreading	Lanceolate	3.1	12.6	6.8	1.4
887	44\10	Spreading	Lanceolate	3.2	15.2	5.7	1.8
888	44\11	Erect	Lanceolate	3.8	17.4	6.7	2.1
889	44\12	Spreading	Ovate	3.8	14.8	6.9	1.9
890	44\13	Erect	Lanceolate	3.1	14.8	6.0	1.7
891	44\14	Erect	Lanceolate	1.0	15.7	8.9	1.5
892	44\15	Erect	Lanceolate	2.9	15.1	6.5	1.6
893	44\16	Spreading	Lanceolate	3.4	15.9	7.3	1.5
894	44\17	Spreading	Lanceolate	3.8	13.6	5.0	1.6
895	44\18	Spreading	Lanceolate	2.8	11.0	6.3	1.8
896	44\19	Erect	Lanceolate	2.6	18.6	8.7	2.1
897	44\20	Spreading	Lanceolate	2.6	13.1	4.9	1.7
898	44\21	Spreading	Lanceolate	2.7	15.2	6.0	1.9
899	44\22	Spreading	Lanceolate	3.5	12.4	5.0	1.4
900	45\1	Spreading	Lanceolate	3.2	16.2	6.8	1.5
901	45\2	Erect	Lanceolate	2.8	15.2	7.2	1.3
902	45\3	Erect	Elliptic	3.2	16.9	7.8	1.6
903	45\4	Erect	Lanceolate	3.2	13.2	6.9	1.7
904	45\5	Spreading	Lanceolate	3.1	15.0	7.2	1.4
905	45\6	Erect	Ovate	4.2	18.7	8.3	1.0
906	45\7	Erect	Lanceolate	3.2	15.5	7.4	1.6
907	45\8	Erect	Lanceolate	3.6	23.4	9.8	1.5
908	45\9	Erect	Elliptic	2.6	15.0	6.8	1.8
909	45\10	Erect	Lanceolate	2.5	20.3	8.4	1.8
910	45\11	Spreading	Lanceolate	3.2	14.8	6.2	1.6
911	45\12	Erect	Lanceolate	3.5	12.3	5.8	1.6
912	45\13	Spreading	Lanceolate	3.8	15.1	6.3	1.6
913	45\14	Erect	Lanceolate	3.5	17.4	8.0	1.7
914	45\15	Erect	Lanceolate	3.5	16.3	8.9	1.6
915	45\16	Spreading	Lanceolate	3.4	17.7	7.8	1.6
916	45\17	Erect	Elliptic	3.3	14.1	8.6	1.6
917	45\18	Erect	Lanceolate	2.9	18.9	8.5	1.6
918	45\19	Spreading	Lanceolate	3.8	14.6	6.9	2.1
919	45\20	Spreading	Lanceolate	2.5	20.1	8.5	1.7

Sl. No.	Progeny	Spreading habit	Leaf shape	Plant height (m)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)
920	45\21	Erect	Lanceolate	3.2	14.2	8.0	1.0
921	45\22	Spreading	Lanceolate	2.5	17.6	8.1	1.6
922	46\1	Spreading	Lanceolate	3.2	11.4	5.3	1.9
923	46\2	Erect	Lanceolate	3.1	16.5	6.4	1.7
924	46\3	Erect	Lanceolate	2.4	15.3	5.4	1.4
925	46\4	Spreading	Lanceolate	3.1	12.1	6.4	1.5
926	46\5	Spreading	Lanceolate	2.4	18.0	7.8	1.5
927	46\6	Erect	Lanceolate	3.3	16.9	6.5	2.5
928	46\7	Spreading	Lanceolate	3.5	18.7	9.3	1.7
929	46\8	Spreading	Lanceolate	3.3	13.1	5.7	1.5
930	46\9	Erect	Lanceolate	3.0	16.0	7.5	1.3
931	46\10	Spreading	Lanceolate	3.5	12.8	6.0	2.0
932	46\11	Erect	Lanceolate	2.9	16.9	8.7	1.8
933	46\12	Spreading	Lanceolate	0.8	15.0	6.4	1.5
934	46\13	Spreading	Lanceolate	3.6	12.0	4.5	1.4
935	46\14	Erect	Ovate	3.2	17.8	9.2	1.2
936	46\15	Spreading	Lanceolate	3.7	12.8	6.0	2.0
937	46\16	Spreading	Lanceolate	2.2	15.0	5.6	1.6
938	46\17	Spreading	Lanceolate	3.1	11.3	4.1	1.6
939	46\18	Spreading	Lanceolate	3.6	15.0	8.9	1.6
940	46\19	Erect	Lanceolate	2.9	14.7	6.8	2.1
941	46\20	Spreading	Lanceolate	3.2	16.9	7.0	1.6
942	46\21	Spreading	Lanceolate	3.0	15.4	7.1	1.7
943	46\22	Spreading	Lanceolate	2.6	12.8	5.3	1.3
944	46\23	Erect	Lanceolate	2.9	12.7	5.1	1.7
945	47\1	Erect	Lanceolate	3.3	18.5	7.3	1.9
946	47\2	Erect	Ovate	3.2	14.3	7.0	1.3
947	47\3	Erect	Lanceolate	3.5	18.5	8.5	1.6
948	47\4	Erect	Lanceolate	2.4	19.4	9.7	1.3
949	47\5	Spreading	Lanceolate	2.3	14.6	5.5	1.7
950	47\6	Erect	Lanceolate	2.8	16.9	7.3	1.6
951	47\7	Erect	Lanceolate	3.5	16.5	9.5	1.3
952	47\8	Erect	Lanceolate	3.2	20.7	9.1	1.4
953	47\9	Erect	Ovate	3.9	17.4	9.4	1.8
954	47\10	Erect	Ovate	2.5	14.7	7.3	1.6
955	47\11	Erect	Lanceolate	2.5	18.3	8.6	1.9
956	47\12	Spreading	Lanceolate	2.6	16.1	7.6	1.5
957	47\13	Spreading	Lanceolate	3.2	12.7	5.0	1.6
958	47\14	Spreading	Lanceolate	2.7	14.1	5.9	1.8
959	47\15	Erect	Lanceolate	3.8	20.2	8.8	1.5

Sl. No.	Progeny	Spreading habit	Leaf shape	Plant height (m)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)
960	47\16	Erect	Lanceolate	3.2	12.7	5.1	1.7
961	47\17	Erect	Elliptic	3.0	17.4	8.0	2.0
962	47\18	Spreading	Lanceolate	3.2	16.2	6.4	1.3
963	47\19	Erect	Lanceolate	3.5	13.7	6.6	1.6
964	47\20	Erect	Ovate	3.0	19.9	7.4	1.7
965	47\21	Erect	Lanceolate	2.7	15.1	5.8	1.8
966	47\22	Erect	Lanceolate	3.6	18.4	8.2	1.4
967	47\23	Erect	Lanceolate	3.2	19.9	9.8	2.1
968	47\24	Spreading	Lanceolate	2.7	15.2	8.2	2.1
969	48\1	Spreading	Lanceolate	3.5	13.3	5.0	1.5
970	48\2	Spreading	Ovate	3.1	18.2	8.0	2.2
971	48\3	Erect	Lanceolate	3.2	16.3	6.0	1.6
972	48\4	Spreading	Lanceolate	3.2	16.5	7.0	1.5
973	48\5	Erect	Lanceolate	3.5	17.4	7.8	1.6
974	48\6	Erect	Lanceolate	2.6	23.6	9.7	1.6
975	48\7	Erect	Lanceolate	2.8	18.0	6.9	1.8
976	48\8	Erect	Lanceolate	3.0	17.2	6.7	1.8
977	48\9	Erect	Lanceolate	3.4	14.2	6.8	1.6
978	48\10	Spreading	Lanceolate	2.6	15.3	6.7	2.0
979	48\11	Erect	Lanceolate	1.9	17.2	7.9	2.0
980	48\12	Erect	Lanceolate	2.2	15.1	7.7	1.6
981	48\13	Erect	Lanceolate	2.7	16.6	7.8	1.4
982	48\14	Spreading	Lanceolate	2.6	16.0	8.3	1.6
983	48\15	Spreading	Elliptic	2.9	18.5	9.0	1.8
984	48\16	Erect	Elliptic	2.8	17.2	9.6	1.8
985	48\17	Spreading	Lanceolate	3.2	16.4	5.6	1.5
986	48\18	Erect	Ovate	3.4	19.6	9.3	1.6
987	48\19	Spreading	Lanceolate	3.3	18.4	9.1	1.7
988	48\20	Erect	Lanceolate	1.6	16.3	5.7	1.6
989	48\21	Spreading	Lanceolate	3.0	16.3	6.8	1.2
990	48\22	Erect	Lanceolate	2.4	19.2	8.9	1.7
991	48\24	Erect	Lanceolate	3.2	14.8	6.4	2.1
992	49\1	Erect	Lanceolate	3.2	19.8	9.2	1.5
993	49\2	Spreading	Lanceolate	3.1	12.8	5.9	1.5
994	49\3	Spreading	Lanceolate	3.2	14.7	6.5	1.6
995	49\5	Spreading	Lanceolate	3.6	17.4	7.3	1.8
996	49\6	Erect	Lanceolate	2.9	17.6	7.6	1.5
997	49\7	Spreading	Lanceolate	3.3	15.0	6.1	1.7
998	49\8	Spreading	Lanceolate	3.2	14.9	7.5	2.0
999	49\9	Erect	Lanceolate	3.2	15.8	6.5	1.6

Sl. No.	Progeny	Spreading habit	Leaf shape	Plant height (m)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)
1000	49\10	Spreading	Ovate	3.1	18.1	9.0	1.6
1001	49\11	Spreading	Lanceolate	2.6	15.2	7.2	2.0
1002	49\12	Erect	Lanceolate	3.2	15.7	7.6	1.3
1003	49\13	Spreading	Lanceolate	2.6	15.5	7.3	1.5
1004	49\14	Erect	Lanceolate	2.7	15.2	5.9	1.5
1005	49\15	Spreading	Ovate	3.0	15.5	8.6	2.1
1006	49\16	Spreading	Lanceolate	2.5	13.1	5.1	1.3
1007	49\17	Spreading	Lanceolate	2.2	20.4	8.3	1.5
1008	49\18	Erect	Lanceolate	3.2	17.2	7.9	1.6
1009	49\19	Spreading	Lanceolate	3.0	21.4	8.9	1.4
1010	49\20	Erect	Lanceolate	3.2	15.8	6.6	1.3
1011	49\21	Spreading	Lanceolate	3.1	18.4	7.9	1.9
1012	49\22	Spreading	Lanceolate	3.5	17.9	6.3	1.9
1013	49\23	Spreading	Lanceolate	1.6	14.8	5.3	1.7
1014	49\24	Spreading	Lanceolate	1.5	11.1	5.6	1.4
1015	50\2	Spreading	Lanceolate	3.2	16.0	5.3	1.5
1016	50\3	Erect	Ovate	3.5	19.7	9.3	1.4
1017	50\4	Erect	Lanceolate	3.1	13.6	6.2	0.8
1018	50\5	Erect	Lanceolate	3.2	22.6	9.4	2.4
1019	50\6	Spreading	Lanceolate	3.5	13.5	5.7	1.5
1020	50\7	Erect	Lanceolate	3.4	16.3	8.7	2.0
1021	50\8	Erect	Lanceolate	3.6	15.0	6.5	2.1
1022	50\9	Spreading	Lanceolate	3.4	16.3	7.4	1.8
1023	50\10	Erect	Lanceolate	2.9	15.4	6.2	2.0
1024	50\11	Spreading	Lanceolate	3.2	17.3	7.3	1.8
1025	50\12	Spreading	Lanceolate	3.1	16.7	7.2	1.5
1026	50\13	Spreading	Lanceolate	3.3	20.3	8.2	1.4
1027	50\14	Erect	Lanceolate	3.2	14.8	8.1	1.4
1028	4\15	Spreading	Ovate	3.2	15.1	6.6	1.5
1029	50\16	Erect	Lanceolate	2.8	15.5	6.1	1.7
1030	50\17	Erect	Ovate	3.2	17.5	7.6	1.8
1031	50\18	Spreading	Lanceolate	3.4	17.6	7.7	1.7
1032	50\19	Spreading	Lanceolate	2.0	14.3	6.2	1.4
1033	50\20	Spreading	Lanceolate	2.6	11.1	4.1	1.8
1034	50\22	Spreading	Ovate	2.9	19.7	9.1	1.5
1035	50\23	Spreading	Lanceolate	2.0	15.0	8.4	1.6
1036	50\24	Spreading	Lanceolate	2.6	12.4	4.9	1.6
1037	51\25	Erect	Lanceolate	2.6	17.2	7.3	1.8
1038	51\1	Erect	Lanceolate	3.1	17.1	6.8	1.4
1039	51\2	Erect	Ovate	3.1	17.5	8.1	1.5

Sl. No.	Progeny	Spreading habit	Leaf shape	Plant height (m)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)
1040	51\3	Erect	Lanceolate	3.8	20.6	9.3	1.7
1041	51\4	Erect	Lanceolate	3.4	18.9	7.7	2.0
1042	51\5	Erect	Lanceolate	3.6	18.3	7.8	1.6
1043	51\6	Spreading	Lanceolate	3.2	15.1	6.6	1.8
1044	51\7	Spreading	Lanceolate	3.5	17.4	7.4	1.0
1045	51\8	Spreading	Lanceolate	3.0	24.6	9.5	2.3
1046	51\9	Erect	Lanceolate	4.2	15.8	7.0	2.0
1047	51\10	Spreading	Lanceolate	3.5	15.1	7.2	1.3
1048	51\11	Spreading	Lanceolate	3.0	13.1	6.3	2.0
1049	51\12	Erect	Lanceolate	2.9	14.8	7.3	1.5
1050	51\13	Spreading	Lanceolate	2.7	14.4	6.0	1.5
1051	51\14	Erect	Lanceolate	3.5	18.9	8.3	1.7
1052	51\15	Erect	Lanceolate	3.1	18.9	7.4	1.9
1053	51\16	Erect	Lanceolate	3.1	14.9	7.5	1.8
1054	51\17	Erect	Lanceolate	3.2	17.3	6.9	1.2
1055	51\18	Erect	Lanceolate	3.7	21.2	8.8	1.8
1056	51\19	Spreading	Lanceolate	2.6	13.6	4.9	1.6
1057	51\20	Spreading	Lanceolate	3.5	11.9	5.4	1.0
1058	51\21	Spreading	Lanceolate	3.5	10.2	8.8	2.0
1059	51\22	Spreading	Lanceolate	3.8	15.9	7.4	1.5
1060	51\23	Spreading	Lanceolate	2.8	13.6	8.1	1.4
1061	51\24	Spreading	Lanceolate	2.9	14.9	6.2	1.3
1062	51\25	Spreading	Lanceolate	2.9	21.8	7.7	1.8
1063	52\1	Spreading	Lanceolate	3.0	15.2	7.8	1.8
1064	52\2	Spreading	Lanceolate	2.9	16.7	7.9	1.7
1065	52\3	Erect	Lanceolate	3.5	17.2	6.8	1.6
1066	52\4	Erect	Lanceolate	2.8	21.3	7.2	1.7
1067	52\5	Spreading	Lanceolate	3.5	12.9	5.8	1.3
1068	52\6	Erect	Lanceolate	3.0	16.5	6.9	1.7
1069	52\7	Spreading	Lanceolate	3.8	9.8	4.7	1.8
1070	52\8	Erect	Lanceolate	2.9	16.3	6.4	1.6
1071	52\9	Spreading	Lanceolate	2.9	13.6	6.0	1.5
1072	52\10	Spreading	Lanceolate	3.3	15.0	7.3	1.4
1073	52\11	Spreading	Lanceolate	3.1	15.4	7.0	1.5
1074	52\12	Spreading	Lanceolate	2.7	14.2	6.0	1.5
1075	52\13	Spreading	Lanceolate	2.4	12.9	5.5	1.4
1076	52\14	Spreading	Lanceolate	2.9	16.7	7.1	1.5
1077	52\15	Spreading	Lanceolate	3.5	19.5	6.8	2.3
1078	52\16	Spreading	Lanceolate	3.0	15.3	7.8	1.5
1079	52\17	Erect	Lanceolate	3.2	17.9	8.3	1.5

Sl. No.	Progeny	Spreading habit	Leaf shape	Plant height (m)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)
1080	52\18	Erect	Lanceolate	3.7	15.9	8.5	2.0
1081	52\19	Erect	Lanceolate	3.3	23.3	8.9	2.1
1082	52\20	Erect	Lanceolate	3.1	15.3	7.3	1.8
1083	52\21	Erect	Ovate	3.7	16.9	8.3	1.6
1084	52\22	Erect	Lanceolate	3.3	15.3	5.7	1.4
1085	52\23	Erect	Lanceolate	3.4	14.6	5.9	1.6
1086	52\24	Spreading	Lanceolate	2.5	15.8	6.9	2.0
1087	52\25	Spreading	Lanceolate	3.3	19.0	9.5	1.5
1088	52\26	Spreading	Ovate	2.4	16.3	9.2	1.6
1089	53\1	Spreading	Lanceolate	3.3	11.6	5.2	1.3
1090	53\2	Spreading	Lanceolate	2.9	17.7	9.6	2.1
1091	53\3	Erect	Lanceolate	2.6	14.5	6.7	2.0
1092	53\4	Spreading	Lanceolate	3.1	17.6	7.9	1.0
1093	53\6	Erect	Lanceolate	3.5	14.8	7.5	1.6
1094	53\7	Spreading	Lanceolate	2.5	19.6	8.3	2.2
1095	53\8	Spreading	Lanceolate	3.7	12.8	5.7	1.6
1096	53\9	Spreading	Lanceolate	2.8	17.6	5.8	1.8
1097	53\10	Erect	Lanceolate	3.2	19.2	7.5	1.7
1098	53\11	Spreading	Lanceolate	2.4	17.2	7.3	1.4
1099	53\12	Erect	Elliptic	3.4	16.0	7.4	1.7
1100	53\13	Erect	Lanceolate	2.1	17.0	6.9	1.7
1101	53\14	Spreading	Lanceolate	3.0	17.2	8.2	1.0
1102	53\15	Erect	Elliptic	3.2	15.9	8.7	1.7
1103	53\16	Spreading	Lanceolate	3.5	17.9	7.7	1.6
1104	53\17	Erect	Elliptic	3.6	19.4	9.4	1.5
1105	53\18	Erect	Lanceolate	3.5	18.2	8.5	1.8
1106	53\19	Spreading	Lanceolate	2.9	15.0	6.3	1.7
1107	53\20	Spreading	Lanceolate	3.1	15.4	8.4	1.7
1108	53\21	Erect	Lanceolate	2.6	11.9	7.0	1.6
1109	53\22	Erect	Lanceolate	3.0	14.4	7.1	1.3
1110	53\23	Erect	Lanceolate	3.5	14.1	7.1	1.3
1111	53\24	Spreading	Lanceolate	3.5	16.3	6.1	2.0
1112	53\25	Erect	Ovate	2.4	16.8	7.1	1.6
1113	53\26	Erect	Elliptic	2.4	16.4	9.6	1.6
	Mean	-	-	**2.7**	**15.1**	**6.6**	**1.5**
	C.V.	-	-	**17.86**	**15.28**	**9.32**	**17.44**
	S.E.	-	-	**0.014**	**0.069**	**0.038**	**0.008**
	Range	-	-	**0.8 - 4.2**	**6.9 - 28.7**	**3.3 - 9.9**	**0.5 - 2.5**

Erect **Spreading**

Plate 4.2a Growth habits of Arka Sahan Custard apple progenies

Elliptic **Ovate** **Lanceolate**

Plate 4.2b Leaf shapes of Arka Sahan Custard apple progenies

4.1.2 Fruits and yield traits (n=222)

4.1.2.1 Number of fruits per tree

In the first year considerable variation was observed concerning the number of fruits per tree of Arka Sahan and Balanagar progenies of Custard apple (Table 4.1.2). Number of fruits per tree ranged from 1 to 80 fruits. Among the progenies, the average number of fruits per tree was recorded at 23 fruits. The maximum (80) fruits per tree was recorded in progeny 27\6 followed by 4\14 and 8\11 (75 fruits) and a minimum of 1 fruit was observed in 5 progenies' (23\19, 31\, 34\1, 35\1 and 43\19)

In the second year also considerable variation was observed concerning the number of fruits per tree of Arka Sahan and Balanagar progenies of the Custard apple (Table 4.1.2). Number of fruits per tree ranged from 1 to 74 fruits. Among the progenies, the average number of fruits per tree was recorded as 16 fruits. The maximum (74) fruits per tree were recorded in progeny 40\5 followed by 28\7 (69 fruits) and a minimum of 1 fruit were observed in more than 15 progenies' (Table 4.1.2).

The mean number of fruits per tree showed considerable variation among the Arka Sahan and Balanagar progenies (Table 4.1.2). The number of fruits per tree ranged from 1 to 64 with an average of 19.48 fruits per tree. A maximum of 64 fruits per tree was recorded in progeny 42\12 followed by 36\16 (60 fruits) and a minimum of 1 fruit was observed in progeny 23\19 (Table 4.1.2).

4.1.2.2 Fruit weight (g)

Fruit weight differed significantly among the progenies studied and ranged from 52.0 to 473.0 g (Table 4.1.2). Among the progenies, average fruit weight was recorded at 168.42 g and it was more (473.0 g) in progeny 25\8 followed by 28\6 (372.5 g), while it was less (52.0 g) in progeny 4\6.

4.1.2.3 Yield per tree (Kg)

Wide variation was observed in yield per tree of Arka Sahan progenies of Cuastrd apple (Table 4.1.2). Yield per tree ranged from 0.07 to 19.22 kg per tree (Table 4.1.2).

Table 4.1.2 Fruits and yield traits of Arka Sahan cuatard apple progenies

S. No.	Progeny	Number of fruits per tree				Yield per tree (Kg)	Estimated yield per ha. (tons)
		First year	Second year	Mean	Fruit weight (gm)		
1	**1\1**	41	23	32.0	270.5	6.44	3.43
2	**1\6**	6	14	10.0	143.0	1.48	0.51
3	**1\7**	22	21	21.5	118.5	1.20	1.03
4	**2\8**	13	19	16.0	100.0	2.19	0.66
5	**2\13**	22	3	12.5	142.0	0.39	0.76
6	**3\1**	17	4	10.5	213.0	0.88	0.88
7	**3\12**	32	7	19.5	189.5	1.34	1.47
8	**3\13**	50	18	34.0	161.0	3.20	2.08
9	**4\3**	4	19	11.5	158.0	3.04	0.73
10	**4\6**	14	47	30.5	52.0	2.44	0.63
11	**4\9**	22	3	12.5	174.5	0.56	0.83
12	**4\10**	36	6	21.0	116.5	0.77	0.91
13	**4\14**	75	14	44.5	129.5	1.82	2.30
14	**4\15**	8	1	4.5	266.5	0.24	0.52
15	**4\16**	14	52	33.0	233.0	11.39	2.97
16	**4\17**	48	7	27.5	166.5	0.96	2.07
17	**4\18**	4	2	3.0	111.0	0.22	0.13
18	**5\20**	23	2	12.5	114.0	0.25	0.53
19	**6\3**	40	33	36.5	205.0	5.28	3.06
20	**6\7**	16	2	9.0	200.0	0.37	0.76
21	**6\9**	34	5	19.5	198.0	1.13	1.38
22	**6\23**	20	6	13.0	118.0	0.59	0.67
23	**7\6**	23	5	14.0	263.5	1.24	1.54
24	**7\12**	25	36	30.5	74.0	2.70	0.91
25	**7\16**	29	18	23.5	118.0	2.09	1.11
26	**7\17**	8	4	6.0	188.5	0.60	0.48
27	**7\19**	6	2	4.0	136.5	0.25	0.23
28	**7\23**	56	27	41.5	132.5	2.35	2.46
29	**8\3**	12	3	7.5	186.5	0.34	0.69
30	**8\9**	42	3	22.5	123.5	0.43	0.95
31	**8\10**	12	42	27.0	99.0	4.28	1.09
32	**8\11**	75	13	44.0	139.5	1.60	2.66
33	**8\14**	18	4	11.0	476.5	2.02	2.01
34	**8\15**	16	30	23.0	143.0	3.72	1.26
35	**8\17**	4	6	5.0	163.5	0.73	0.31
36	**8\18**	45	11	28.0	127.0	1.41	1.42
37	**8\20**	12	1	6.5	207.5	0.19	0.58

S. No.	Progeny	Number of fruits per tree				Yield per tree (Kg)	Estimated yield per ha. (tons)
		First year	Second year	Mean	Fruit weight (gm)		
38	**9\10**	38	2	20.0	144.5	0.24	1.32
39	**9\11**	16	11	13.5	171.5	2.20	0.90
40	**9\13**	30	4	17.0	148.0	0.62	0.97
41	**9\21**	32	14	23.0	158.0	2.17	1.46
42	**10\3**	58	54	56.0	355.5	19.22	7.96
43	**10\7**	10	1	5.5	175.5	0.16	0.41
44	**10\8**	5	6	5.5	70.5	0.40	0.15
45	**10\11**	8	3	5.5	151.0	0.53	0.31
46	**10\18**	2	1	1.5	95.5	0.11	0.05
47	**11\6**	11	24	17.5	88.5	2.11	0.62
48	**11\12**	8	1	4.5	136.0	0.12	0.26
49	**11\24**	28	3	15.5	149.5	0.57	0.73
50	**12\2**	14	7	10.5	189.0	1.64	0.73
51	**13\1**	5	35	20.0	203.0	7.70	1.73
52	**13\9**	2	1	1.5	186.5	0.15	0.12
53	**13\13**	12	6	9.0	80.0	0.38	0.31
54	**14\4**	75	30	52.5	144.5	3.96	3.15
55	**14\13**	8	1	4.5	221.5	0.10	0.57
56	**14\19**	22	22	22.0	122.0	1.74	1.07
57	**15\2**	18	20	19.0	101.5	1.94	0.77
58	**15\8**	24	2	13.0	199.5	0.39	1.05
59	**15\15**	15	19	17.0	246.5	4.73	1.68
60	**15\19**	10	2	6.0	78.0	0.14	0.20
61	**15\20**	32	1	16.5	85.5	0.09	0.55
62	**16\3**	36	15	25.5	82.5	1.23	0.84
63	**16\7**	3	1	2.0	124.0	0.13	0.10
64	**16\8**	44	5	24.5	179.0	0.89	1.76
65	**16\15**	7	30	18.5	283.5	8.61	2.11
66	**17\1**	28	23	25.5	197.0	4.16	2.03
67	**17\2**	16	5	10.5	137.1	0.66	0.59
68	**17\4**	5	6	5.5	194.0	1.18	0.43
69	**17\23**	25	3	14.0	262.5	0.83	1.40
70	**17\24**	42	24	33.0	118.5	2.81	1.57
71	**18\6**	9	2	5.5	201.0	0.41	0.44
72	**18\24**	17	4	10.5	187.5	0.75	0.79
73	**19\3**	46	20	33.0	142.0	2.60	1.94
74	**19\10**	35	12	23.5	235.5	3.10	2.11
75	**19\11**	36	12	24.0	242.0	2.71	2.40

S. No.	Progeny	Number of fruits per tree				Yield per tree (Kg)	Estimated yield per ha. (tons)
		First year	Second year	Mean	Fruit weight (gm)		
76	**19\17**	12	1	6.5	237.0	0.24	0.60
77	**20\2**	10	3	6.5	141.0	0.43	0.36
78	**21\1**	6	6	6.0	208.5	1.27	0.50
79	**21\9**	42	3	22.5	201.0	0.56	1.93
80	**21\11**	3	3	3.0	136.5	0.43	0.16
81	**21\14**	10	3	6.5	139.5	0.43	0.36
82	**21\17**	18	4	11.0	129.0	0.53	0.56
83	**21\19**	11	4	7.5	223.0	0.91	0.66
84	**22\6**	12	3	7.5	146.5	0.44	0.44
85	**22\7**	30	2	16.0	80.5	0.19	0.45
86	**22\8**	14	15	14.5	130.5	2.13	0.76
87	**22\15**	28	7	17.5	189.0	1.30	1.34
88	**23\10**	10	5	7.5	114.5	0.60	0.34
89	**23\12**	5	2	3.5	310.0	0.60	0.44
90	**23\19**	1	1	1.0	85.5	0.09	0.03
91	**24\4**	26	15	20.5	199.0	3.00	1.63
92	**24\7**	20	9	14.5	273.5	2.46	1.59
93	**24\17**	14	17	15.5	175.0	2.82	1.08
94	**24\21**	21	12	16.5	81.0	0.98	0.53
95	**24\22**	20	20	20.0	113.0	2.30	0.90
96	**25\5**	48	13	30.5	169.5	2.17	2.09
97	**25\6**	30	7	18.5	339.5	2.27	2.58
98	**25\8**	4	5	4.5	473.0	2.37	0.85
99	**25\9**	5	9	7.0	129.0	1.07	0.35
100	**25\12**	32	29	30.5	126.5	3.74	1.54
101	**25\13**	2	8	5.0	326.5	2.46	0.63
102	**26\3**	32	41	36.5	179.5	7.34	2.62
103	**26\6**	44	21	32.5	321.5	6.55	4.22
104	**26\7**	30	33	31.5	198.5	6.34	2.50
105	**26\10**	10	3	6.5	237.0	0.69	0.62
106	**26\11**	43	14	28.5	176.0	2.39	2.04
107	**26\15**	16	34	25.0	224.5	7.51	2.23
108	**26\16**	10	15	12.5	144.0	2.13	0.72
109	**27\6**	80	36	58.0	200.5	7.42	4.60
110	**27\10**	28	10	19.0	224.0	2.28	1.69
111	**27\14**	48	7	27.5	95.5	0.64	1.08
112	**27\15**	23	46	34.5	98.5	4.42	1.35
113	**28\5**	39	34	36.5	114.5	4.32	1.66

S. No.	Progeny	Number of fruits per tree				Yield per tree (Kg)	Estimated yield per ha. (tons)
		First year	Second year	Mean	Fruit weight (gm)		
114	**28\6**	14	40	27.0	372.5	14.20	3.93
115	**28\7**	40	69	54.5	121.5	9.32	2.73
116	**28\10**	30	19	24.5	214.5	3.99	2.11
117	**28\13**	23	26	24.5	288.5	7.28	2.82
118	**29\2**	60	5	32.5	89.5	0.44	1.19
119	**29\4**	52	13	32.5	265.0	3.54	3.39
120	**30\4**	33	15	24.0	209.0	2.40	2.18
121	**30\8**	2	8	5.0	233.5	1.82	0.46
122	**30\12**	20	5	12.5	191.0	0.94	0.96
123	**30\14**	9	12	10.5	71.0	0.77	0.29
124	**30\15**	48	52	50.0	215.5	11.60	4.32
125	**30\16**	15	39	27.0	230.0	9.13	2.50
126	**31\5**	1	2	1.5	134.0	0.26	0.08
127	**31\11**	52	32	42.0	90.0	2.69	1.54
128	**31\15**	44	18	31.0	290.0	5.35	3.56
129	**32\11**	40	8	24.0	246.0	2.10	2.25
130	**32\17**	18	13	15.5	64.0	0.70	0.41
131	**32\18**	20	24	22.0	158.5	3.60	1.39
132	**33\2**	29	7	18.0	125.5	0.85	0.92
133	**33\6**	36	1	18.5	133.0	0.13	1.01
134	**34\1**	1	6	3.5	300.5	1.86	0.43
135	**34\2**	25	29	27.0	252.0	7.40	2.72
136	**34\4**	2	2	2.0	142.0	0.27	0.11
137	**34\7**	17	2	9.5	104.5	0.21	0.40
138	**34\9**	5	2	3.5	119.5	0.25	0.16
139	**34\10**	12	8	10.0	239.5	1.98	0.95
140	**34\12**	11	31	21.0	160.0	5.24	1.38
141	**34\14**	9	15	12.0	119.0	1.79	0.57
142	**34\17**	8	61	34.5	200.0	12.75	2.86
143	**34\19**	32	38	35.0	195.0	7.56	2.73
144	**35\1**	1	3	2.0	148.5	0.44	0.12
145	**35\3**	21	6	13.5	160.5	0.92	0.89
146	**35\7**	25	4	14.5	88.0	0.36	0.50
147	**35\9**	19	9	14.0	222.0	1.99	1.25
148	**36\2**	10	8	9.0	148.0	1.23	0.53
149	**36\3**	44	15	29.5	161.5	2.61	1.83
150	**36\5**	4	2	3.0	101.0	0.20	0.12
151	**36\9**	24	2	13.0	139.5	0.29	0.71

S. No.	Progeny	Number of fruits per tree				Yield per tree (Kg)	Estimated yield per ha. (tons)
		First year	Second year	Mean	Fruit weight (gm)		
152	**36\12**	36	19	27.5	152.0	3.00	1.65
153	**36\13**	27	37	32.0	108.5	3.74	1.37
154	**36\15**	34	48	41.0	135.0	6.67	2.23
155	**36\16**	60	59	59.5	87.5	4.78	2.08
156	**36\17**	52	4	28.0	77.5	0.30	0.89
157	**37\10**	25	12	18.5	138.5	1.72	1.01
158	**38\3**	21	4	12.5	201.5	0.72	1.08
159	**38\5**	4	6	5.0	112.5	0.70	0.23
160	**38\6**	16	5	10.5	171.0	0.86	0.72
161	**38\7**	16	6	11.0	70.5	0.44	0.31
162	**38\14**	34	2	18.0	178.0	0.37	1.24
163	**38\19**	12	5	8.5	168.5	0.85	0.57
164	**39\12**	3	1	2.0	75.5	0.07	0.06
165	**39\21**	13	44	28.5	189.5	9.06	2.26
166	**40\5**	32	74	53.0	230.0	17.09	4.88
167	**40\7**	2	4	3.0	141.0	0.54	0.17
168	**40\11**	4	3	3.5	116.0	0.34	0.16
169	**40\13**	8	18	13.0	127.0	2.36	0.67
170	**40\14**	36	13	24.5	115.0	1.33	1.19
171	**41\11**	17	11	14.0	192.5	2.20	1.07
172	**41\12**	26	48	37.0	159.5	7.97	2.39
173	**41\14**	46	1	23.5	176.5	0.17	1.75
174	**41\16**	2	6	4.0	126.0	0.77	0.20
175	**41\17**	23	3	13.0	222.0	0.67	1.15
176	**42\8**	12	27	19.5	60.5	1.49	0.46
177	**42\12**	60	67	63.5	177.0	11.99	4.50
178	**42\15**	14	7	10.5	204.0	1.56	0.83
179	**42\16**	30	17	23.5	107.5	1.87	1.00
180	**43\2**	32	12	22.0	295.5	3.73	2.54
181	**43\7**	6	6	6.0	99.0	0.61	0.24
182	**43\8**	24	8	16.0	118.5	0.94	0.76
183	**43\13**	25	30	27.5	164.0	5.19	1.81
184	**43\16**	4	7	5.5	107.0	0.73	0.23
185	**43\19**	1	1	1.0	192.5	0.19	0.08
186	**44\9**	4	6	5.0	219.0	1.33	0.44
187	**44\13**	20	22	21.0	156.0	3.39	1.31
188	**45\5**	30	18	24.0	121.5	2.27	1.16
189	**45\9**	60	15	37.5	149.5	2.28	2.22

S. No.	Progeny	Number of fruits per tree				Yield per tree (Kg)	Estimated yield per ha. (tons)
		First year	Second year	Mean	Fruit weight (gm)		
190	**45\12**	32	12	22.0	82.5	1.13	0.68
191	**45\19**	30	27	28.5	152.0	4.24	1.73
192	**46\1**	8	8	8.0	143.5	1.11	0.46
193	**46\16**	19	4	11.5	280.0	1.10	1.30
194	**46\17**	8	2	5.0	165.0	0.34	0.33
195	**47\18**	53	36	44.5	109.0	4.07	1.93
196	**47\19**	26	4	15.0	150.0	0.78	0.71
197	**48\3**	32	38	35.0	135.5	5.17	1.90
198	**48\9**	45	63	54.0	241.5	14.74	5.19
199	**48\14**	62	11	36.5	236.0	2.57	3.47
200	**48\24**	11	10	10.5	275.5	2.77	1.16
201	**49\8**	4	2	3.0	249.5	0.50	0.30
202	**49\9**	26	27	26.5	224.0	5.97	2.37
203	**49\12**	10	27	18.5	137.5	3.89	1.04
204	**49\13**	2	39	20.5	83.0	2.93	0.62
205	**50\8**	49	17	33.0	78.0	1.33	1.03
206	**50\10**	54	13	33.5	187.0	2.46	2.49
207	**50\13**	21	25	23.0	133.0	3.25	1.22
208	**50\14**	36	29	32.5	92.0	2.84	1.19
209	**50\16**	31	22	26.5	247.0	5.48	2.61
210	**50\24**	2	3	2.5	97.5	0.28	0.10
211	**51\16**	24	34	29.0	103.5	4.08	1.23
212	**51\17**	40	38	39.0	229.5	8.78	3.58
213	**51\19**	12	8	10.0	176.5	1.29	0.72
214	**51\24**	33	1	17.0	65.0	0.07	0.39
215	**52\6**	24	12	18.0	131.0	1.57	0.94
216	**52\11**	28	20	24.0	276.5	5.56	2.65
217	**52\20**	22	20	21.0	178.5	3.48	1.50
218	**52\22**	18	18	18.0	129.5	2.38	0.93
219	**52\24**	36	61	48.5	96.5	7.50	2.00
220	**53\9**	5	5	5.0	173.0	0.87	0.35
221	**53\24**	18	49	33.5	187.0	9.75	2.58
222	**53\25**	26	8	17.0	219.2	1.77	1.48
	Mean	**23**	**16**	**19.48**	**168.42**	**2.64**	**1.31**
	C.V.	**71.81**	**100.51**	**67.90**	**41.18**	**119.91**	**84.66**
	S.E±m	**1.126**	**1.052**	**0.88**	**4.65**	**0.212**	**0.074**
	Range	**1 - 80**	**1 - 74**	**1 - 63.5**	**52 - 473**	**0.07 - 19.22**	**0.03 - 7.96**

Among the progenies of Arka Sahan, the highest (19.22 kg) yield was recorded in progeny 10\3, followed by 40\5 (17.09 kg). The lowest (0.07 kg) yield per tree was observed in progeny 39\12.

4.1.2.4 Estimated yield (t/ha)

Wide variation was observed in the estimated yield per hactare of Arka Sahan progenies of Cuastrd apple (Table 4.1.2). The estimated yield per hectare ranged from 0.03 to 7.96 tons per hactare with an average yield of 1.31 tons (Table 4.1.2). Among progenies of Arka Sahan the highest (7.96 tons) estimated yield was recorded in progeny 10\3, followed by 48\9 (5.19 tons). The lowest (0.03 tons) estimated yield per hactare was observed in progeny followed by 23\9.

4.1.3 Fruit traits of Arka Sahan progenies (n=56)

4.1.3.1 Fruit length (cm)

The progenies revealed a considerably higher range of variations for fruit length (Table 4.1.3). The fruit length in progenies ranged from 6.0 to 9.1 cm. The data about fruit length in progenies of Arka Sahan revealed that maximum (9.1 cm) fruit length was recorded in progeny 10\3 followed by 50\16 (8.8 cm) with a mean of 7.11 cm, whereas the minimum (6.0 cm) in 7\16 and 30\16.

4.1.3.2 Fruit width (cm)

Among Arka Sahan progenies, fruit width ranged from 4.5 to 8.0 cm with an average value of 6.76 cm (Table 4.1.3). The highest (8.0 cm) fruit width was recorded in 10\3, 48\14 and 51\17 followed by 31\15 (7.8 cm), while, the lowest (4.5 cm) was observed in progeny 28\6.

4.1.3.3 Peduncle length (cm)

Peduncle length in Arka Sahan progenies ranged from 1.2 to 4.0 cm with a mean of 2.10 cm (Table 4.1.3). Among progenies, maximum (4.0 cm) peduncle length was recorded in 26\7 followed by 10\3 (3.9cm), while minimum (1.2 cm) was observed in progeny 30\15 and 51\17.

4.1.3.4 Peduncle weight (g)

The Peduncle weight varied significantly ranging from 1.02 to 3.77 g (Table 4.1.3). In Arka Sahan, progenies the average value of 1.97 g and maximum (3.77 g) was observed in 25\6 followed by 15\15 (3.47 g), while minimum (1.02 g) was recorded in 28\6.

4.1.3.5 Peel weight (g)

There were significant differences in the peel weight of progenies which ranged from 60.3 to 157.5 g (Table 4.1.3). Among the Arka Sahan custard apple progenies, average peel weight was 96.7 g and the highest (157.5 g) peel weight was recorded in progeny 41\17 followed by 50\16 (151.8 g), while the minimum (60.3 g) peel weight was observed in progeny 30\16.

4.1.3.6 Pulp weight (g)

Pulp weight in progenies of Arka Sahan custard apple varied from 109.5 to 243.8 g with an average of 145.4 g (Table 4.1.3). Maximum (243.8 g) pulp weight was recorded in progeny 10\3, followed by 41\17 (208.0g) and minimum (109.5g) pulp weight was observed in 7\16.

4.1.3.7 Seed weight (g)

Seed weight among the progenies (Table 4.1.3) ranged from 1.4 to 18.8 g with a mean seed weight of 8.10 g. Among the progenies of Arka Sahan Custard apple, the maximum seed weight (18.8 g) was recorded in progeny 30\4, followed by 25\12 (18.0g), while the minimum (1.4 g) was observed in 26\6.

4.1.3.8 Peel content (%)

Peel content in progenies studied in the present investigation (Table 4.1.3). Among Arka Sahan Custard apple progenies, average peel content was 37.74 % and ranged from 26.2 to 50.9 %. The highest (50.9%) was recorded in progeny 7\16 followed by 34\2 (49.6 %) and the lowest (26.2 %) peel content was observed in 30\16 (Table 4.1.3).

Table 4.1.3 Anatomical and qualitative characteristics of fruits of Arka Sahan custard apple progenies

S. No.	Progeny	Fruit length (cm)	Fruit width (cm)	Peduncle length (cm)	Peduncle weight (gm)	Peel weight (gm)	Pulp weight (gm)	Seed weight (gm)	Peel content (%)	Pulp recovery (%)	Seed content (%)	Number of flakes with seed	Number of flakes without seed
1	**1\1**	6.4	7.1	1.8	1.88	104.5	155.2	9.0	38.4	57.6	3.4	23.0	40.5
2	**3\13**	7.0	6.3	2.6	2.37	83.0	116.7	11.0	38.9	54.9	5.2	33.5	31.0
3	**4\14**	7.0	7.0	2.3	1.43	115.5	143.6	6.0	43.9	53.4	2.2	21.5	41.0
4	**4\16**	7.2	6.1	2.7	1.75	110.5	116.8	4.0	47.7	49.9	1.7	14.5	34.0
5	**6\3**	7.1	6.5	2.9	1.90	96.0	145.1	5.5	38.7	58.4	2.2	14.5	40.5
6	**7\6**	6.8	6.9	1.5	1.90	108.5	154.6	15.0	38.8	55.2	5.4	38.0	39.5
7	**7\12**	7.5	6.6	2.1	1.84	78.5	139.2	10.5	34.2	60.8	4.3	32.0	35.5
8	**7\16**	6.0	5.9	1.3	1.49	117.5	109.5	2.5	50.9	47.4	1.1	17.0	32.5
9	**8\9**	6.8	7.3	1.6	1.75	124.0	123.3	10.0	47.8	47.7	3.9	21.0	33.0
10	**8\18**	6.6	5.1	1.9	1.36	74.0	127.9	5.3	35.5	61.4	2.5	14.5	34.5
11	**9\21**	7.9	6.5	2.0	2.00	66.5	154.0	5.0	29.2	67.7	2.2	13.5	45.0
12	**10\3**	9.1	8.0	3.9	2.30	101.0	243.8	8.4	28.4	68.6	2.4	34.5	58.0
13	**13\1**	6.5	6.5	1.7	1.43	89.5	125.9	3.8	40.6	57.1	1.7	14.5	33.5
14	**14\4**	7.6	7.6	1.5	1.74	84.0	181.1	8.1	30.8	66.5	2.1	17.0	40.5
15	**15\8**	7.0	6.1	2.4	1.55	77.0	119.5	13.4	37.4	58.0	4.0	25.0	31.5
16	**15\15**	7.3	7.4	3.2	3.47	105.0	129.6	8.5	42.5	52.7	3.4	35.0	37.0
17	**16\15**	6.5	7.4	1.4	2.10	110.0	162.9	8.5	38.9	57.4	3.0	22.0	40.0
18	**17\1**	6.7	6.9	2.7	1.50	68.5	129.5	11.1	32.6	62.0	4.8	39.5	34.0
19	**17\23**	6.8	6.6	1.4	2.05	89.0	163.5	8.0	33.8	62.3	3.2	20.5	41.5
20	**19\10**	6.9	7.2	2.1	1.77	78.5	141.8	13.5	32.8	60.8	5.7	30.5	31.0

S. No.	Progeny	Fruit length (cm)	Fruit width (cm)	Peduncle length (cm)	Peduncle weight (gm)	Peel weight (gm)	Pulp weight (gm)	Seed weight (gm)	Peel content (%)	Pulp recovery (%)	Seed content (%)	Number of flakes with seed	Number of flakes without seed
21	**19\11**	7.2	6.4	1.3	1.62	98.5	134.4	7.5	40.6	55.7	3.1	22.0	32.5
22	**21\9**	6.7	6.0	1.9	1.69	89.0	125.3	2.4	40.6	57.1	1.6	13.0	33.5
23	**24\7**	7.7	7.4	1.9	1.85	84.5	180.2	11.8	30.9	65.9	2.6	27.0	37.0
24	**25\6**	6.7	7.7	3.6	3.77	99.5	132.8	11.0	40.2	53.9	4.5	40.5	39.5
25	**25\12**	7.2	6.5	3.2	3.20	65.8	149.1	18.0	27.9	63.2	7.7	43.5	38.5
26	**26\6**	6.4	6.3	1.8	1.77	86.5	131.3	1.4	39.0	59.1	1.1	12.0	32.5
27	**26\7**	7.1	7.0	4.0	1.79	66.0	128.0	13.3	31.4	61.4	6.4	51.0	31.0
28	**26\11**	6.2	7.0	1.3	1.63	102.5	127.1	2.9	43.2	53.7	2.5	14.5	35.5
29	**26\15**	7.1	6.6	2.5	1.75	94.3	126.6	2.0	41.9	56.4	0.9	12.0	32.0
30	**27\10**	7.1	6.0	2.2	2.74	89.5	122.0	9.8	39.8	54.5	4.4	36.0	34.0
31	**28\6**	7.3	4.5	1.4	1.02	134.3	180.5	7.3	41.6	56.3	1.8	14.0	44.0
32	**28\7**	7.0	6.8	3.1	1.90	80.0	112.6	8.9	38.9	54.8	5.4	33.5	29.5
33	**28\10**	6.5	5.7	1.4	2.08	78.3	128.2	4.0	36.5	59.7	2.8	18.0	36.0
34	**28\13**	7.0	6.9	1.6	1.75	118.0	157.8	9.7	41.2	54.4	3.8	38.5	36.0
35	**29\4**	7.1	7.3	1.3	1.80	80.8	173.3	6.8	30.5	65.4	3.5	25.0	44.5
36	**30\4**	7.5	6.7	2.8	2.77	78.8	152.3	18.8	31.2	60.3	7.5	44.0	40.0
37	**30\15**	6.0	6.5	1.2	1.65	67.0	138.6	7.8	31.2	64.3	3.8	31.5	32.5
38	**30\16**	7.2	6.3	2.7	2.78	60.3	152.0	15.0	26.2	66.2	6.5	47.0	40.5
39	**31\15**	8.3	7.8	1.6	1.07	128.0	156.7	5.2	44.1	54.1	1.5	14.0	44.0
40	**32\11**	6.7	7.3	1.6	1.56	101.5	140.0	2.1	41.6	56.6	1.2	11.0	38.0
41	**34\2**	7.1	7.6	2.8	3.32	125.0	113.2	10.7	49.6	44.9	4.2	36.0	34.0

S. No.	Progeny	Fruit length (cm)	Fruit width (cm)	Peduncle length (cm)	Peduncle weight (gm)	Peel weight (gm)	Pulp weight (gm)	Seed weight (gm)	Peel content (%)	Pulp recovery (%)	Seed content (%)	Number of flakes with seed	Number of flakes without seed
42	**34\12**	7.5	7.5	1.4	1.70	89.0	142.8	4.0	37.0	59.8	2.5	17.0	36.0
43	**34\19**	7.3	5.7	1.6	1.63	82.5	129.9	8.0	37.2	58.5	3.6	23.5	33.5
44	**38\3**	6.6	6.0	1.4	1.67	97.0	120.9	5.0	43.2	53.8	2.3	15.5	34.5
45	**40\5**	7.8	7.5	1.4	1.64	84.0	138.4	6.0	36.5	60.2	2.6	19.0	36.0
46	**41\17**	7.9	7.5	2.0	1.99	157.5	208.0	5.0	42.2	55.9	1.4	15.5	55.0
47	**43\2**	8.0	6.3	1.7	1.86	98.0	182.7	11.9	33.1	61.7	4.5	33.0	46.0
48	**44\13**	6.4	7.0	1.5	1.55	76.0	139.0	2.5	34.7	63.5	1.2	18.5	32.5
49	**45\19**	7.5	6.5	1.8	1.75	97.0	175.0	6.1	34.6	62.5	2.2	17.5	46.0
50	**48\9**	7.2	7.5	2.9	3.44	95.5	131.8	14.4	39.2	55.0	4.4	38.5	39.0
51	**48\14**	7.8	8.0	3.5	2.21	122.5	193.8	9.0	37.4	59.6	2.4	25.0	41.0
52	**49\9**	7.3	5.4	1.5	1.51	73.5	142.0	7.0	32.9	63.3	3.1	17.0	42.0
53	**50\16**	8.8	7.6	3.6	3.31	151.8	168.7	6.9	44.5	49.9	4.7	40.0	41.5
54	**51\17**	7.0	8.0	1.2	1.52	77.0	144.3	6.8	33.5	62.9	3.0	17.0	36.5
55	**52\11**	7.0	7.0	1.9	1.95	98.5	163.6	12.5	35.6	59.1	4.6	26.0	38.5
56	**53\25**	6.8	5.8	2.0	1.64	93.0	119.4	5.2	42.4	54.4	2.4	15.0	35.0
	Mean	**7.11**	**6.76**	**2.10**	**1.97**	**96.7**	**145.4**	**8.10**	**37.74**	**58.17**	**3.32**	**25.06**	**37.71**
	C.V (%)	**9.54**	**9.55**	**42.07**	**40.76**	**18.93**	**12.24**	**53.15**	**17.92**	**11.80**	**1.77**	**49.94**	**14.69**
	S.E.	**0.47**	**0.45**	**0.61**	**0.56**	**12.67**	**12.59**	**3.03**	**4.78**	**4.85**	**1.25**	**8.85**	**3.91**
	C.D 5%	**0.95**	**0.91**	**1.23**	**1.13**	**25.35**	**25.19**	**6.07**	**9.57**	**9.70**	**2.51**	**17.70**	**7.83**
	Range	**6.0-9.1**	**4.5-8.0**	**1.2-4.0**	**1.02-3.77**	**60.3-157.5**	**109.5-243.8**	**1.4-18.8**	**26.2-50.9**	**44.9-68.9**	**0.9-7.7**	**11.0-51.0**	**29.5-58.0**

4.1.3.9 Pulp recovery (%)

Among Arka Sahan progenies, pulp recovery per cent ranged from 44.9 % to 68.6 % and a mean of 58.17 % (Table 4.1.3). Maximum pulp recovery percentage (68.6 %) was recorded in progeny 10\3, followed by 9\21 (67.7 %), while, the minimum pulp recovery per cent was (44.9 %) recorded in progeny 34\2.

4.1.3.10 Seed content (%)

The seed content of Arka Sahan Custard apple progenies varied from 0.9 to 7.7 % with a mean of 3.32 % (Table 4.1.3). Maximum seed content (7.7 %) was recorded in progeny 25\12 followed by 30\4 (7.5 %), whereas the minimum seed content was (0.9 %) observed in progeny 26\15.

4.1.3.11 Number of flakes with seed

The number of flakes with seed per fruit in progenies varied from 11 to 51 with a mean of 25.06 (Table 4.1.3). The maximum number of flakes with seed per fruit (51) was recorded in progeny 26\7 followed by 30/16 (47.0), whereas the minimum number of flakes with seed per fruit was (11.0) observed in progeny 32\11.

4.1.3.12 Number of flakes without seed

The number of flakes without seed per fruit in progenies varied from 29.5 to 58.0 with a mean of 37.71. The maximum number of flakes without seed per fruit (58.0) was recorded in progeny 10\3 followed by 41\17 (55.0), whereas the minimum number of flakes without seed per fruit was (29.5) observed in progeny 28\7 (Table 4.1.3).

4.1.4 Biochemical characteristics (n=50)

4.1.4.1 TSS (°Brix)

Significant differences were observed in the total soluble solids of progenies studied in the present investigation. Among the Arka Sahan progenies, average total soluble solids was 28.6 ºBrix and highest (32 ºBrix) was recorded in progenies 13\1 followed by (31 ºBrix) was observed in three progenies 15\15, 26\15, 30\15 and 50\16

while lowest (24.5 ºBrix) total soluble solids was observed in progenies' 26\7, 28\7 and 51\17 (Table 4.1.4).

4.1.4.2 Titrable acidity (%)

Titrable acidity (%) in progenies of Arka Sahan varied from 0.22 % to 0.33 %. Maximum (0.33 %) acidity was recorded in progenies 10\3 followed by 32\11 (0.31 %) and minimum (0.22 %) was observed in progeny 17\23, with mean acidity (0.24 %) (Table 4.1.4).

4.1.4.3 TSS: Acidity

The TSS: Acidity ratio ranged from 89.0 to 120.1 in the progenies of Arka Sahan (Table 4.1.4). The highest (120.1) TSS: acidity ratio was recorded in progeny 50\16 followed by 21\9 (119.6) while the lowest (89.0) was found in 30\4.

4.1.4.4 Total sugars (%)

Total sugars in progenies of Arka Sahan ranged from 22.30 to 30.08 mg/100g with a mean of 26.84 mg/100g (Table 4.1.4). The highest (30.03 mg/100g) total sugars were recorded in 13\1, followed by 14\4 (29.90 mg/100g) while, the lowest (22.30 mg/100g) total sugars were recorded in progeny17\23, followed by 4\14 (22.89 mg/100g).

4.1.4.5 Reducing sugars (%)

The reducing sugars ranged from 15.31 to 23.43 % in progenies of Arka Sahan with a mean of 20.61 % (Table 4.1.4). The highest (23.43 %) reducing sugars was recorded in progeny 21\9, followed by 30\15 (23.23 %) while the lowest (15.31 %) was found in progeny 17\23 followed by 4\14 (16.64 %).

4.1.4.6 Non-reducing sugars (%)

The non-reducing sugars ranged from 3.78 to 8.27 % in progenies of Arka Sahan with a mean of 6.23 % (Table 4.1.4). The highest (8.27 %) non-reducing sugars were recorded in 3\13, followed by 13\1 (8.23 %) while the lowest (3.78 %) was found in 34\19 followed by 40\5 (4.03 %).

Table 4.1.4 Biochemical characteristics of Arka Sahan Custard apple progenies showing good fruit anatomical traits

S. No.	Progeny	TSS °Brix	Acidity (%)	TSS: Acidity	Total sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)	Total antioxidents DPPH (mgAEAC/100g)	Total Flavanoids (mg Catechin equivalent/100g)	Total Phenols (mgGAE/100g)
1	**1\1**	30.5	0.26	107.6	28.28	19.45	7.83	91.26	22.81	78.16
2	**3\13**	30.0	0.27	113.3	27.42	20.15	8.27	85.95	22.28	71.26
3	**4\14**	25.7	0.25	110.6	22.87	16.64	6.23	81.23	22.73	71.47
4	**4\16**	31.0	0.29	108.5	28.42	21.65	6.77	94.25	22.60	72.42
5	**6\3**	31.0	0.26	119.3	28.18	21.45	6.73	94.42	22.72	72.28
6	**7\6**	31.0	0.26	107.3	28.42	22.24	6.18	87.29	21.26	73.10
7	**7\12**	30.3	0.28	110.5	28.24	20.57	7.67	94.21	21.72	74.30
8	**7\16**	29.0	0.26	111.5	28.01	22.54	5.47	93.51	23.35	71.19
9	**8\9**	27.5	0.26	106.0	26.33	19.53	6.80	87.92	23.78	71.52
10	**8\18**	26.5	0.28	101.7	25.76	20.03	5.73	91.32	21.92	76.15
11	**10\3**	30.5	0.33	93.9	28.03	21.96	6.07	92.41	23.76	77.81
12	**13\1**	32.0	0.30	106.8	30.08	21.85	8.23	92.31	22.87	71.23
13	**14\4**	31.1	0.29	109.2	29.90	23.07	6.83	87.16	22.75	71.38
14	**15\8**	25.2	0.27	98.9	23.90	18.93	4.97	86.22	21.77	72.31
15	**15\15**	31.5	0.30	107.4	29.65	21.90	7.75	87.12	22.33	72.31
16	**16\15**	25.5	0.27	106.9	24.20	17.07	7.13	88.59	23.21	77.46
17	**17\1**	25.3	0.26	93.6	24.76	19.46	5.30	86.31	23.62	73.47
18	**17\23**	25.5	0.22	111.5	22.30	15.31	6.93	86.92	22.82	73.41
19	**19\10**	27.0	0.26	106.0	26.30	20.40	5.90	94.41	22.47	72.14

S. No.	Progeny	TSS °Brix	Acidity (%)	TSS: Acidity	Total sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)	Total antioxidents DPPH (mgAEAC/100g)	Total Flavanoids (mg Catechin equivalent/100g)	Total Phenols (mgGAE/100g)
20	**19\11**	30.1	0.27	106.3	29.79	23.09	6.70	87.66	21.64	76.42
21	**21\9**	31.1	0.26	119.6	29.26	23.43	5.83	86.05	20.45	69.03
22	**25\6**	25.0	0.25	109.6	23.78	19.40	4.38	91.84	20.84	78.52
23	**25\12**	27.5	0.25	112.4	25.38	19.45	5.93	90.42	20.44	73.57
24	**26\6**	29.5	0.28	106.7	27.18	21.80	5.38	91.83	20.84	71.73
25	**26\7**	24.5	0.25	96.7	23.54	19.23	4.31	95.72	21.94	72.60
26	**26\11**	28.5	0.27	108.4	26.23	20.45	5.78	94.70	24.03	74.84
27	**26\15**	31.5	0.26	115.3	29.25	21.45	7.80	81.12	20.74	75.66
28	**27\10**	28.8	0.29	102.1	27.30	22.30	5.00	85.22	22.08	75.66
29	**28\6**	27.7	0.24	115.5	25.15	19.20	5.95	84.91	23.57	72.60
30	**28\7**	24.5	0.26	97.1	22.83	18.18	4.65	84.83	20.93	71.83
31	**28\10**	29.5	0.26	107.1	27.83	21.78	6.05	93.27	20.10	73.06
32	**28\13**	30.7	0.29	102.6	28.16	21.68	6.48	90.93	22.19	72.80
33	**30\4**	30.8	0.29	89.0	28.16	22.18	5.98	86.71	24.12	73.82
34	**30\15**	31.5	0.26	107.2	29.48	23.23	6.25	84.91	22.07	73.06
35	**30\16**	30.5	0.29	100.5	28.75	22.54	6.21	94.95	22.19	74.53
36	**31\15**	28.5	0.24	113.7	26.76	19.58	7.18	87.48	24.15	77.35
37	**32\11**	29.8	0.31	98.9	27.83	21.18	6.65	94.12	22.07	79.18
38	**34\2**	30.5	0.29	102.4	28.18	21.23	6.95	85.27	22.14	76.11
39	**34\12**	29.7	0.28	109.6	27.18	21.23	5.95	81.35	22.41	75.23

S. No.	Progeny	TSS °Brix	Acidity (%)	TSS: Acidity	Total sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)	Total antioxidents DPPH (mgAEAC/100g)	Total Flavanoids (mg Catechin equivalent/100g)	Total Phenols (mgGAE/100g)
40	**34\19**	25.8	0.28	101.8	23.23	19.45	3.78	88.52	21.4	71.89
41	**38\3**	26.5	0.28	96.4	24.48	20.33	4.15	94.72	22.27	71.16
42	**40\5**	26.8	0.24	111.7	25.26	21.23	4.03	84.54	22.59	72.81
43	**41\17**	28.1	0.26	116.0	26.29	19.26	7.03	87.15	21.67	73.20
44	**48\9**	25.5	0.29	91.1	24.78	19.73	5.05	89.90	23.59	74.21
45	**48\14**	28.7	0.30	100.5	27.50	21.32	6.18	90.18	21.71	71.81
46	**49\9**	30.5	0.29	107.4	28.38	21.25	7.13	91.73	22.49	77.19
47	**50\16**	31.5	0.26	120.1	29.71	21.76	7.95	84.20	21.75	79.23
48	**51\17**	24.5	0.28	101.4	23.18	18.28	4.90	94.53	22.25	76.24
49	**52\11**	30.2	0.27	114.1	28.94	21.53	7.41	87.22	21.26	77.52
50	**53\25**	30.0	0.25	120.0	27.53	19.53	8.00	87.48	24.15	77.35
	Mean	**28.6**	**0.24**	**106.6**	**26.84**	**20.61**	**6.23**	**89.12**	**22.29**	**74.07**
	C.V (%)	**1.625**	**2.93**	**2.676**	**0.951**	**1.264**	**4.559**	**0.791**	**2.188**	**1.213**
	S.E.	**0.267**	**0.004**	**0.004**	**0.147**	**0.150**	**0.162**	**0.407**	**0.280**	**0.517**
	CD 1%	**0.531**	**0.009**	**0.009**	**0.294**	**0.301**	**0.324**	**0.814**	**0.560**	**1.035**
	Range	**24.5-32**	**0.22-0.33**	**89.0-120.1**	**22.30-30.08**	**15.31-23.43**	**3.78-8.27**	**81.12-95.72**	**20.1-24.15**	**69.03-79.23**

4.1.4.7 Total Antioxidant activity (mg AEAC/100g)

Total Antioxidant activity in progenies of Arka Sahan ranged from 81.12 to 95.72 mg AEAC/100g with a mean of 89.12 mg AEAC/100g (Table 4.1.4). The highest (95.72 mg AEAC/100g) total antioxidant activity was recorded in 26\7, followed by 30\16 (94.95 mg AEAC/100g) while, the lowest (81.12 mg AEAC/100g) total antioxidant activity was recorded in 26\15, followed by 4\14 (81.23 mg AEAC/100g).

4.1.4.8 Total phenolic compounds (mg gallic acid equivalents /100g)

Total phenolic compounds in progenies of Arka Sahan ranged from 69.03 to 79.23 mg gallic acid equivalents /100g with a mean of 74.07 mg gallic acid equivalents /100g (Table 4.1.4). The highest (79.23 mg gallic acid equivalents /100g) total phenolic compounds were recorded in 50\16, followed by 32\11 (79.18 mg gallic acid equivalents /100g) while, the lowest (69.03 mg gallic acid equivalents /100g) total phenolic compounds were recorded in 21\9, followed by 38\3 (71.16 mg gallic acid equivalents /100g).

4.1.4.9 Total Flavonoid compounds (mg catechin equivalents/100g)

Total Flavonoid compounds in progenies of Arka Sahan ranged from 20.10 to 24.15 mg catechin equivalents/100g with a mean of 22.29 mg catechin equivalents/100g (Table 4.1.4). The highest (24.15 mg catechin equivalents/100g) total flavonoid compounds were recorded in progenies 31\15 and 53\25, followed by 28\7 (24.03 mg catechin equivalents/100g) while, the lowest (20.10 mg catechin equivalents/100g) total flavonoid compounds were recorded in 28\10, followed by 25\12 (20.44 mg catechin equivalents/100g).

4.1.5 Genetic variability studies in Arka Sahan progenies (n=56)

4.1.5.1 Co-efficient of variation

The estimated genotypic coefficient variation (GCV) and phenotypic coefficient variation (PCV) in Arka Sahan progenies are presented in (Table 4.1.5b). The highest GCV and PCV were recorded for traits like seed weight at 33.79 and 62.99 followed by a number of flakes with seed per fruit at 24.00 and 54.41, respectively. The GCV and PCV for the

remaining traits like number of fruits per tree 8.88 and 18.63, average fruit weight 14.82 and 15.72, fruit length 5.03 and 10.79, fruit width 8.90 and 13.06, pedicel length 21.35 and 47.18, pedicel weight 11.40 and 42.32, peel weight 17.69 and 25.91, pulp weight 15.56 and 19.80, number of flakes without seed 10.68 and 18.16, TSS (°B) 7.18 and 8.43, acidity % 2.26 and 10.10, TSS: acidity 5.85 and 11.11 and yield per tree 19.56 and 24.92 respectively were recorded.

Table 4.1.5a Estimates of genetic parameters for various traits of Arka Sahan custard apple progenies

Character	Mean	CV	MSV	MSE	GVAR	PVAR
Number of fruits per tree	40.34	16.38	69.38	43.68	12.84	56.53
Average fruit weight (gm)	250.2	5.25	2925.2	173.0	1376.1	1549.17
Fruit length(cm)	7.10	9.54	0.71	0.45	0.12	0.58
Fruit width (cm)	6.73	9.55	1.13	0.41	0.35	0.77
Pedicel length (cm)	2.08	42.06	1.16	0.76	0.19	0.96
Pedicel weight (gm)	1.97	40.76	0.74	0.64	0.05	0.69
Peel weight (gm)	94.66	18.93	882.4	321.4	280.5	601.94
Pulp weight (gm)	145.4	12.24	1341.8	317.3	512.2	829.61
Seed weight (gm)	8.08	53.16	33.41	18.48	7.46	25.94
Peel content (%)	37.75	17.93	62.04	45.85	8.09	53.94
Pulp recovery (%)	58.14	11.80	53.44	47.10	30.17	50.27
Seed content (%)	3.30	53.79	5.19	3.15	1.02	4.17
Number of flakes with seed	25.06	49.94	229.0	156.6	36.19	192.88
Number of flakes without seed	37.71	14.69	63.19	30.71	16.24	46.95
TSS °Brix	28.74	4.41	10.14	1.61	4.26	5.87
Acidity (%)	0.26	9.85	0.0007	0.0007	0.00003	0.0007
TSS : acidity	107.6	9.45	183.0	103.6	39.69	143.34
Yield per tree (Kg)	10.10	15.43	10.24	2.431	3.90	6.34

The genetic parameters, viz., phenotypic coefficient of variation (PCV), and genotypic coefficient of variation (GCV), were estimated for progenies of Arka Sahan. In this study, the phenotypic coefficient of variation (PCV) was higher than the genotypic coefficient of variation (GCV) for all the traits and the difference between GCV and PCV was high (Table 4.1.5b).

4.1.5.2 Heritability and genetic advance

The results on heritability and genetic advancement are presented in (Table 4.1.5b). The traits like average fruit weight (88.82), fruit width (46.46%), peel weight (46.60%), pulp weight (61.75 %), TSS (°B) (72.55%) yield per tree (61.64%) showed the highest heritability in progenies of Arka Sahan. The highest genetic advance was observed in average fruit weight (28.82%), pulp weight (25.22%), number of flakes with seed (21.45%) and yield per (31.69%) respectively.

Average fruit weight, fruit width, peel weight, Pulp weight, pulp recovery, number of flakes without seed, TSS °Brix and yield per tree showed more than 50% heritability in the broad sense and genetic advance as per cent mean were showed more than 20 %.

4.1.6 Relative contribution of different traits towards genetic divergence (n=56)

The relative contribution of various character components to divergence in progenies of the Arka Sahan Custard apple is furnished in (Table 4.1.6). The result of character-wise contribution towards total genetic divergence showed that number of fruits per tree contributed maximum (13.00 %) followed by fruit width, peduncle weight and seed content each contributing (10 %), pulp recovery and fruit length each (8.00 %), peel content, acidity and yield per tree each (7.00%), fruit weight, peduncle length, number of flakes with seed and number of flakes without seed each (4.00%), towards total divergence. Out of 14 traits studied four traits viz., number of fruits per tree, fruit width, peduncle weight and seed content had major contributions towards divergence.

Table 4.1.5b Estimates of genetic parameters for various traits of Arka Sahan custard apple progenies

Character	Coefficient of variation		Heritability %	Genetic Advancement %	Genetic advance % of mean %
	Genotypic	Phenotypic			
Number of fruits per tree	8.88	18.63	22.72	3.52	8.73
Average fruit weight (g)	14.82	15.72	88.82	72.12	28.82
Fruit length (cm)	5.03	10.79	21.74	0.34	4.84
Fruit width (cm)	8.90	13.06	46.43	0.84	12.51
Pedicel length (cm)	21.35	47.18	20.49	0.41	19.94
Pedicel weight (g)	11.40	42.32	7.25	0.12	6.33
Peel weight (g)	17.69	25.91	46.60	23.58	24.91
Pulp weight (g)	15.56	19.80	61.75	36.69	25.22
Seed weight (g)	33.79	62.99	28.77	3.02	37.39
Peel content (%)	7.53	19.45	15.00	2.27	6.02
Pulp recovery (%)	3.06	12.19	60.01	0.92	1.58
Seed content (%)	30.61	61.89	24.47	1.03	31.24
Number of flakes with seed	24.00	55.41	18.76	5.37	21.45
Number of flakes without seed	10.68	18.16	34.58	4.88	12.96
TSS °Brix	7.18	8.43	72.55	3.62	12.62
Acidity %	2.26	10.10	5.01	0.002	1.04
TSS : acidity	5.85	11.11	27.69	6.84	6.35
Yield per tree (Kg)	19.56	24.92	61.64	3.20	31.69

Table 4.1.6 Relative contribution of different characters towards genetic divergence

Source	Contribution %
Number of fruits per tree	13
Fruit weight	4
Fruit length	8
Fruit width	10
Peduncle length	4
Peduncle weight	10
Peel content	7
Pulp recovery	8
Seed content	10
Number of flakes with seed	4
Number of flakes without seed	4
TSS	4
Acidity	7
Yield per tree	7

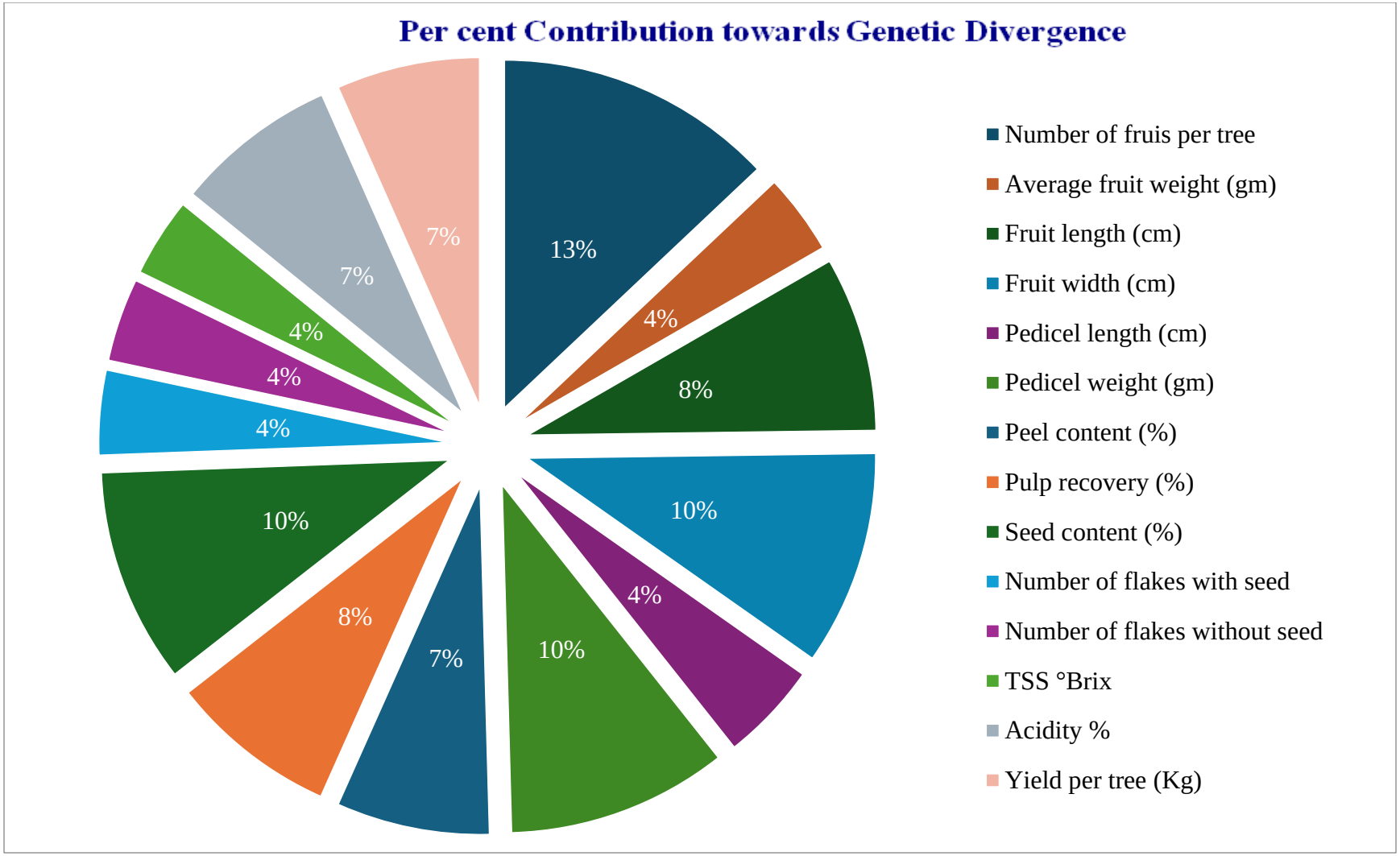


Fig. 4.1 Relative contribution of different characters towards genetic divergence

4.1.7 Cluster analysis of progenies of Arka Sahan Custard apple (n=56)

The data collected from Arka Sahan progenies were assessed for genetic distance and the dissimilarity matrix was used for cluster development by using the SPSS. Cluster mean and genetic distance were estimated in progenies of Arka Sahan.

The cluster mean of 56 progenies developed by Arka Sahan was computed in 6 clusters for 14 traits studied and is presented in Table 4.1.7. Cluster I contained the maximum (20) number of progenies followed by Cluster IV with 13 progenies, Cluster III with 10 progenies, Cluster II with 7 progenies, Cluster V with 6 progenies, Cluster VI with 1 progeny each (Figure 4.2).

4.1.7.1 Mean performance of trait clusters

Cluster means indicated the average performance of all progenies clubbed into a cluster. The number of fruits per tree and fruit weight was observed maximum in cluster VI (56 and 355.75), followed by cluster II (42 and 28.07) and was found minimum in cluster I (39 and 232.36) (Table 4.1.8).

Fruit length and fruit width were recorded in cluster VI (9.05 and 7.95), while the lowest was observed in cluster I (6.70 and 6.33). Maximum peduncle length (3.90) was recorded in cluster VI, followed by cluster V (3.25) and minimum in cluster III (1.51). The maximum peduncle weight was observed in cluster V (3.25) and the minimum in cluster III (1.65).

Concerning the peel content, cluster V (42.25) exhibited maximum, while the minimum was observed in cluster VI (28.42). Pulp recovery was observed maximum in cluster VI (68.55) followed by cluster III (63.43) was found minimum in cluster V (52.63). Cluster IV had maximum seed content (5.23) followed by cluster V (3.92), while minimum reported in cluster VI (2.35). The maximum total soluble solids were observed in cluster IV (10.24) and the minimum in cluster VIII (8.55).

Table 4.1.7 Distribution of Arka Sahan Custard apple progenies in different cluster

Cluster group	No. Progenies	List of progenies
Cluster 1	20	1\1, 6\3, 4\16, 26\15, 19\11, 21\9, 13\1, 32\11, 7\16, 8\9, 26\11, 8\18, 15\8, 34\19, 28\10, 41\17, 44\13, 38\3, 53\25
Cluster 2	7	4\14, 40\5, 16\5, 52\11, 17\23, 28\6, 31\15
Cluster 3	10	9\21, 45\19, 49\9, 26\6, 14\4, 30\15, 24\7, 29\4, 34\12, 51\17
Cluster 4	13	3\13, 27\10, 7\12, 7\6, 28\13, 43\2, 30\4, 30\16, 48\14, 17\1, 19\10, 26\7, 28\7
Cluster 5	6	15\15, 50\16, 34\2, 25\6, 25\12, 48\9,
Cluster 6	1	10\3

Table 4.1.8 Cluster means for Arka Sahan Custard apple progenies

	Number of fruis per tree	Average fruit weight (gm)	Fruit length (cm)	Fruit width (cm)	Pedicel length (cm)	Pedicel weight (gm)	Peel content (%)	Pulp recovery (%)	Seed content (%)	Number of flakes with seed	Number of flakes without seed	TSS °Brix	Acidity %	Yield per tree (kg)
Cluster 1	38.68	232.36	6.70	6.33	1.78	1.68	40.83	56.04	2.41	17.85	34.75	29.17	0.27	9.00
Cluster 2	42.29	283.07	7.31	7.23	1.69	1.75	39.30	57.46	2.61	19.79	42.29	26.31	0.25	11.72
Cluster 3	41.10	254.5	7.28	6.71	1.51	1.65	33.24	63.43	2.66	19.65	40.40	29.36	0.28	10.47
Cluster 4	39.15	238.23	7.12	6.58	2.39	2.13	35.30	58.55	5.23	37.88	35.54	28.74	0.27	9.29
Cluster 5	40.00	275.50	7.45	7.63	3.25	3.25	42.25	52.63	3.92	35.83	38.67	29.70	0.27	10.96
Cluster 6	56.00	355.75	9.05	7.95	3.90	2.30	28.42	68.55	2.35	34.50	48.00	30.50	0.33	19.90

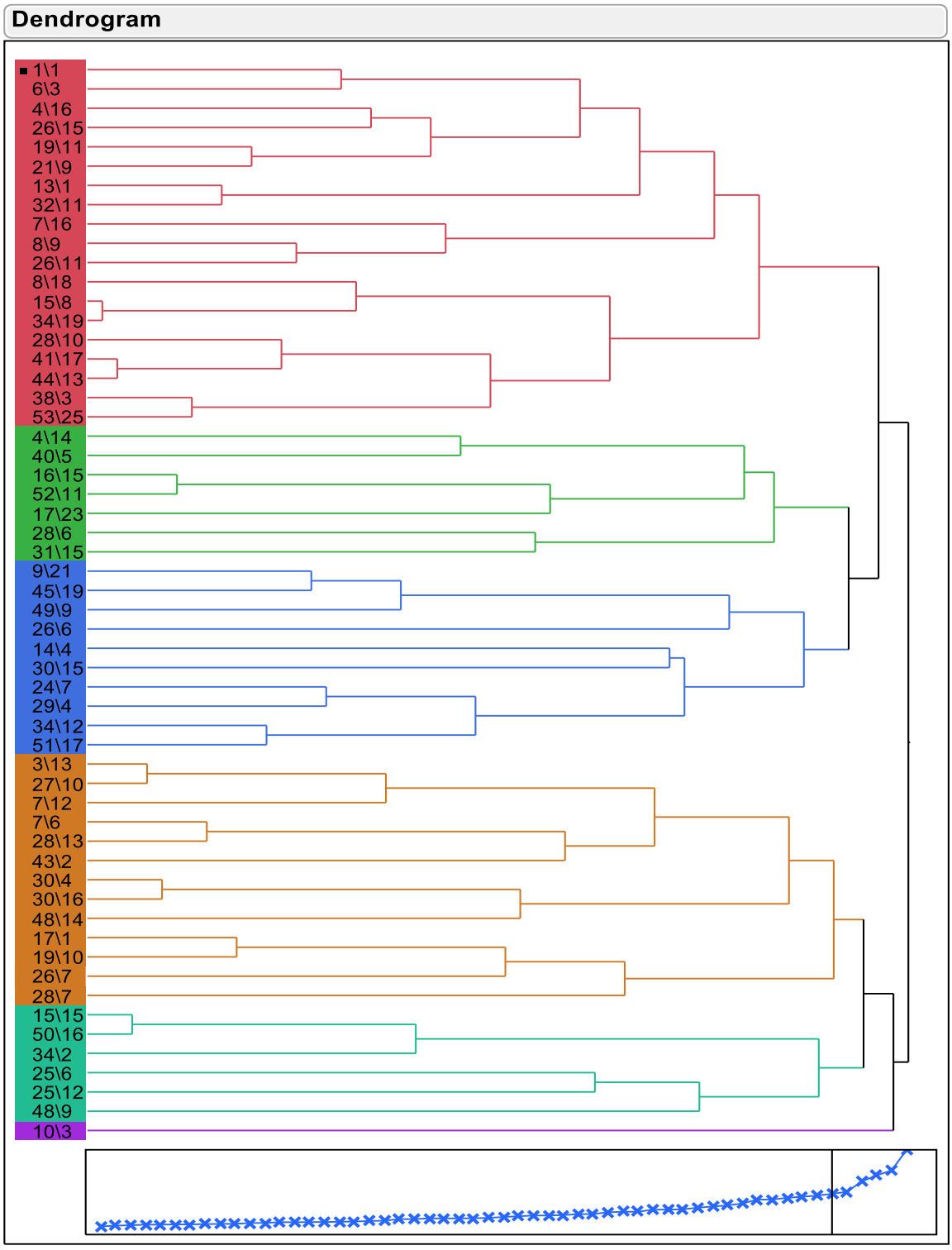


Fig. 4.2 Tocher method dendrogram for Arka Sahan Custard apple progenies (n=56)

Table 4.1.9 Average intra and inter cluster among the clusters of Arka Sahan Custard apple progenies

Cluster	I	II	III	IV	V	VI
I	1.9125	2.2581	2.0415	2.1663	3.0353	3.1780
II		**2.2130**	2.3520	2.4347	2.9078	3.0877
III			1.7327	2.1998	**3.2957**	3.2518
IV				**1.9744**	3.1558	3.1345
V					0.0000	**3.3173**
VI						0.0000

The highest diameter of TSS was recorded in cluster VI (30.50), while the lowest was observed in cluster II (26.31). Maximum acidity (40.33) was recorded in cluster VI, followed by cluster III (0.28) and minimum in cluster II (0.25).

Yield per tree was observed maximum in cluster VI (19.90), followed by cluster II (11.72) and was found minimum in cluster I (9.00).

4.1.7.2 Average intra and inter-cluster among the clusters of Arka Sahan Custard apple progenies

Maximum intra-cluster distance (2.2130) was recorded in cluster II followed by cluster IV (1.9744). The highest inter-cluster distance (3.3173) was recorded between clusters V and VI followed by clusters III and IV (3.2957), whereas, the minimum inter-cluster distance was observed between clusters I and III (2.0415). The maximum genetic distance showed more proximity to hybridization (Table 4.1.9).

4.1.8 Principle component analysis of progenies of Arka Sahan Custard apple

The principle components, Eigen values, per cent variability, cumulative per cent variability and factor loading of different traits studied are furnished in (Table 4.1.10)**.** The principle components with Eigen values less than one were considered nonsignificant as per the procedure.

Table 4.1.10 Eigen values, factor loadings and cumulative variability in progenies of Arka Sahan Custard apple

Variables	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	PC11	PC12	PC13	PC14
Number of fruits per tree	0.085	-0.049	0.171	0.429	0.880	-0.010	-0.006	-0.002	-0.009	-0.001	-0.000	-0.008	0.000	0.000
Fruit weight	0.995	-0.096	0.001	-0.010	-0.001	-0.008	-0.000	-0.000	0.000	-0.000	0.000	-0.000	-0.000	0.000
Fruit length (cm)	0.628	0.124	0.180	0.282	0.029	0.155	0.078	0.190	0.293	0.479	0.304	-0.035	0.001	-0.000
Fruit width (cm)	0.403	0.007	0.219	-0.009	0.173	-0.113	0.328	0.697	-0.373	0.083	-0.074	0.000	-0.000	0.000
Peduncle length	0.152	0.260	0.533	-0.128	0.156	0.185	0.266	0.300	0.593	-0.052	-0.180	-0.016	-0.000	0.000
Peduncle weight	0.154	0.325	0.529	-0.234	0.023	0.314	0.063	0.360	0.099	-0.433	0.320	0.007	0.010	0.000
Peel content	0.082	0.165	-0.560	-0.754	0.267	0.085	0.057	-0.020	-0.006	0.006	-0.004	-0.000	0.002	0.000
Pulp recovery	-0.040	-0.260	0.313	0.859	-0.276	-0.106	0.068	-0.021	-0.003	-0.003	-0.004	-0.001	0.002	0.000
Seed content	-0.114	0.226	0.853	-0.118	-0.037	-0.010	-0.425	0.095	0.012	0.029	-0.034	0.012	0.008	0.000
Number of flakes with seed	0.063	0.252	0.943	-0.204	0.012	0.014	0.011	-0.005	-0.002	-0.002	-0.000	-0.000	0.000	-0.000
Number of flakes without seed	0.778	-0.267	0.060	0.338	-0.089	0.444	-0.001	-0.002	-0.007	-0.007	-0.003	-0.000	0.000	0.000
TSS (°B)	0.415	0.906	-0.061	0.051	-0.008	0.002	-0.000	-0.000	-0.000	-0.000	-0.000	0.000	0.000	0.000
Acidity	0.002	-0.118	0.165	0.044	-0.201	0.204	0.094	-0.084	0.194	0.194	0.215	0.215	-0.062	0.790
Yield per tree	0.749	-0.111	0.124	0.306	0.552	0.009	0.039	-0.002	0.015	0.015	0.004	0.004	-0.000	-0.000

Eigenvalues

Number	Eigenvalue	Percent	20 40 60 80	Cum Percent	ChiSquare	DF	Prob>ChiSq
1	1538.868	73.349		73.349	3716.45	104.000	<.0001 *
2	343.9207	16.393		89.742	2952.06	90.000	<.0001 *
3	119.2359	5.683		95.425	2489.11	77.000	<.0001 *
4	54.0030	2.574		97.999	2157.42	65.000	<.0001 *
5	33.0810	1.577		99.576	1855.28	54.000	<.0001 *
6	6.9835	0.333		99.909	1253.22	44.000	<.0001 *
7	0.8344	0.040		99.948	737.239	35.000	<.0001 *
8	0.4450	0.021		99.970	637.460	27.000	<.0001 *
9	0.3239	0.015		99.985	571.966	20.000	<.0001 *
10	0.1647	0.008		99.993	488.843	14.000	<.0001 *
11	0.0988	0.005		99.998	428.002	9.000	<.0001 *
12	0.0506	0.002		100.000	351.914	5.000	<.0001 *
13	0.0007	0.000		100.000	12.012	2.000	0.0025 *
14	0.0003	0.000		100.000	0.000	0.000	.

Fig. 4.3 Eigen values, percent variability and cumulative variability for principal component analysis of fruit quality characters in Arka Sahan custard apple progenies

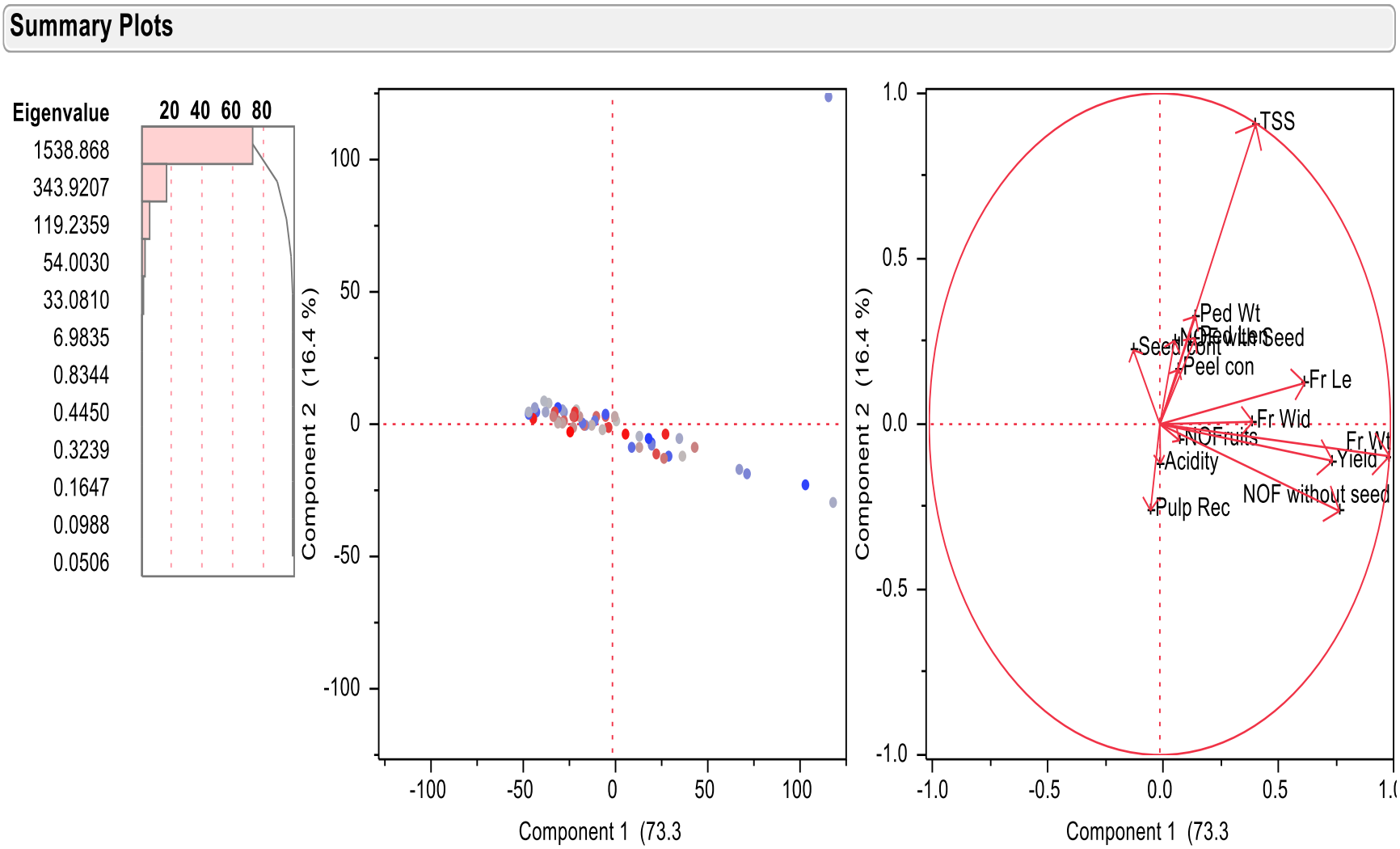


Fig. 4.4 Biplot for Arka Sahan Custard apple progenies on principle component analysis

In the present investigation, the first six principle components with eigen values were more than one contributing 99.90 per cent variability among the 56 progenies of the Arka Sahan custard apple (Table 4.1.10).

The first principle component (PC I) contributed to the highest variability (73.38%). The character loading values for principle components represented the weights defining the contribution of different traits for respective principal components. Traits like number of fruits per tree (0.085), fruit weight (0.995) fruit length (0.628), fruit width (0.403), peduncle length (0.152), peduncle weight (0.154), peel content (0.082), number of flakes with seed (0.063), number of flakes without seed (0.778), TSS (°B) (0.415), acidity (0.002), yield per tree (0.749) had positive loading and were coupled with negative loadings for pulp recovery (-0.040), seed content (-0.114), in decreasing order of the elements, explained about variability in the first principle component.

The second principle component, contributing 16.39 per cent variability, showed high positive loadings for fruit length (0.124), fruit width (0.007), peduncle length (0.260), peduncle weight (0.325), peel content (0.165), seed content (0.226), number of flakes with seed (0.252), TSS (°B) (0.906), had positive loading and were coupled with negative loadings for number of fruits per tree (-0.049), fruit weight (-0.096) pulp recovery (-0.260), number of flakes without seed (-0.267) acidity (-0.118), yield per tree (-0.111)) in decreasing order of the elements, explained about variability in the second principle component.

The third principle component explained 5.68 per cent variability and showed high positive correlation for number of fruits per tree (0.171), fruit weight (0.001), fruit length (0.180), fruit width (0.219), peduncle length (0.533), peduncle weight (0.529), pulp recovery (0.313), seed content (0.853), number of flakes with seed (0.943), number of flakes without seed (0.060), acidity (0.165), yield per tree (0.124) had positive loading and were coupled with negative loadings for peel content (-0.560), TSS (°B) (-0.061) in decreasing order of the elements, explained about variability in the third principle component.

The fourth principle component (2.57 % variability) showed high positive loadings for number of fruits per tree (0.171), fruit length (0.282), pulp recovery (0.859), number of flakes without seed (0.338), TSS (°B) (0.051), acidity (0.044), yield per tree (0.306) had positive loading and were coupled with negative loadings for fruit weight (-0.010), fruit width (-0.009), peduncle length (-0.128), peduncle weight (-0.234), peel content (-0.754), seed content (-0.118), number of flakes with seed (-0.204) in decreasing order of the elements, explained about variability in the fourth principle component.

The fifth component (1.57% variability) had a number of fruits per tree (0.880) contributed positively to the diversity followed by fruit length (0.029), fruit width (0.173), peduncle length (0.156), peduncle weight (0.023), peel content (0.267), number of flakes with seed (0.012), yield per tree (0.552) had positive loading and were coupled with negative loadings for fruit weight (-0.001), pulp recovery (-0.276), seed content (-0.037), number of flakes without seed (-0.089), TSS (°B) (-0.008), acidity (-0.201) in decreasing order of the elements, explained about variability in the fifth principle component.

4.1.9 Correlation of fruit quality traits in Arka Sahan custard apple progenies (n=56)

Fruit weight had a direct positive effect (0.084) on number of fruits per tree. Fruit length significant association with fruit weight (0.609) and a direct positive effect on the number of fruits per tree (0.223). Fruit width significant association with fruit weight (0.401) and fruit length (0.344) and a positive effect on the number of fruit per tree (Table 4.1.11).

Peduncle length had a direct positive effect on number of fruits per tree (0.168), fruit weight (0.127), fruit width (0.271) and significant association with fruit length (0.394). Peduncle weight was significantly associated with peduncle length (0.632), fruit width (0.327) had a direct positive effect on fruit weight (0.123) and fruit length (0.209).

Peel content had a direct positive effect on fruit weight (0.072), but it exhibited an indirect negative effect through the number of fruits per tree (-0.187), fruit length (-0.219), fruit width (-0.037), peduncle length (-0.083) and peduncle width (-0.0.28).

Pulp recovery was significantly negatively associated with peel content (-0.949) and had a positive association with the number of fruits (0.189), fruit length (0.217) and fruit width (0.016) but it exhibited a negative effect through fruit weight (-0.022), peduncle length (-0.069) and peduncle weight (-0.173).

Seed content had a direct negative (-0.339) effect on peel content and fruit weight (0.132) also a significant positive effect through peduncle weight (0.515), peduncle length (0.430) and had a positive effect on the number of fruits per tree (0.043), fruit length (0.064), fruit width (0.065) and pulp recovery (0.093).

Number of flakes with seed exhibited a direct positive effect (0.872) on seed content and also an indirect positive effect through peduncle length (0.609), peduncle weight (0.642), number of fruits per tree (0.077), fruit weight (0.043), fruit length (0.185), fruit width (0.237), pulp recovery (0.047), but it exhibited an indirect negative effect through peel content (-0.322). A number of flakes without seed exhibited a direct positive effect (0.793) on fruit weight, (0.627) on fruit length, pulp recovery (0.324) and an indirect positive effect number of fruits per tree (0.152), fruit width (0.257), peduncle length (0.103), and peduncle weight (0.122). Nonetheless, this trait exhibited an indirect negative effect through peel content (-0.254), seed content (-0.137) and number of flakes with seed (-0.023).

Among all the traits studied, the number of fruits per tree (0.708), fruit weight (0.752), fruit length (0.595), fruit width (0.426) and a number of flakes without seed (0.679) were showed significant positive association with yield per tree, However, peel content (-0.106), seed content (-0.077) showed a negative non-significant association with yield per tree, besides exhibiting a positive non-significant association with pedicel length (0.216), pedicel weight (0.090) and pulp recovery (0.149).

Table 4.1.11 Correlation coefficients of fruit quality traits of Arka Sahan custard apple progenies (n=56)

	Number of fruits per tree	Fruit weight	Fruit length	Fruit width	Peduncle length	Peduncle weight	Peel content	Pulp recovery	Seed content	Number of flakes with seed	Number of flakes without seed	Yield per tree
Number of fruits per tree	1	0.084	0.223	0.218	0.168	0.004	-0.187	0.189	0.043	0.077	0.152	0.708**
Fruit weight		1	**0.609****	0.401**	0.127	0.123	0.072	- 0.022	- 0.132	0.042	**0.793***	**0.752****
Fruit length			1	0.344*	0.394**	0.209	- 0.219	0.217	0.064	0.185	**0.627***	**0.595****
Fruit width				1	0.271	0.327*	- 0.037	0.016	0.065	0.237	0.257	**0.426****
Peduncle length					1	**0.632****	- 0.083	- 0.069	0.430**	0.609**	0.103	0.216
Peduncle weight						1	- 0.028	- 0.173	0.515**	0.642**	0.122	0.090
Peel content							1	**- 0.949****	- 0.399**	- 0.322*	- 0.254	-0.106
Pulp recovery								1	0.093	0.047	0.324*	0.149
Seed content									1	**0.872****	- 0.137	- 0.077
Number of flakes with seed										1	- 0.023	0.081
Number of flakes without seed											1	**0.679****
Yield per tree												1

Critical r value 1%=0.356 5%=0.273 * and ** indicates significant @5% and 1% level respectively

4.1.10 Gene action for TSS (n=222)

Based on the calculated p-value of 0.4040, which is greater than the table value at the chosen significance level, it can be concluded that there is no significant difference between the observed and expected frequencies.

For the gene action analysis, among progenies with a phenotypic ratio of >30 (°B), a total of 63 individuals were observed, with an expected value of 65 in this category. In the category of progenies with a phenotypic ratio of ≤30 (°B), 159 individuals were observed, and the expected value for this category was 156. This distribution results in a phenotypic ratio of approximately 1:3, which is consistent with the expected outcome (Table 4.1.12).

Table 4.1.12 Gene action for TSS

TSS	Observed progenies	Expected progenies	Phenotypic ratio
>30 (°B)	63	65	1
≤ 30 (°B)	159	156	3

P = 0.4046 (non significant at 5%

These findings suggest that the observed phenotypic ratios align well with the expected ratios based on the gene action being studied. The calculated chi-square test result further supports the conclusion that there is no statistically significant difference between the observed and expected frequencies, indicating that the gene action does not significantly deviate from the expected pattern.

4.2 To study the floral biology in self fruitful and unfruitful Arka Sahan progenies.

4.2.1 Flowering time

The flowering time of self-fruitful and unfruitful progenies of Arka Sahan was recorded from March to July after pruning (Plate 3b**)**. The progenies showed no variation in the onset and duration of flowering. The highest flowering intensity in both the progenies

was observed in May, indicating that these months are optimal for pollination and fruit set (Table 4.2.1a and Table 4.2.1b).

4.2.2 Days required for first flowering

There is no significant difference was observed concerning days required for first flowering in both the self-fruitful and unfruitful progenies of Arka Sahan custard apple progenies. Also it was noticed that in both the progenies the minimum time was 22 days, while the maximum time was 24 days (Table 4.2.1a and Table 4.2.1b) **(**Table 4.2.5).

4.2.3 Flower bud diameter (mm)

There is no significant difference for flower bud diameter between the self-fruitful and unfruitful progenies of Arka Sahan Custard apple progenies (Table 4.2.5).

The average flower bud diameter of self-fruitful progenies of Arka Sahan was 7.83 mm. More than five progenies had the largest flower bud diameter of 9.5 mm, followed by 3\13 with 9.0 mm. The smallest flower bud diameter of 6.5 mm was observed in three progenies: 7\3, 19\3 and 36\16 **(**Table 4.2.1a).

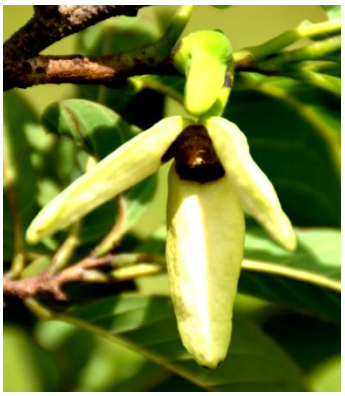
In unfruitful progenies of Arka Sahan, the mean flower bud diameter was 7.77 mm, ranging from 6.0 to 9.5 mm. Progeny 15\7 had the largest flower bud diameter of 9.5 mm, followed by 18\1 with 9.0 mm. Progeny 5\5 had the smallest flower bud diameter of 6.0 mm. **(**Table 4.2.1b).

4.2.4 Petal outer colour

There is no notable distinction regarding the outer colour of petals between the self-fruitful and unfruitful offspring of the Arka Sahan Custard apple (Plate 3c**)**. However, a few progenies in both groups exhibited minor alterations in colour. Among 50 Arka Sahnan self fruitful progenies, 2 progenies had yellow green group 144B, 2 progenies had yellow green group 144C, 16 progenies had yellow green group 145A, 28 progenies had yellow green group 145B and 2 progenies had yellow green group 145C **(**Table 4.2.1a).

Self fruitful progeny **Unfruitful progeny**

Plate 3a Self fruitful and unfruitful progeny



Flower bud **Just opened flower** **Fully opened flower**

Plate 3b Flowers of Arka Sahan Custard apple progeny

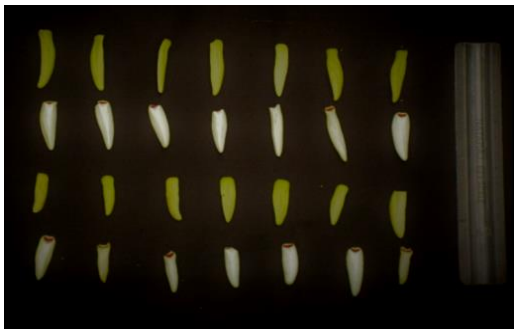


Plate 3c Petal inner and outer color and different growing stages of flower bud development

Table 4.2.1a Flowering time and petal traits of self fruitful Arka Sahan custard apple progenies

S. No.	Progeny	Flowering time	Days required for first flowering	Flower bud diam. (mm)	Petal outer colour	Petal inner Colour	Petal length (cm)	Petal width (cm)
1	1\1	11 April- 28 June	24	7.5	Yellow-Green Group 145A	Yellow-Green Group 150D	2.5	0.9
2	1\23	2 April- 18 June	23	9.5	Yellow-Green Group 145A	Yellow-Green Group 150D	3.5	0.9
3	3\13	9 April- 24 June	24	9.0	Yellow-Green Group 145B	Yellow-Green Group 150D	0.7	1.3
4	4\6	23 April- 21 July	22	7.0	Yellow-Green Group 145A	Yellow-Green Group 150D	3.8	0.7
5	4\14	05 March - 25 May	23	7.0	Yellow-Green Group144B	Yellow-Green Group 150D	0.6	0.6
6	4\16	12 March - 28 May	23	9.5	Yellow-Green Group 145B	Yellow-Green Group 150D	2.1	0.5
7	4\17	07 April- 20 June	23	8.5	Yellow-Green Group 145B	Yellow-Green Group 150D	2.4	1.5
8	6\9	02 April- 24 June	23	7.5	Yellow-Green Group 145B	Yellow-Green Group 150D	2.2	0.5
9	7\3	05 April- 26 June	23	6.5	Yellow-Green Group 145B	Yellow-Green Group 150C	2.3	0.8
10	7\6	19 March - 05 June	24	7.5	Yellow-Green Group 145A	Yellow-Green Group 150D	2.6	0.7
11	7\23	21 March - 02 June	23	8.0	Yellow-Green Group 145C	Yellow-Green Group 150D	2.2	0.8
12	8\9	09 April- 24 June	24	9.5	Yellow-Green Group 145A	Yellow-Green Group 150D	2.3	0.9
13	8\11	5 April- 25 June	23	8.0	Yellow-Green Group 145B	Yellow-Green Group 150D	2.4	0.9
14	9\21	9 April- 25 June	24	8.0	Yellow-Green Group 145B	Yellow-Green Group 150D	2.8	0.8
15	10\3	4 April- 23 June	22	9.5	Yellow-Green Group 145B	Yellow-Green Group 150D	2.0	0.6
16	13\1	23 March - 10 June	23	7.0	Yellow-Green Group 145A	Yellow-Green Group 150D	2.4	0.6
17	15\2	7 March - 28 May	23	7.5	Yellow-Green Group 145B	Yellow-Green Group 150D	2.2	0.9
18	19\3	2 April- 25 June	23	6.5	Yellow-Green Group 145A	Yellow-Green Group 150D	2.8	0.8

S. No.	Progeny	Flowering time	Days required for first flowering	Flower bud diam. (mm)	Petal outer colour	Petal inner Colour	Petal length (cm)	Petal width (cm)
19	19\11	11 April- 26 June	23	7.5	Yellow-Green Group 145A	Yellow-Green Group 150D	3.0	0.9
20	22\7	3 April- 20 June	23	7.5	Yellow-Green Group 145B	Yellow-Green Group 150D	2.8	1.0
21	25\6	7 March - 23 May	24	7.0	Yellow-Green Group 145A	Yellow-Green Group 150D	2.2	0.7
22	25\12	2 April- 14 June	23	7.0	Yellow-Green Group 144B	Yellow-Green Group 149D	2.5	0.8
23	26\7	04 March- 25 May	24	8.0	Yellow-Green Group145C	Yellow-Green Group 150D	2.4	0.8
24	27\6	02 April- 21 June	23	7.5	Yellow-Green Group 145B	Yellow-Green Group 150D	3.0	0.7
25	27\14	05 April- 22 June	24	8.0	Yellow-Green Group 145B	Yellow-Green Group 150D	3.0	0.8
26	28\6	23 March - 10 June	22	8.0	Yellow-Green Group 145A	Yellow-Green Group 150D	3.4	0.8
27	29\2	2 April- 28 June	23	7.5	Yellow-Green Group 144C	Yellow-Green Group 150D	2.7	0.8
28	29\4	6 April- 23 June	23	8.0	Yellow-Green Group 145B	Yellow-Green Group 150D	3.1	0.9
29	30\6	9 April- 24 June	23	8.0	Yellow-Green Group 145A	Yellow-Green Group 150D	2.8	0.9
30	30\15	18 March - 2 June	23	8.0	Yellow-Green Group 145A	Yellow-Green Group 150D	3.0	0.8
31	31\11	05 April- 24 June	23	8.0	Yellow-Green Group 145A	Yellow-Green Group 150D	3.8	0.8
32	31\15	05 April- 25 June	24	9.5	Yellow-Green Group 145A	Yellow-Green Group 150D	3.0	0.9
33	32\11	7 March - 22 May	23	8.0	Yellow-Green Group 145B	Yellow-Green Group 150D	2.3	0.9
34	33\2	9 April- 25 June	24	8.0	Yellow-Green Group 145B	Yellow-Green Group 150D	2.4	0.8
35	33\6	5 April-23 June	23	9.5	Yellow-Green Group 145B	Yellow-Green Group 150D	2.8	1.0
36	34\19	9 April- 25 June	24	7.0	Yellow-Green Group 145B	Yellow-Green Group 150D	2.7	0.7
37	35\16	14 March - 04 June	22	7.5	Yellow-Green Group 145B	Yellow-Green Group 150D	2.2	0.5

S. No.	Progeny	Flowering time	Days required for first flowering	Flower bud diam. (mm)	Petal outer colour	Petal inner Colour	Petal length (cm)	Petal width (cm)
38	36\16	05 April- 24 June	23	6.5	Yellow-Green Group 145A	Yellow-Green Group 150D	2.8	0.9
39	36\17	8 April- 22 June	23	7.5	Yellow-Green Group 145A	Yellow-Green Group 150D	2.8	0.8
40	40\5	26 March - 7 June	23	7.5	Yellow-Green Group 145A	Yellow-Green Group 150D	3.0	0.8
41	41\14	3 April- 24 June	23	7.0	Yellow-Green Group 144B	Yellow-Green Group 150D	2.4	0.9
42	42\12	3 April- 18 June	23	7.0	Yellow-Green Group 145B	Yellow-Green Group 150D	2.7	0.7
43	44\13	05 April- 18 June	24	8.0	Yellow-Green Group 145B	Yellow-Green Group 150D	2.7	0.7
44	45\21	3 April- 25 June	23	7.5	Yellow-Green Group 144C	Yellow-Green Group 150D	2.9	1.0
45	47\18	9 March - 28 May	24	8.0	Yellow-Green Group 145B	Yellow-Green Group 150D	3.1	0.9
46	48\9	12 April- 29 June	23	8.0	Yellow-Green Group 145B	Yellow-Green Group 150D	2.3	0.9
47	48\14	3 April- 17 June	24	7.5	Yellow-Green Group 145B	Yellow-Green Group 150D	2.7	0.7
48	50\10	16 March - 29 May	22	8.0	Yellow-Green Group 145B	Yellow-Green Group 150D	2.5	0.8
49	51\16	4 April-16 June	23	8.0	Yellow-Green Group 145B	Yellow-Green Group 150D	2.2	0.7
50	51\17	28 March - 14 June	23	8.0	Yellow-Green Group 145A	Yellow-Green Group 150D	2.7	0.7
	Mean	-	**23.18**	**7.83**	-	-	**2.59**	**0.81**
	C.V (%)	-	**5.734**	**7.82**	-	-	**18.28**	**20.18**
	S.E.	-	**0.939**	**0.434**	-	-	**0.335**	**0.116**
	C D 5%	-	**1.879**	**0.869**	-	-	**0.670**	**0.232**
	Range	-	**22-24**	**6.5-9.5**	-	-	**0.6-3.8**	**0.5-1.5**

Table 4.2.1b Flowering time and petal traits of unfruitful Arka Sahan custard apple progenies

S. No.	Progeny	Flowering time	Days required for first flowering	Flower bud diam. (mm)	Petal outer colour	Petal inner Colour	Petal length (cm)	Petal width (cm)
1	1\3	7 March - 23 May	24	9.0	Yellow-Green Group 144A	Yellow-Green Group 145D	2.3	0.8
2	2\2	7 April- 21 June	22	7.0	Yellow-Green Group 145B	Yellow-Green Group 150D	2.3	0.7
3	3\5	25 March - 07 June	23	8.5	Yellow-Green Group 145B	Yellow-Green Group 150D	2.4	0.7
4	4\4	4 April- 16 June	23	7.0	Yellow-Green Group 145B	Yellow-Green Group 150D	2.3	0.7
5	5\5	24 March- 14 June	23	6.0	Yellow-Green Group 145A	Yellow-Green Group 145D	2.4	0.8
6	6\1	3 April- 15 May	23	7.0	Yellow-Green Group 145A	Yellow-Green Group 145D	2.2	0.9
7	7\1	22 March - 7 June	23	8.0	Yellow-Green Group 144B	Yellow-Green Group 145C	2.4	0.6
8	8\5	3 April- 25 June	24	8.0	Yellow-Green Group 144B	Yellow-Green Group 145C	2.0	0.8
9	8\16	04 April- 21 June	23	8.0	Yellow-Green Group 145B	Yellow-Green Group 150D	2.5	0.9
10	9\1	7 March - 25 May	24	8.0	Yellow-Green Group 145B	Yellow-Green Group 145D	2.6	0.8
11	10\5	13 March - 31 May	23	7.0	Yellow-Green Group 144C	Yellow-Green Group 150D	2.2	0.9
12	12\9	6 April- 20 June	24	7.5	Yellow-Green Group 144B	Yellow-Green Group 150D	1.9	0.9
13	13\3	18 March - 06 June	22	7.5	Yellow-Green Group 144C	Yellow-Green Group 150D	2.1	0.6
14	14\9	7 April- 25 June	23	8.0	Yellow-Green Group 145B	Yellow-Green Group 145D	2.1	0.6
15	15\7	9 March - 23 May	23	9.5	Yellow-Green Group 145B	Yellow-Green Group 150D	2.5	0.9
16	16\1	2 April- 20 June	23	8.0	Yellow-Green Group 144B	Yellow-Green Group 145C	2.5	1.0
17	17\7	2 April- 28 June	23	7.0	Yellow-Green Group 144B	Yellow-Green Group 145C	3.0	0.8
18	18\1	22 March - 10 June	23	9.0	Yellow-Green Group 145A	Yellow-Green Group 150D	2.6	0.9
19	19\7	18 March - 31 May	24	7.0	Yellow-Green Group 144C	Yellow-Green Group 150D	2.0	0.9
20	20\5	6 April- 20 June	23	8.5	Yellow-Green Group 144B	Yellow-Green Group 145C	1.7	0.6
	Mean	-	**23.15**	**7.77**	-	-	**2.30**	**0.79**
	C.V (%)	-	**6.140**	**8.599**	-	-	**12.52**	**12.008**
	S.E.	-	**1.005**	**0.472**	-	-	**0.203**	**0.067**
	C D 5%	-	**2.103**	**0.989**	-	-	**0.426**	**0.140**
	Range	-	**22-24**	**6.0-9.5**	-	-	**1.7-3.0**	**0.6-1.0**

Among 20 unfruitful Arka Sahan progenies, single progeny had yellow green group 144A, 6 progenies had yellow green group 144B, 3 progenies had yellow green group 144C, 3 progenies had yellow green group 145A and 7 progenies had yellow green group 145B (Table 4.2.4b).

4.2.5 Petal inner colour

The inner petal colour showed no significant difference between the self-fruitful and unfruitful progeny of the Arka Sahan Custard apple. Nonetheless, some descendants in both categories displayed slight colour changes (Plate 3c).

Among 50 self fruitful Arka Sahan progenies, a single progeny had yellow green group 149D, 1 progeny had yellow green group 150C, and 48 progenies had yellow green group 150 **(**Table 4.2.1a).

Among 20 self unfruitful Arka Sahan progenies, 5 progeny had yellow green group 145C, 5 progenies had yellow green group 145D, 10 progenies had yellow green group 150D **(**Table 4.2.1b)

4.2.6 Petal length (cm)

A noticeable disparity in petal length was noted between the self-fruitful and unfruitful descendants of the Arka Sahan Custard apple (Table 4.2.5).

In progenies of self fruitful Arka Sahan petal length varied from 0.6 to 3.8 cm. Maximum (3.8 cm) petal length was recorded in progeny 4\6 and 31\11 with an average value of 2.59 cm followed by 1\23 (3.5 cm), while the minimum (0.6 cm) in 4\14 **(**Table 4.2.1a).

Among self unfruitful progenies of Arka Sahan, the maximum (3.0 cm) petal length was recorded in 17\7 followed by 9\1 and 18\1 (2.6 cm), whereas the minimum (1.7 cm) was observed in 20\5 **(**Table 4.2.1b).

4.2.7 Petal width (cm)

Petal width demonstrates no substantial distinction between the self-fruitful and unfruitful offspring of the Arka Sahan Custard apple. However, some descendants in both groups exhibited minor alterations in colour (Table 4.2.5).

Among the self fruitful progenies, of Arka Sahan revealed a considerably higher range of variations for petal width. The petal width in self fruitful progenies ranged from 0.5 to 1.5 cm. The data on petal width in progenies revealed that maximum (1.5 cm) petal width in 4\17, followed by 3\13 (1.3 cm) with a mean value of 0.81 cm, whereas the minimum (0.5 cm) was observed in 3 progenies 4\16, 6\9 and 35\16 (Table 4.2.1a).

Among unfruitful progenies of Arka Sahan, petal width ranged from 0.6 to 1.0 cm with an average of 0.79 cm. Maximum (1.0 cm) petal width was recorded in progeny 16\1, followed by more than 5 progenies having 0.9 cm, while minimum (0.6 cm) was observed in 4 progenies' (Table 4.2.1b).

4.2.8 Duration of flowering

The duration of flowering showed no significant difference between the self-fruitful and unfruitful progeny of the Arka Sahan Custard apple. Nevertheless, some descendants in both categories displayed minor colour changes (Table 4.2.5).

Duration of flowering in both the self fruitful progenies of Arka Sahan progenies varied from 73 to 87 days with a mean of 78.08 days. Maximum (87 days) duration of flowering was recorded in progeny 29\2 followed by 19\3 (84 days), whereas the minimum (73 days) in 3 progenies' (7\23, 25\12 and 51\16**) (**Table 4.2.2a).

In unfruitful progenies of Arka Sahan mean duration of flowering of 77.95 days and a maximum (87 days) was recorded in progeny 17\7, followed by 8\5 (83 days), whereas the minimum (73 days) duration of flowering was observed in 4\4 and 6\1 **(**Table 4.2.2b).

4.2.9 Peduncle length (cm)

There has a noteworthy distinction in peduncle length between the self-fruitful and unfruitful offspring of the Arka Sahan Custard apple (Table 4.2.5).

Among self fruitful progenies of Arka Sahan, the maximum (3.1 cm) peduncle length was recorded in progeny 44\13 and 48\14, followed by 3\13 (2.9 cm) while the minimum (1.0 cm) was observed in 10\3 with a mean value of 1.92 cm **(**Table 4.2.2a).

The mean peduncle length was 1.60 cm in self unfruitful progenies of Arka Sahan. Maximum (2.7 cm) peduncle length was recorded in progeny 14\9 followed by 7\1 (2.5 cm) whereas, the minimum (1.0 cm) in 8\5 and 8\16 **(**Table 4.2.2b).

4.2.10 Initial angle of petal opening

There has a significant difference in the initial angle of petal opening between the self-fruitful and unfruitful descendants of the Arka Sahan Custard apple (Table 4.2.5).

In self fruitful progenies of Arka Sahan, the initial angle of petal opening was varied from 10º to 30º. Maximum (30º) in the progenies4\6 and 50\10 followed by 20º was observed in more than 20 progenies and minimum (10º) was observed in 3 progenies like 7\3, 27\6 and 31\11**(**Table 4.2.2a) (Plate 4c).

The range of the initial angle of petal opening among self unfruitful progenies of Arka Sahan analysed in the present investigation was 10º to 15º **(**Table 4.2.2b). Among progenies, 5 progeny recorded the highest (15º) initial angle of petal opening which was followed by 10\5 (12º), with a mean of 12.1º and lowest (10º) recorded in more than 10 progenies.

4.2.11 Final angle of petal opening

There has a significant difference in the final angle of petal opening between the self-fruitful and unfruitful descendants of the Arka Sahan Custard apple (Table 4.2.5) (Plate 4c).

The progeny 19\3 recorded the highest (80^0) final angle of petal opening among self fruitful progenies of Arka Sahan which was followed by 30\15 and 51\16 (75^0), with a mean of 56.5^0. The progeny 30\6 recoded lowest (35^0) in Arka Sahan self fruitful progenies (Table 4.2.2a).

In self unfruitful progenies of Arka Sahan, the maximum (50^0) final angle of petal opening was recorded in progeny 18\1, followed by 45^0 in 5 progenies, whereas the lowest (20^0) was recorded in 8\16 (Table 4.2.2b).

4.2.12 Number of flowers per 10 cm shoot

A significant difference existed in the number of flowers per 10 cm shoot between the self-fruitful and unfruitful progeny of the Arka Sahan Custard apple (Table 4.2.5) (Plate 5**)**.

The number of flowers per 10 cm shoots was found highest (10 flowers) in progeny 29\2 followed by 27\14 (9 flowers), among self fruitful progenies of Arka Sahan with a mean of 5 flowers per 10cm shoot, while lowest (single flower) was recorded in 15\2 **(**Table 4.2.2a).

The number of flowers per 10 cm shoots ranged from 1 to 4 flowers in unfruitful progenies of Arka Sahan (Table 4.2.2b). The highest (4 flowers) per 10 cm shoot was recorded in progeny 6\1, followed by 9\1 (3 flowers), while, the lowest (1 flower) was found in more than 10 progenies (Table 4.2.2b).

4.2.13 Anthesis time

There was a notable difference in the timing of anthesis between the self-fruitful and unfruitful offspring of the Arka Sahan custard apple.

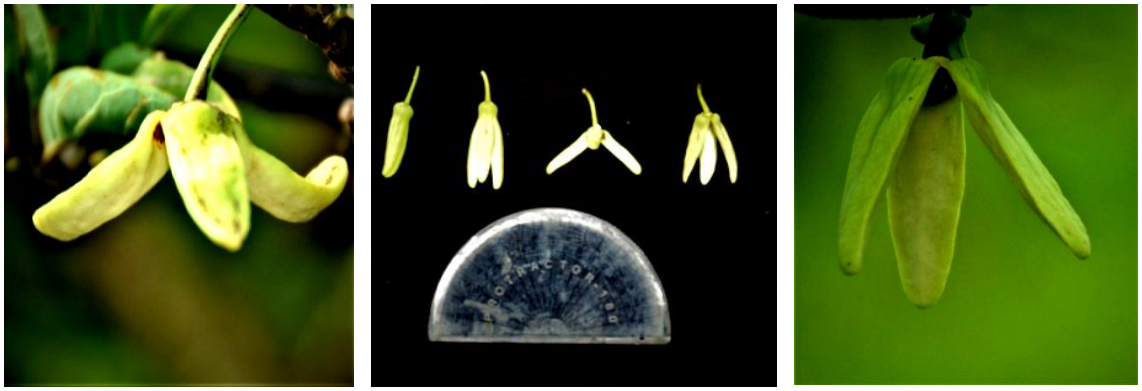
Among the self-fruitful progenies of Arka Sahan have flowers that start to open between 4:30 and 4:45 am, with the highest number of open flowers at 6:00 am. The flowers remain open for about 10 to 12 hours until 7:00 p.m. (Table 4.2.2a).

Morning anthesis **Pollination by honeybee** **Afternoon anthesis**

Plates 4a Anthesis of Arka Sahan Custard apple progenies

Anthers **Anther dehiscene** **Male phase of flower**

Plate 4b Anther deshiscence of Arka Sahan Custard apple progenies



Wide angle of petal opening in self fruitfull progenies **Phases of anthesis** **Narrow angle of petal opening ufruitful progenies**

Plate 4c Angle of petal opening in Arka Sahan Custard apple progenies

Table 4.2.2a Morphological traits of flowering in self fruitful Arka Sahan custard apple progenies

S. No.	Progeny	Duration of flowering	Peduncle length (cm)	Angle of petal opening		Number of flowers per 10 cm shoot	Anthesis			Anther dehiscence		
				Initial	Final		Initiation	Peak	End	Initiation	Peak	End
1	1\1	78	1.5	20°	70°	8	11:40 AM	12:00 PM	2:30 PM	10:00 AM	10:00 AM	10:30 AM
2	1\23	77	1.8	15°	60°	3	12:00 PM	12:30 PM	3:00 PM	9:45 AM	10:30 AM	12:00 PM
3	3\13	76	2.9	15°	60°	4	5:15 AM	6:00 AM	8:30 AM	5:45 AM	6:30 AM	7:15 AM
4	4\6	79	2.0	30°	50°	3	2:15 PM	4:00 PM	4:45 PM	6:05 AM	7:15 AM	2:00 PM
5	4\14	77	1.9	15°	40°	3	6:15 AM	6:20 AM	3:15 PM	5:00 AM	5:45 AM	6:20 AM
6	4\16	77	2.3	15°	55°	3	5:45 AM	6:00 AM	6:00 PM	5:30 AM	6:00 AM	7:00 AM
7	4\17	74	2.0	20°	70°	4	5:30 AM	6:00 AM	7:00 AM	6:00 AM	7:00 AM	7:00 AM
8	6\9	82	2.4	20°	65°	5	5:45 AM	6:30 AM	7:00 AM	5:30 AM	7:00 AM	7:30 AM
9	7\3	82	1.7	10°	40°	3	5:00 AM	5:30 AM	3:15 PM	7:10 AM	7:30 AM	2:00 PM
10	7\6	78	2.3	20°	65°	5	5:30 AM	6:00 AM	6:15 AM	5:15 AM	6:30 AM	7:15 AM
11	7\23	73	1.8	15°	45°	6	6:30 AM	6:30 AM	7:15 AM	5:45 AM	6:30 AM	7:15 AM
12	8\9	76	2.1	20°	55°	6	6:10 AM	7:30 AM	5:45 PM	5:40 AM	6:15 AM	7:10 AM
13	8\11	81	1.2	15°	55°	3	11:40 AM	12:00 PM	2:30 PM	10:00 AM	10:00 AM	10:30 AM
14	9\21	77	1.2	15°	50°	5	6:00 AM	6:15 AM	8:30 AM	10:00 AM	10:15 AM	10:30 AM
15	10\3	80	1.0	20°	65°	5	2:15 PM	4:00 PM	6:15 PM	6:00 AM	6:05 AM	6:15 AM
16	13\1	79	2.3	15°	50°	5	5:30 AM	6:00 AM	2:00 PM	7:10 AM	7:30 AM	1:30 PM
17	15\2	82	1.5	15°	55°	1	5:45 AM	6:00 AM	6:00 AM	5:30 AM	5:30 AM	7:15 AM
18	19\3	84	2.1	20°	80°	5	6:00 AM	6:30 AM	9:00 AM	4:30 AM	5:30 AM	5:45 AM

S. No.	Progeny	Duration of flowering	Peduncle length (cm)	Angle of petal opening		Number of flowers per 10 cm shoot	Anthesis			Anther dehiscence		
				Initial	Final		Initiation	Peak	End	Initiation	Peak	End
19	19\11	76	2.0	15°	45°	4	6:20 AM	6:20 AM	6:30 AM	5:00 AM	5:15 AM	5:30 AM
20	22\7	78	1.6	15°	55°	4	6:15 AM	6:20 AM	3:15 PM	5:00 AM	5:45 AM	6:20 AM
21	25\6	77	2.3	20°	70°	3	6:10 AM	7:30 AM	1:30 AM	5:40AM	6:10 AM	7:15 AM
22	25\12	73	1.1	15°	60°	4	11:40 AM	12:00 PM	2:30 PM	10:00 AM	10:00 AM	10:30 AM
23	26\7	82	1.9	20°	50°	2	6:20 AM	6:20 AM	7:15 AM	6:20 AM	6:20 AM	8:30 AM
24	27\6	80	1.7	10°	55°	5	5:45 AM	6:00 AM	6:00 AM	5:30 AM	5:30 AM	7:15 AM
25	27\14	78	1.6	20°	55°	9	6:20 AM	6:30 AM	6:30 AM	4:45 AM	5:15 AM	5:45 AM
26	28\6	78	1.8	15°	40°	4	6:10 AM	7:30 AM	1:30 AM	5:40 AM	6:10 AM	7:15 AM
27	29\2	87	1.6	20°	55°	10	6:00 AM	6:20 AM	9:00 AM	5:15 AM	5:30 AM	5:45 AM
28	29\4	78	2.2	15°	55°	8	6:20 AM	6:20 AM	7:15 AM	6:20 AM	6:20 AM	7:30 AM
29	30\6	76	2.0	12°	35°	3	5:00 PM	6:00 PM	6:00 PM	4:15 AM	5:30 AM	5:45 AM
30	30\15	75	1.6	20°	75°	6	10:00 AM	1:30 PM	2:15 PM	9:45 AM	10:00 AM	10:00 AM
31	31\11	80	2.0	10°	50°	4	6:10 AM	7:30 AM	1:30 AM	5:40 AM	6:10 AM	7:15 AM
32	31\15	81	2.0	15°	55°	6	6:00 AM	6:30 AM	9:00 AM	5:00 AM	5:30 AM	5:45 AM
33	32\11	76	2.5	15°	55°	6	5:30 AM	6:00 AM	6:15 AM	5:15 AM	6:30 AM	7:15 AM
34	33\2	77	1.2	20°	65°	3	1:30 PM	3:00 PM	5:30 PM	9:15 AM	10:30 AM	1:15 AM
35	33\6	79	1.4	20°	50°	2	4:45 AM	5:55 AM	6:30 AM	5:15 AM	5:30 AM	6:45 AM
36	34\19	77	1.8	15°	55°	4	2:15 PM	4:00 PM	6:15 PM	6:00 AM	6:05 AM	6:15 AM
37	35\16	82	2.5	20°	55°	3	6:15 AM	6:20 AM	3:15 PM	5:00 AM	5:45 AM	6:20 AM

S. No.	Progeny	Duration of flowering	Peduncle length (cm)	Angle of petal opening		Number of flowers per 10 cm shoot	Anthesis			Anther dehiscence		
				Initial	Final		Initiation	Peak	End	Initiation	Peak	End
38	36\16	80	2.0	20°	65°	8	5:00 PM	6:00 PM	6:00 PM	5:15 AM	5:30 AM	6:15 AM
39	36\17	75	2.1	20°	50°	6	6:20 AM	6:30 AM	6:30 AM	4:45 AM	5:15 AM	5:45 AM
40	40\5	74	1.6	20°	55^0	4	1:00 PM	2:15 PM	5:00 PM	9:45 AM	10:00 AM	10:15 AM
41	41\14	82	1.6	15°	50°	5	10:00 AM	1:30 PM	2:15 PM	9:45 AM	10:00 AM	10:00 AM
42	42\12	76	1.8	20°	70°	3	2:15 PM	3:30 PM	7:00 PM	9:30 AM	10:30 AM	5:00 AM
43	44\13	74	3.1	20°	65°	6	4:45 AM	5:55 AM	6:30 AM	5:15 AM	5:30 AM	6:45 AM
44	45\21	83	1.9	15°	60°	6	3:45 PM	4:30 PM	5:45 PM	5:30 AM	6:15 AM	2:15 PM
45	47\18	80	2.2	15°	50°	8	1:00 PM	2:15 PM	5:00 PM	9:45 AM	10:00 AM	10:15 AM
46	48\9	78	2.5	15°	55°	7	3:00 PM	5:30 PM	6:30 PM	6:30 AM	10:30 AM	2:00 PM
47	48\14	75	3.1	15°	60°	3	6:00 AM	5:30 PM	6:30 PM	7:30 AM	4:00 PM	5:30 PM
48	50\10	74	1.8	30°	50°	5	6:30 AM	6:30 AM	3:15 PM	5:00 AM	6:00 AM	10:00 AM
49	51\16	73	2.2	20°	75°	3	2:15 PM	4:00 PM	4:45 PM	6:05 AM	7:15 AM	2:00 PM
50	51\17	78	1.5	15°	55°	7	2:15 PM	4:30 PM	6:30 PM	4:30 PM	5:30 PM	7:00 PM
	Mean	**78.08**	**1.92**	**17.34**	**56.5**	**4.76**	-	-	-	-	-	-
	C.V(%)	**1.259**	**20.39**	**30.14**	**9.900**	**33.95**	-	-	-	-	-	-
	S.E.	**0.695**	**0.227**	**3.696**	**3.958**	**1.142**	-	-	-	-	-	-
	C D 5%	**1.390**	**0.554**	**7.428**	**7.955**	**2.285**	-	-	-	-	-	-
	Range	**73-87**	**1.0-3.1**	**10°-30°**	**35°-80°**	**1-10**	-	-	-	-	-	-

Table 4.2.2b Morphological traits of flowering in unfruitful Arka Sahan custard apple progenies

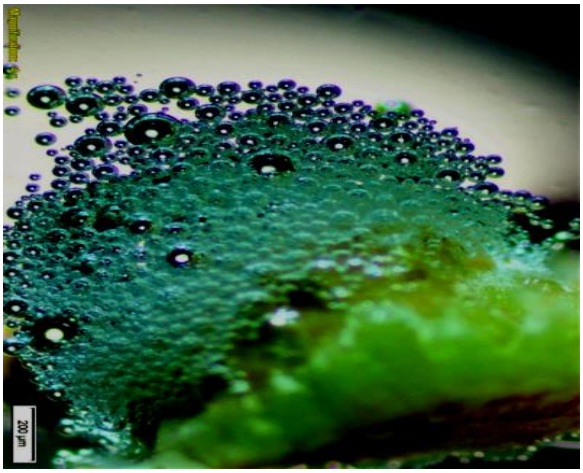
S. No.	Progeny	Duration of flowering	Peduncle length (cm)	Angle of petal opening		Number of flowers per 10 cm shoot	Anthesis			Anther dehiscence		
				Initial	Final		Initiation	Peak	End	Initiation	Peak	End
1	1\3	77	1.8	10°	45°	1	2:30 PM	4:15 PM	6:05 PM	10:05 AM	11:30 AM	1:30 PM
2	2\2	75	1.5	10°	40°	2	2:15 PM	3:45 PM	6:30 PM	10:00 AM	1:30 PM	5:30 PM
3	3\5	75	1.1	10°	40°	2	10:00 AM	3:45 PM	6:30 PM	6:30 AM	6:00 PM	6:30 PM
4	4\4	73	1.7	15°	45°	1	6:00 AM	5:30 PM	6:30 PM	7:30 AM	4:00 PM	5:30 PM
5	5\5	82	1.6	15°	40°	2	7:00 AM	5:30 PM	5:45 PM	8:30 AM	4:15 PM	5:45 PM
6	6\1	73	1.7	15°	45°	4	5:00 AM	5:30 AM	3:15 PM	7:10 AM	7:30 AM	2:00 PM
7	7\1	77	2.5	10°	35°	1	1:30 PM	2:15 PM	5:00 PM	9:45 AM	10:00 AM	12:30 PM
8	8\5	83	1.0	15°	25°	2	12:00 PM	12:30 PM	3:00 PM	9:45 AM	10:30 AM	12:00 PM
9	8\16	82	1.0	10°	20°	2	2:15 PM	3:30 PM	7:00 PM	9:30 AM	10:30 AM	4:00 PM
10	9\1	79	2.0	10°	35°	3	5:30 AM	6:00 AM	7:00 AM	6:00 AM	7:00 AM	7:00 AM
11	10\5	79	1.1	12°	30°	1	4:00 PM	5:30 PM	6:15 PM	2:00 PM	3:00 PM	5:30 PM
12	12\9	75	1.1	10°	25°	2	6:10 AM	7:30 AM	5:45 PM	5:40 AM	6:15 AM	7:10 AM
13	13\3	80	2.0	10°	25°	1	3:45 PM	4:00 PM	6:00 PM	1:00 PM	2:30 PM	6:00 PM
14	14\9	79	2.7	15°	30°	1	5:45 AM	6:00 AM	6:00 AM	5:30 AM	5:30 AM	7:15 AM
15	15\7	75	1.4	15°	45°	1	1:30 PM	3:45 PM	6:30 PM	5:15 AM	3:15 PM	4:00 PM
16	16\1	79	1.2	15°	40°	1	11:40 AM	12:00 PM	2:30 PM	10:00 AM	10:00 AM	10:30 AM
17	17\7	87	1.9	10°	40°	1	1:00 PM	4:30 PM	6:30 PM	3:15 PM	5:30 PM	6:00 PM
18	18\1	80	1.3	10°	50°	1	6:20 AM	6:30 AM	6:30 AM	4:45 AM	5:15 AM	5:45 AM
19	19\7	74	1.5	15°	50°	2	2:45 PM	5:30 PM	6:45 PM	5:45 PM	6:00 PM	6:00 PM
20	20\5	75	2.0	10°	45°	2	1:30 PM	2:15 PM	5:00 PM	9:45 AM	10:00 AM	12: 30PM
	Mean	**77.95**	**1.60**	**12.1**	**37.5**	**1.65**	-	-	-	-	-	-
	C.V(%)	**8.507**	**25.150**	**25.57**	**16.057**	**41.94**	-	-	-	-	-	-
	S.E.	**4.689**	**0.285**	**2.187**	**4.256**	**0.489**	-	-	-	-	-	-
	C D 5%	**9.814**	**0.597**	**4.571**	**8.907**	**1.024**	-	-	-	-	-	-
	Range	**73-87**	**1.0-2.7**	**10°-15°**	**20°-50°**	**1-4**	-	-	-	-	-	-

Single flower per shoot

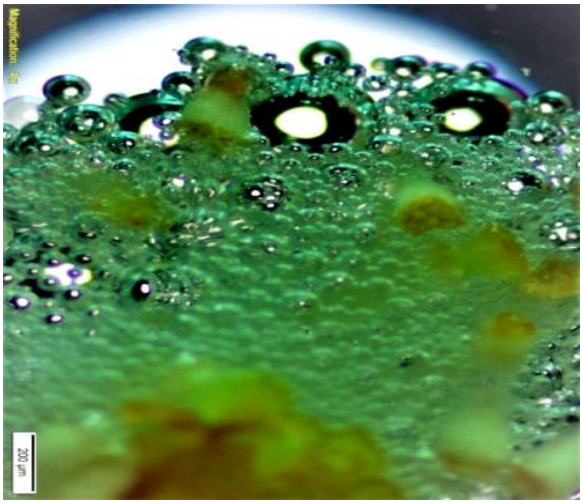
5-6 flower per 10 shoot

9-10 flower per 10 shoot

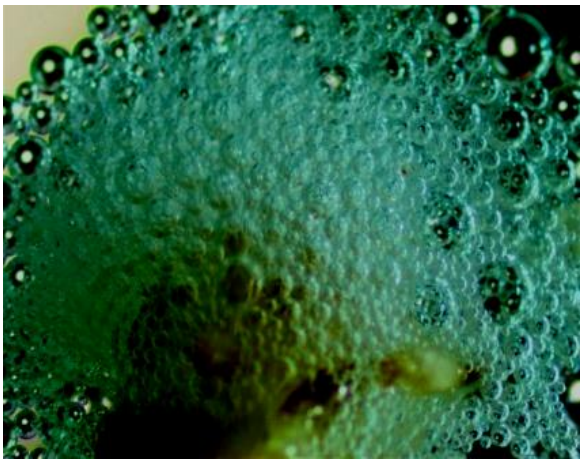
Plate 5 Number of flowers per 10 cm of shoot in self fruitful and unfruitful progenies



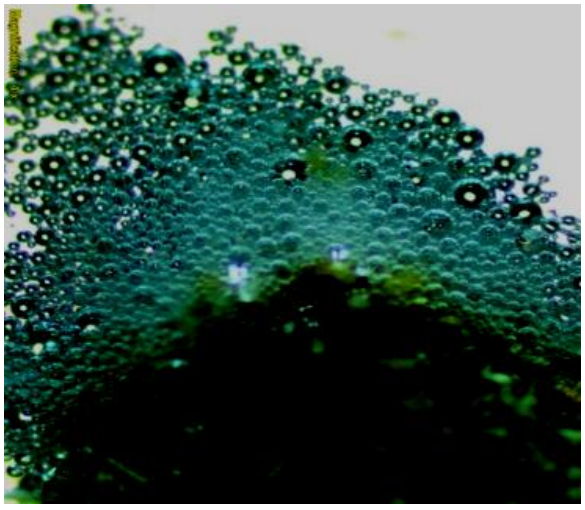
2 day before anthesis



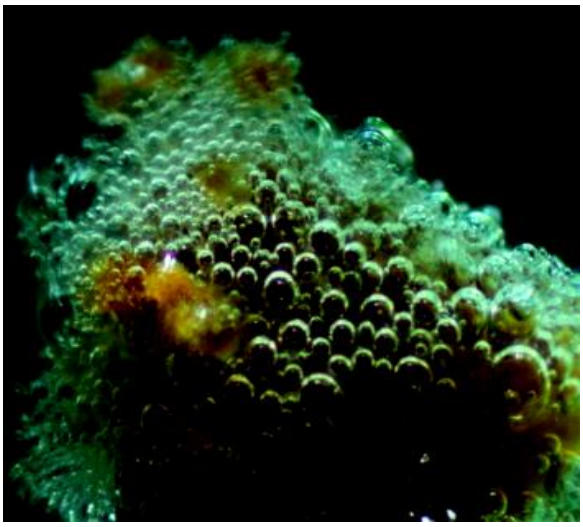
1 day before anthesis



On the day of anthesis



1 day after anthesis



2 days after anthesis

Plate 6 : Stigma receptivity by Hanging drop method

Among the unfruitful progenies of Arka Sahan have different patterns of flower opening. Some progenies have flowers that start to open between 1:00 and 2:00 p.m., with the peak of anthesis at 4:00 to 4:30 p.m. The flowers stay open for about 5 to 6 hours. Other progenies have flowers that start to open between 6:00 and 7:00 a.m., with the peak of anthesis at 3:00 to 4:00 p.m. The flowers stay open for about 10 to 12 hours **(**Table 4.2.2b).

4.2.14 Anther dehiscence

A noticeable difference exists in the timing of anther dehiscence between the self-fruitful and unfruitful progeny of the Arka Sahan custard apple (Plate 3b).

The anthers of self-fruitful progenies of Arka Sahan begin to release pollen between 5:00 and 5:30 am in most of the progenies, reaching the maximum pollen release at 6:00 to 6:30 am. The pollen release lasts for about an hour until 7:00 to 7:30 a.m. **(**Table 4.2.2a).

The anthers of self-unfruitful progenies of Arka Sahan have different timings of pollen release. Some progenies release pollen between 9:00 and 10:00 a.m., with the highest amount of pollen released at 10:00 to 10:30 a.m. Other progenies release pollen between 1:00 and 2:00 p.m., with the highest amount of pollen released at 3:00 to 4:00 p.m. The pollen release ends between 6:30 and 7:00 p.m. **(**Table 4.2.2b).

4.2.15 Diameter of stigma cone (mm)

There is no discernible difference in the diameter of the stigma cone between the self-fruitful and unfruitful progenies of the Arka Sahan custard apple (Table 4.2.5).

The average diameter of the stigma cone in self fruitful progenies of Arka Sahan was 2.67 mm. Progeny 1\23 had the largest diameter (4.5 mm), followed by 4\17, 10\3, 44\13 and 48\14 (3.5 mm each). Progeny 7\6, 9\21, 25\6 and 50\10 had the smallest diameter (2.0 mm each) (Table 4.2.3a).

The average diameter of the stigma cone in unfruitful progenies was 2.7 mm, ranging from 2 mm to 3.5 mm. Progeny 15\7 had the largest diameter (3.5 mm), followed

by more than five progenies with 3.0 mm each. Progeny 1\3 and 2\2 had the smallest diameter (2.0 mm each) (Table 4.2.3a).

4.2.16 Stigma receptivity

The stigma reactivity of Arka Sahan was measured in both self fruitful and self unfruitful progenies using the hydrogen peroxide method **(**Plate 6**)**. The results showed that the stigma reactivity was low two days before anthesis, reached its peak on the day of anthesis and declined gradually until two days after anthesis. The pattern of stigma reactivity was similar in both types of progenies (Table 4.2.3a and 3b).

4.2.17 Time taken for fruit maturity

Time taken for fruit maturity among selected self fruitful progenies of Arka Sahan varied from 121 to 129 days with a mean of 125 days. Maximum (129 days) was recorded in progeny 3\13, 7\6, 15\2, 33\2 and 41\14, while minimum (121 days) in 8\11, 19\11, 34\19, 44\13 and 51\16 (Table 4.2.3a).

4.2.18 Fruit set (%)

The percentage of fruit set varied among some self fruitful progenies of Arka Sahan. The average percentage was 8.35 %. The progeny with the highest fruit set was 9\21, which had 11.66 % of the fruit set. The variety with the lowest fruit set was 33\2, which had only 4.55 % of the fruit set. The variety 19\11 had the second highest fruit set, with 11.47 % (Table 4.2.3a).

4.2.19 Fruit retention (%)

The fruit retention percentage of self fruitful selected progenies ranged from 80.13 to 89.39 % with a mean value of 85.04 % (Table 4.2.3a). Maximum (89.39 %) fruit retention among self fruitful Arka Sahan progenies was recorded in 31\15 followed by 27\14 and 34\19 (88.82 %), while the minimum (80.13 %) in 44\13.

Table 4.2.3a Stigma receptivity and its relationship with fruit maturity, fruit set, and fruit retention in self fruitful Arka Sahan custard apple progenies

S. No.	Progeny	Diameter of stigma cone (mm)	Stigma receptivity					Time is taken for fruit maturity	Fruit set (%)	Fruit retention (%)
			2 days before anthesis	1 day before anthesis	On the day of anthesis	1 day after anthesis	2 days after anthesis			
1	1\1	2.5	+	++	+++	++	+	127	11.37	86.24
2	1\23	4.5	+	++	+++	++	+	126	10.66	88.16
3	3\13	2.5	+	++	+++	++	+	126	9.52	86.10
4	4\6	3.0	+	++	+++	++	+	129	10.87	87.25
5	4\14	3.0	+	++	+++	++	+	126	9.52	83.14
6	4\16	2.5	+	++	+++	++	+	122	6.06	82.40
7	4\17	3.5	+	++	+++	++	+	127	8.69	81.67
8	6\9	3.0	+	++	+++	++	+	123	7.28	85.81
9	7\3	2.5	+	++	+++	++	+	128	6.12	82.79
10	7\6	2.0	+	++	+++	++	+	124	8.81	84.27
11	7\23	2.5	+	++	+++	++	+	129	10.62	85.28
12	8\9	2.5	+	++	+++	++	+	125	6.88	85.12
13	8\11	3.0	+	++	+++	++	+	121	10.59	81.25
14	9\21	2.0	+	++	+++	++	+	126	11.66	85.51
15	10\3	3.5	+	++	+++	++	+	122	9.23	82.71
16	13\1	2.5	+	++	+++	++	+	127	7.33	85.81
17	15\2	2.5	+	++	+++	++	+	129	6.47	88.81

S. No.	Progeny	Diameter of stigma cone (mm)	Stigma receptivity					Time is taken for fruit maturity	Fruit set (%)	Fruit retention (%)
			2 days before anthesis	1 day before anthesis	On the day of anthesis	1 day after anthesis	2 days after anthesis			
18	19\3	2.5	+	++	+++	++	+	125	10.57	82.28
19	19\11	2.5	+	++	+++	++	+	121	11.42	85.22
20	22\7	2.5	+	++	+++	++	+	126	6.57	88.26
21	25\6	2.0	+	++	+++	++	+	122	8.57	85.62
22	25\12	2.5	+	++	+++	++	+	127	10.57	85.31
23	26\7	2.5	+	++	+++	++	+	122	7.12	88.42
24	27\6	3.0	+	++	+++	++	+	127	8.66	88.59
25	27\14	2.5	+	++	+++	++	+	123	7.88	88.82
26	28\6	2.5	+	++	+++	++	+	128	7.19	82.21
27	29\2	2.5	+	++	+++	++	+	122	8.88	85.05
28	29\4	2.5	+	++	+++	++	+	126	8.26	83.56
29	30\6	2.5	+	++	+++	++	+	122	6.66	85.24
30	30\15	2.5	+	++	+++	++	+	127	6.44	88.47
31	31\11	3.0	+	++	+++	++	+	123	6.55	85.19
32	31\15	2.5	+	++	+++	++	+	128	5.33	89.39
33	32\11	2.5	+	++	+++	++	+	124	7.55	85.22
34	33\2	2.5	+	++	+++	++	+	129	4.55	88.04
35	33\6	2.5	+	++	+++	++	+	125	9.33	81.32
36	34\19	2.5	+	++	+++	++	+	121	5.66	88.82
37	35\16	3.0	+	++	+++	++	+	127	6.33	86.16

S. No.	Progeny	Diameter of stigma cone (mm)	Stigma receptivity					Time is taken for fruit maturity	Fruit set (%)	Fruit retention (%)
			2 days before anthesis	1 day before anthesis	On the day of anthesis	1 day after anthesis	2 days after anthesis			
38	36\16	2.5	+	++	+++	++	+	123	8.66	82.43
39	36\17	2.5	+	++	+++	++	+	128	6.53	82.32
40	40\5	2.5	+	++	+++	++	+	124	7.75	85.79
41	41\14	2.5	+	++	+++	++	+	129	11.33	80.35
42	42\12	2.5	+	++	+++	++	+	125	7.25	82.68
43	44\13	3.5	+	++	+++	++	+	121	11.37	80.13
44	45\21	3.0	+	++	+++	++	+	127	7.33	84.92
45	47\18	2.5	+	++	+++	++	+	127	10.66	88.67
46	48\9	2.5	+	++	+++	++	+	128	8.42	83.83
47	48\14	3.5	+	++	+++	++	+	124	6.54	88.35
48	50\10	2.0	+	++	+++	++	+	125	10.21	83.83
49	51\16	3.0	+	++	+++	++	+	121	8.27	84.94
50	51\17	2.5	+	++	+++	++	+	126	7.45	80.5
	Mean	**2.67**	-	-	-	-	-	**125.2**	**8.35**	**85.04**
	CV(%)	**4.23**	-	-	-	-	-	**3.824**	**6.268**	**1.382**
	C D 5%	**0.161**	-	-	-	-	-	**6.772**	**0.740**	**1.637**
	S.E.	**0.080**	-	-	-	-	-	**3.386**	**0.370**	**0.818**
	Range	**2-4.5**	-	-	-	-	-	**121-129**	**4.55-11.66**	**80.13-89.39**

Table 4.2.3b Stigma diameter and receptivity in unfruitful Arka Sahan custard apple progenies

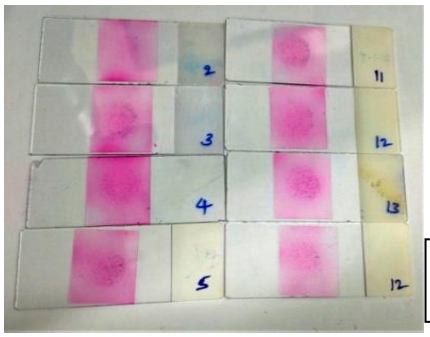
S. No.	Progeny	Diameter of stigma (mm)	Stigma receptivity				
			2 days before anthesis	1 day before anthesis	On the day of anthesis	1 day after anthesis	2days after anthesis
1	1\3	2.0	+	++	+++	++	+
2	2\2	2.0	+	++	+++	++	+
3	3\5	2.5	+	++	+++	++	+
4	4\4	2.5	+	++	+++	++	+
5	5\5	3.0	+	++	+++	++	+
6	6\1	2.5	+	++	+++	++	+
7	7\1	3.0	+	++	+++	++	+
8	8\5	3.0	+	++	+++	++	+
9	8\16	3.0	+	++	+++	++	+
10	9\1	3.0	+	++	+++	++	+
11	10\5	3.0	+	++	+++	+	++
12	12\9	2.5	+	++	+++	++	+
13	13\3	2.5	+	++	+++	++	+
14	14\9	3.0	+	++	+++	++	+
15	15\7	3.5	+	++	+++	++	+
16	16\1	3.0	+	++	+++	++	+
17	17\7	2.5	+	++	+++	++	+
18	18\1	3.0	+	++	+++	++	+
19	19\7	2.5	+	++	+++	++	+
20	20\5	2.5	-	-	-	-	-
	Mean	**2.72**	-	-	-	-	-
	C.V.	**9.639**	-	-	-	-	-
	S.E.	**0.185**	-	-	-	-	-
	CD 5%	**0.3887**	-	-	-	-	
	Range	**2 - 3.5**	-	-	-	-	-

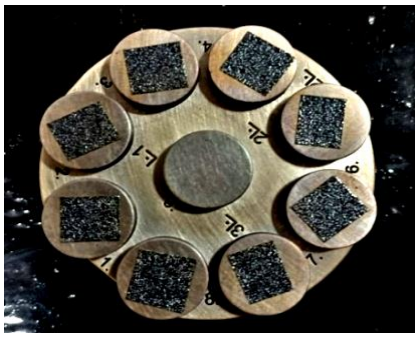
Carpophilus domidiatus *Carpophilus hemipterous* *Apis mellifera*

Plate 7 Pollinators in Arka Sahan Custard apple progenies

Pollen collection immidiatly after anther dehiscence

Pollen incubation for germination and viability





Pollen for SEM observation

Compound microscope **Scannig electron microscope**

Plate 8 Pollen processing for morphological studies

4.2.20 Pollen morphological traits

4.2.20.1 Pollen shape and surface

Both self-fruitful and self-unfruitful progenies of Arka Sahan exhibit consistent shape regardless of their fertility status. However, the shape of pollen grains can differ based on the type of pollen unit. For monads, two distinct shapes were observed: elliptic with one or two furrows on the proximal face, and boat-shaped. The furrows on these grains can be monosulcate or disulcate, depending on their number. In dyads and tetrads, no specific shapes were observed. Among tetrads, three shapes were identified: isobilateral, decussate, and tetrahedral **(**Plate 10**)**.

Both the self-fruitful and self-unfruitful progeny of Arka Sahan display two distinct types of pollen surfaces, irrespective of their fertility status. Some pollen grains exhibit a verrucate surface, characterized by a warty texture, while others possess a smooth surface (Plate 9).

4.2.20.2 Pollen units

Annona produces and releases different types of pollen units from its anthers. These include monads, which are single pollen grains, dyads, which are pairs of pollen grains, and tetrads, which are groups of four pollen grains. The number and arrangement of the pollen grains in each unit may vary depending on the species of Annona (Plate 11).

4.2.20.2a Monads (%)

A noticeable disparity exists in the percentage of monad pollen grains between the self-fruitful and unfruitful progenies of the Arka Sahan Custard apple.

The monads per cent varied significantly ranging from 1.8 to 57.1 % **(**Table 4.2.4a) in Arka Sahan self fruitful progenies. The average of 19.72 % and maximum (57.1 %) monads was recorded in progeny 9\21 followed by 34\19 (52.2 %) and minimum (1.8 %) in 7\23.

The monads percentage differed significantly among the unfruitful progenies studied and ranged from 0 to 25 % **(**Table 4.2.4b). Among Arka Sahan unfruitful progenies average monads were recorded at 6.82 % and it was more (25 %) in 3\5 and 7\1 followed by 4\4 (16.7 %), while it was nil in more than 5 progenies.

4.2.20.2b Dyads (%)

A noticeable difference can be observed in the percentage of dyad pollen grains between the self-fruitful and unfruitful progenies of the Arka Sahan custard apple.

The dyads percentage varied significantly ranging from 0 to 45.8 % **(**Table 4.2.4a) in Arka Sahan self fruitful progenies. The average of 15.53 % and maximum (45.8 %) dyads was recorded in progeny 36\16 followed by 31\11 (34 %) and nil in progeny 13\1.

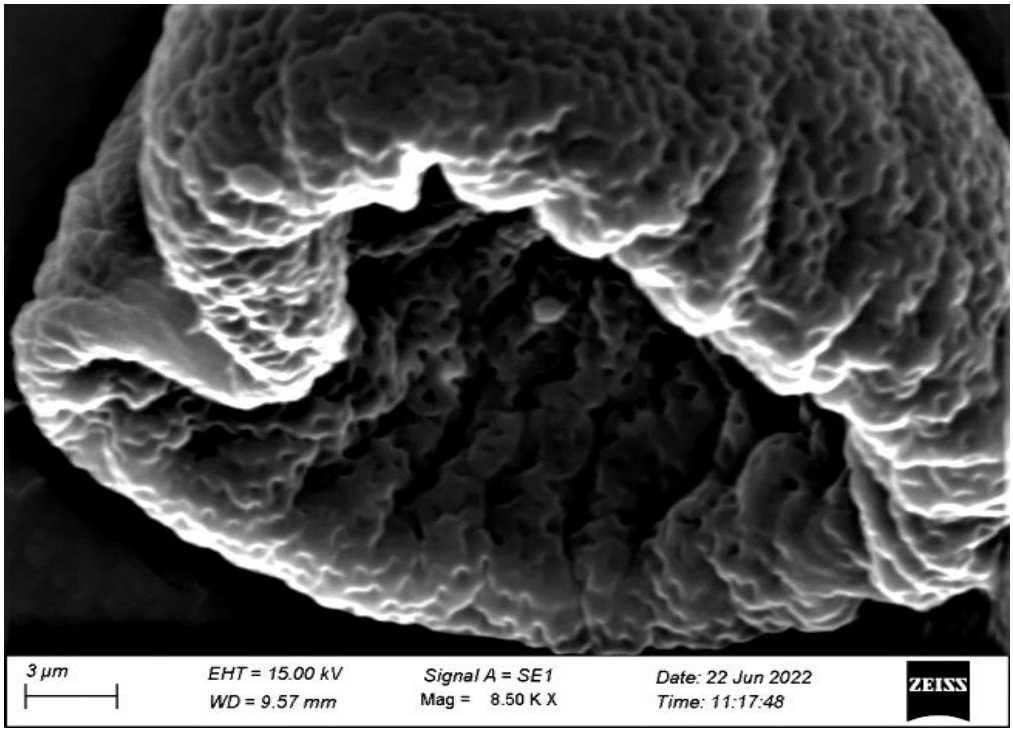
The dyad's percentage differed significantly among the unfruitful progenies studied and ranged from 0 to 22.2 % **(**Table 4.2.4b). Among Arka Sahan unfruitful progenies average dyads were recorded at 9.01 % and it was more (22.2 %) in 16\1 and followed by 18\8 (18.8 %), while it was nil in more than 3 progenies.

4.2.20.2c Triads (%)

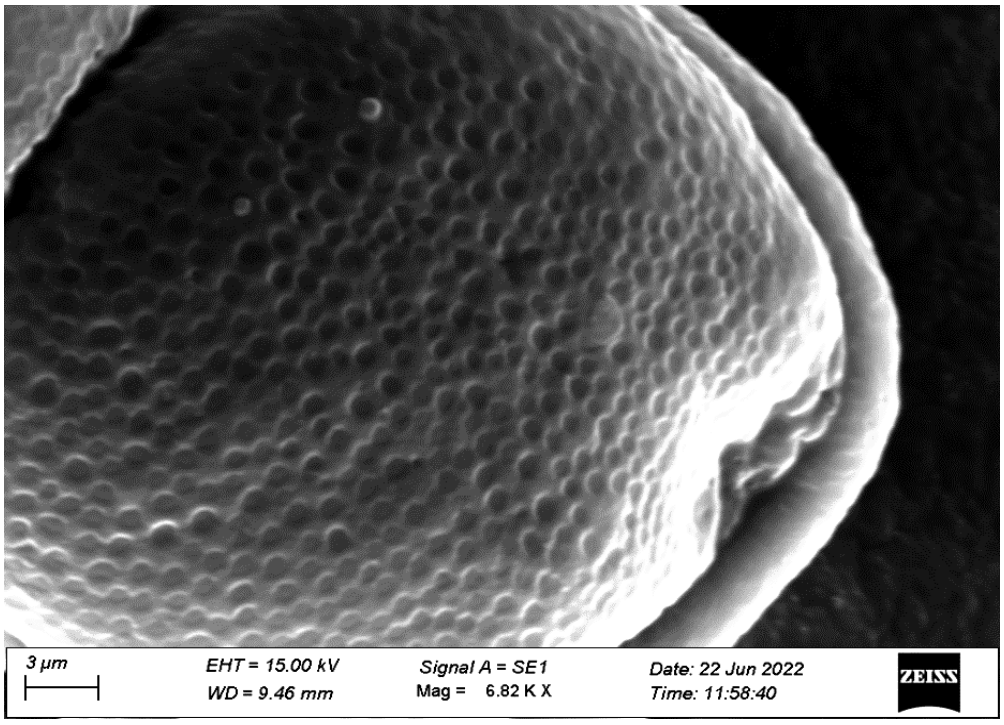
No significant difference can be observed in the percentage of triad pollen grains between the self-fruitful and unfruitful progenies of the Arka Sahan custard apple.

The triads per cent range from 0 to 40 % in Arka Sahan self fruitful progenies **(**Table 4.2.4a). The average of 6.44 % and maximum (40 %) triads was recorded in progeny 13\1 followed by 4\6 (25 %) and nil in more than 15 progenies.

The triads percentage among the unfruitful progenies studied ranged from 0 to 25 % **(**Table 4.2.4b). Among Arka Sahan unfruitful progenies average triads were recorded at 9.28 % and it was more (25 %) in 7\1 and followed by 16\1 (22.2 %), while absent in progeny single progeny.

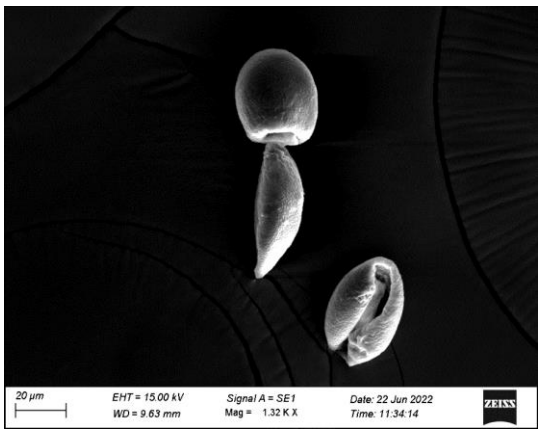


Verrucate

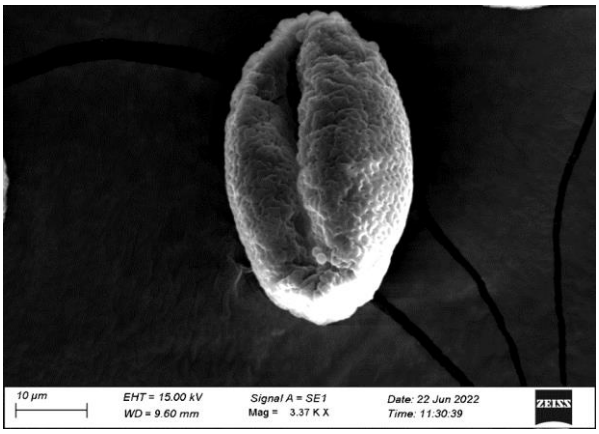


Smooth

Plate 9 Pollen surface (ornamentation)

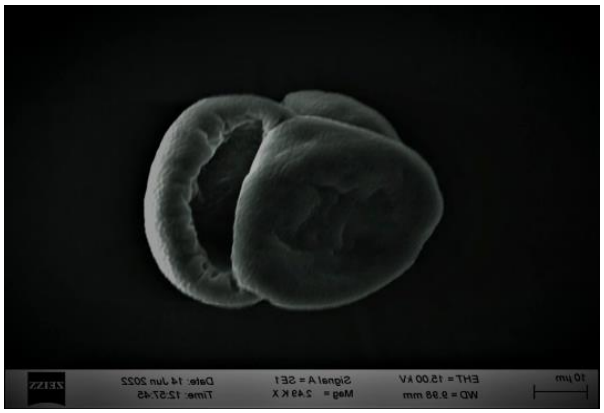


Elliptic with a single furrow monad

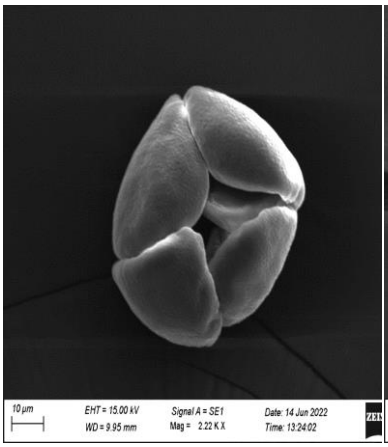


Boat-shaped monad

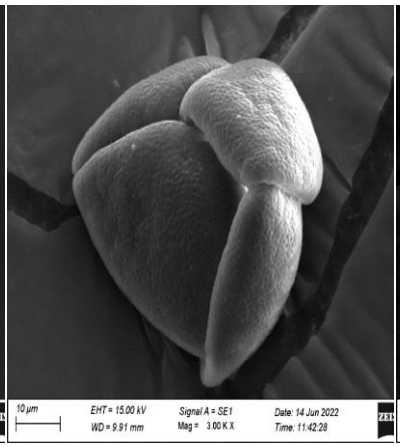
Dyad pollen



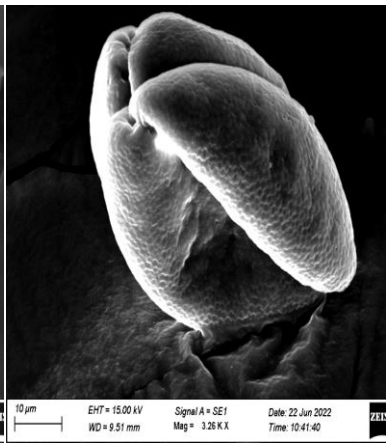
Triad pollen



Isobilateral tetrad

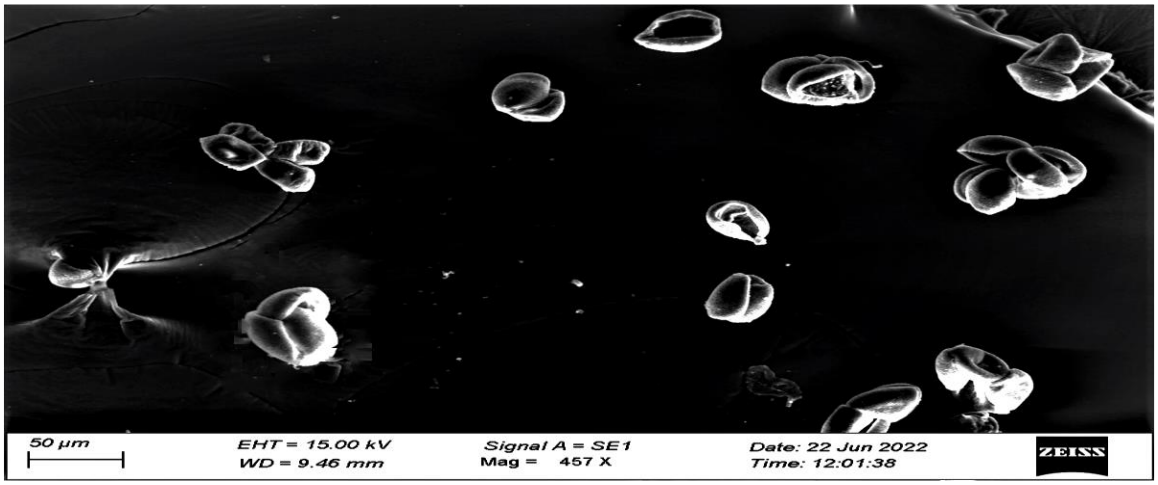


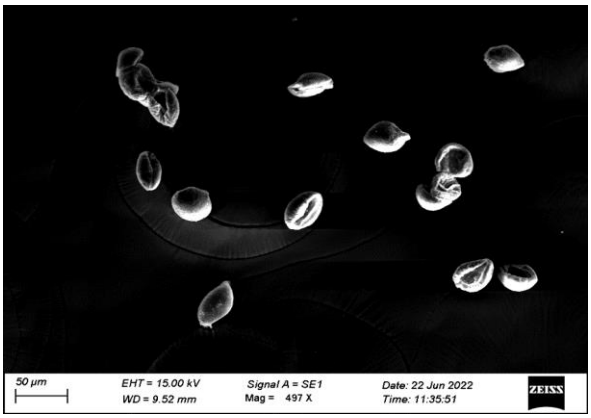
Decussate tetrad

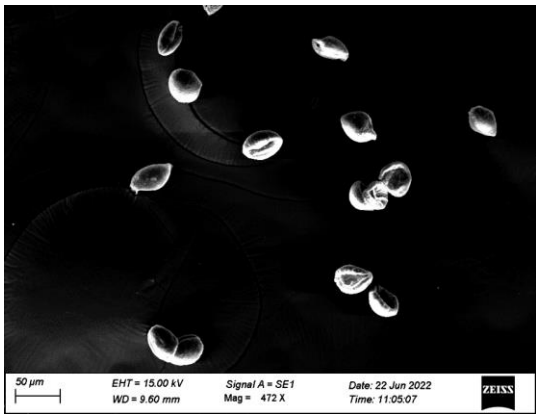


Tetrahedral tetrad

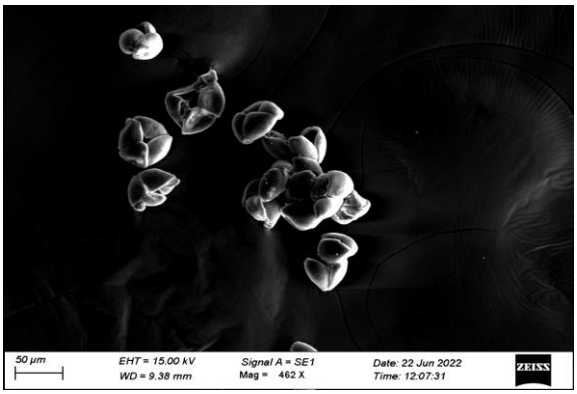
Plate 10 Pollen shapes of different pollen units

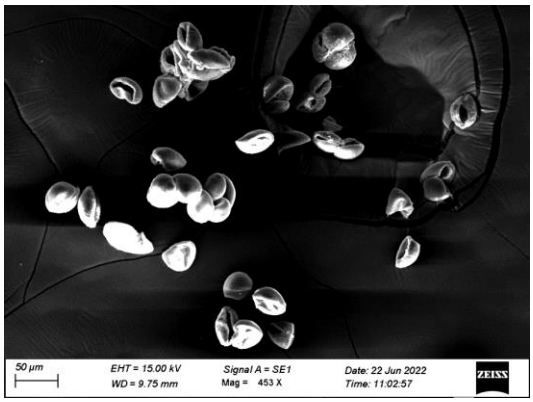






Individual pollens





Aggregated pollens

Plate 11 Aggregated pollens (monads, dyads, triads and tetrads)

4.2.20.2d Tetrads (%)

A significant disparity is evident in the percentage of tetrad pollen grains between the self-fruitful and unfruitful progenies of the Arka Sahan custard apple.

The tetrads percentage varied significantly ranging from 20 to 90.3 % **(**Table 4.2.4a) in Arka Sahan self fruitful progenies. The average of 58.31 % and maximum (90.3 %) triads was recorded in progeny 4\17 followed by 7\23 (87.3 %), while minimum in progeny 13\1 (20 %).

The tetrads percentage differed significantly among the unfruitful progenies studied and ranged from 50 to 100 % **(**Table 4.2.4b). Among Arka Sahan unfruitful progenies average tetrads were recorded at 74.94 % and it was more (100%) in 6\1 and followed by 12\9 (87.5 %), while minimum in progeny was 7\1 (50 %).

4.2.20.3 Pollen viability (%)

Pollen viability showed a noticeable difference between the self-fruitful and unfruitful progenies of the Arka Sahan Custard apple (Plate 12).

Among the self fruitful Arka Sahan Progenies, the average pollen viability of 88.45 % **(**Table 4.2.4a). The highest (99 %) pollen viability was recorded in 29\9 followed by 19\3 (98.4 %), whereas, the lowest (71.8 %) was observed in 10.3 %.

Among unfruitful Arka Sahan progenies, the pollen viability ranged from 49.4 to 92.1 % with a mean value of 73.35 % **(**Table 4.2.4b). Maximum (92.1 %) pollen viability was recorded in progeny 4\4 followed by 10\5 (90.3 %), while, minimum (49.4 %) was found in 20\5.

4.2.20.4 Pollen germination (%)

Pollen germination exhibits a noticeable difference between the self-fruitful and unfruitful progenies of Arka Sahan custard apple.

Table 4.2.4a Pollen traits of self fruitful Arka sahan custard apple progenies

S. No.	Progeny	Pollen units				Pollen viability (%)	Pollen germination (%)	Pollen tube length (µm)	Pollen length x width (µm)			
		Monads (%)	Dyads (%)	Triads (%)	Tetrads (%)				Monad	Dyad	Triad	Tetrads
1	1\1	6.3	8.1	2.5	83.1	95.3	90.2	211	28.2 x 36.8	44.2 x 52.5	52.4 x 50.2	48.2 x 64.4
2	1\23	7.7	11.5	19.2	61.5	95.3	90.2	228	23.3 x 35.2	41.5 x 52.0	51.2 x 54.0	48.2 x 62.0
3	3\13	20.0	25.0	0.0	55.0	93.5	86.5	176	27.5 x 41.2	42.7 x 55.1	-	45.2 x 64.8
4	4\6	12.5	12.5	25.0	50.0	85.4	52.9	196	25.6 x 33.1	48.5 x 53.2	51.2 x 54.5	46.0 x 65.2
5	4\14	8.3	3.8	3.8	84.1	79.8	43.4	215	21.9 x 42.2	42.2 x 52.7	52.4 x 50.2	48.1 x 64.1
6	4\16	10.2	8.0	0.0	81.8	83.3	52.0	289	27.6 x 36.2	42.8 x 52.0	-	45.2 x 64.5
7	4\17	4.4	5.4	0.0	90.3	95.5	95.2	208	26.0 x 33.9	42.9 x 55.1	-	46.5 x 64.9
8	6\9	8.0	16.0	0.0	76.0	94.1	94.0	335	29.3 x 42.2	43.6 x 52.0	-	46.0 x 62.9
9	7\3	18.1	7.6	0.0	74.3	89.9	88.6	131	31.0 x 42.1	42.8 x 55.3	-	47.6 x 62.1
10	7\6	50.0	16.7	0.0	33.3	86.9	85.3	192	25.2 x 42.8	43.9 x 53.2	-	46.4 x 60.4
11	7\23	1.8	9.1	1.8	87.3	95.8	89.6	153	26.2 x 20.3	42.8 x 52.3	52.8 x 51.3	52.2 x 62.0
12	8\9	3.7	3.7	14.8	77.8	85.2	81.9	220	33.9 x 37.3	43.1 x 55.3	52.5 x 51.3	42.2 x 66.2
13	8\11	13.1	8.7	8.7	69.6	88.6	82.8	152	31.0 x 27.4	44.6 x 56.2	50.3 x 54.8	46.6 x 63.4
14	9\21	57.1	14.3	0.0	28.6	81.5	34.9	282	21.3 x 20.2	42.1 x 52.4	-	48.1 x 66.2
15	10\3	42.9	25.7	5.7	25.7	71.8	74.9	267	31.2 x 28.6	44.5 x 53.2	53.2 x 53.4	48.8 x 65.6
16	13\1	40.0	0.0	40.0	20.0	86.0	72.8	228	32.8 x 23.5	-	52.2 x 55.0	48.1 x 66.7
17	15\2	9.0	7.7	6.4	76.9	88.6	84.2	240	27.1 x 31.4	42.1 x 51.9	52.6 x 50.8	47.2 x 60.3
18	19\3	17.4	13.1	2.2	67.4	98.4	85.3	217	25.3 x 48.1	45.2 x 52.2	53.0 x 52.7	47.6 x 64.2

S. No.	Progeny	Pollen units				Pollen viability (%)	Pollen germination (%)	Pollen tube length (µm)	Pollen length x width (µm)			
		Monads (%)	Dyads (%)	Triads (%)	Tetrads (%)				Monad	Dyad	Triad	Tetrads
19	19\11	27.8	16.7	11.1	44.4	85.5	81.6	309	21.5 x 44.8	41.8 x 55.2	52.0 x 52.4	46.8 x 64.2
20	22\7	4.8	4.8	6.3	84.1	95.0	85.4	208	28.9 x 42.9	41.2 x 50.4	55.5 x 51.3	48.1 x 62.0
21	25\6	15.8	10.5	10.5	63.2	78.6	41.2	247	25.9 x 41.5	44.9 x 52.3	52.1 x 54.4	45.9 x 63.9
22	25\12	14.3	28.6	4.8	52.4	84.6	50.0	144	25.1 x 38.3	44.8 x 53.7	53.7 x 52.4	49.5 x 64.7
23	26\7	8.0	28.0	16.0	48.0	80.2	37.4	247	21.8 x 35.4	49.5 x 50.6	50.6 x 51.0	49.6 x 63.2
24	27\6	34.5	30.4	0.0	35.1	93.8	86.9	198	23.4 x 35.2	41.3 x 56.1	-	47.2 x 61.7
25	27\14	16.9	18.6	1.7	62.7	87.2	73.6	101	23.1 x 35.9	47.2 x 55.4	52.4 x 54.9	45.3 x 61.5
26	28\6	30.8	19.2	3.8	46.2	90.9	95.2	261	23.4 x 26.2	42.8 x 52.1	55.4 x 52.5	47.6 x 62.1
27	29\2	20.0	20.0	10.0	50.0	99.0	92.1	150	26.1 x 32.5	44.5 x 52.8	54.4 x 52.1	47.5 x 65.1
28	29\4	21.3	17.0	0.0	61.7	81.7	96.9	128	36.1 x 28.4	41.4 x 51.9	-	46.2 x 65.2
29	30\4	12.4	18.9	10.8	57.9	82.4	66.8	192	21.5 x 22.5	45.5 x 53.1	52.1 x 53.4	45.5 x 61.1
30	30\15	31.8	9.1	9.1	50.0	85.9	88.1	156	31.2 x 27.3	44.1 x 52.1	50.4 x 52.4	45.5 x 61.1
31	31\11	10.7	34.0	0.0	55.3	96.0	82.6	220	24.1 x 31.3	41.3 x 54.4	-	45.1 x 62.6
32	31\15	17.6	23.5	11.8	47.1	85.7	55.6	218	36.9 x 44.5	44.8 x 53.7	54.4 x 53.7	45.1 x 61.5
33	32\11	17.6	17.6	5.9	58.8	86.1	64.7	220	43.5 x 47.6	43.8 x 50.6	50.7 x 51.0	47.0 x 64.5
34	33\2	6.9	23.6	0.0	69.4	87.6	84.5	149	23.4 x 31.2	47.2 x 55.4	-	48.5 x 61.9
35	33\6	5.6	5.6	11.1	77.8	90.5	59.1	228	31.5 x 47.5	49.4 x 55.3	53.6 x 57.9	47.0 x 62.9
36	34\19	52.2	18.4	4.1	25.6	87.5	62.7	211	23.8 x 44.5	42.8 x 52.1	52.1 x 53.3	45.4 x 64.2
37	35\16	35.7	21.4	0.0	42.9	83.1	47.0	236	48.2 x 21.3	42.4 x 54.0	-	47.0 x 65.4

S. No.	Progeny	Pollen units				Pollen viability (%)	Pollen germination (%)	Pollen tube length (µm)	Pollen length x width (µm)			
		Monads (%)	Dyads (%)	Triads (%)	Tetrads (%)				Monad	Dyad	Triad	Tetrads
38	36\16	20.8	45.8	0.0	33.3	92.6	90.4	292	35.1 x 23.5	45.1 x 51.4	-	45.2 x 61.7
39	36\17	10.7	10.7	3.6	75.0	96.5	93.8	241	27.1 x 23.5	41.8 x 51.8	51.4 x 54.5	46.5 x 62.2
40	40\5	15.4	6.9	17.2	61.1	94.8	64.4	238	23.3 x 31.7	44.6 x 52.4	52.2 x 54.8	46.1 x 65.4
41	41\14	19.0	19.0	0.0	61.9	75.4	73.1	270	25.2 x 44.2	44.8 x 51.1	50.1 x 54.5	45.3 x 61.0
42	42\12	8.6	28.6	2.9	60.0	88.5	74.4	267	23.6 x 42.8	44.1 x 51.1	52.1 x 51.2	45.1 x 62.6
43	44\13	17.1	20.0	2.9	60.0	84.4	33.5	260	23.3 x 29.3	41.2 x 51.9	52.1 x 55.1	45.7 x 61.5
44	45\9	31.6	5.3	0.0	63.2	94.1	67.8	204	27.2 x 31.6	41.4 x 51.1	-	45.2 x 65.5
45	47\18	14.3	7.1	4.8	73.8	93.7	85.6	220	27.6 x 36.4	40.4 x 53.2	53.2 x 53.1	45.3 x 64.7
46	48\9	37.5	12.5	18.8	31.3	91.2	75.4	204	28.2 x 32.6	42.3 x 54.8	54.8 x 55.7	49.5 x 62.2
47	48\14	14.3	7.1	14.3	64.3	88.6	67.4	191	20.4 x 33.2	41.7 x 55.2	55.8 x 54.1	48.5 x 60.3
48	50\10	28.6	4.8	4.8	61.9	80.5	70.9	167	30.7 x 22.0	42.3 x 52.2	54.2 x 54.8	48.9 x 62.9
49	51\16	33.3	20.0	0.0	46.7	89.7	33.5	170	27.6 x 44.1	47.4 x 52.6	-	48.2 x 64.2
50	51\17	20.0	26.0	6.00	48.0	96.4	70.3	216	31.2 x 42.2	44.8 x 52.7	55.2 x 54.8	49.1 x 62.1
	Mean	**19.72**	**15.53**	**6.44**	**58.31**	**88.45**	**72.73**	**214.06**	-	-	-	-
	CV (%)	**6.974**	**10.017**	**16.08**	**2.785**	**2.182**	1.958	**2.870**	-	-	-	-
	S.E.	**0.972**	**1.100**	**0.733**	**1.148**	**1.366**	**1.007**	**4.345**	-	-	-	-
	C D 1%	**1.945**	**2.200**	**1.466**	**2.297**	**2.733**	**2.014**	**8.690**	-	-	-	-
	Range	**1.8-57.1**	**0-45.8**	**0-40**	**20.90.3**	**71.8-99.0**	**33.5-96.9**	**101-335**	-	-	-	-

Table 4.2.4b Pollen traits of unfruitful Arka sahan custard apple progenies

S. No.	Progeny	Pollen units				Pollen viability (%)	Pollen germination (%)	Pollen tube length (µm)	Pollen length width (µm)			
		Monads (%)	Dyads (%)	Triads (%)	Tetrads (%)				Monad	Dyad	Triad	Tetrads
1	1\3	9.2	7.7	10.8	72.3	86.8	1.7	20	22.0 x 28.2	41.6 x 55.1	51.7 x 51.4	45.5 x 62.9
2	2\2	15.2	18.2	9.1	57.6	88.3	5.5	19	22.9 x 37.9	44.4 x 52.5	55.3 x 52.2	46.8 x 63.4
3	3\5	25.0	0.0	6.3	68.8	82.5	3.6	18	23.2 x 45.9	-	50.2 x 53.4	48.4 x 56.1
4	4\4	16.7	8.3	0.0	75.0	92.1	3.6	21	29.5 x 32.0	47.5 x 51.5	-	40.2 x 63.2
5	5\5	9.2	6.6	1.3	82.9	56.3	18.6	20	22.5 x 34.2	41.5 x 54.6	51.3 x 55.4	49.5 x 62.2
6	6\1	0.0	0.0	0.0	100.0	81.2	6.4	15	-	-	-	49.5 x 62.6
7	7\1	25.0	0.0	25.0	50.0	81.5	19.5	12	21.6 x 36.6	-	52.8 x 54.5	51.6 x 64.4
8	8\5	0.0	18.8	18.8	62.8	87.3	22.3	12	-	41.2 x 51.3	54.0 x 50.2	48.7 x 63.9
9	8\16	2.9	9.6	3.8	83.7	82.3	3.7	20	28.8 x 36.6	44.5 x 54.6	52.7 x 52.5	46.6 x 61.5
10	9\1	0.0	13.5	4.1	82.4	77.7	25.3	19	-	44.0 x/52.4	53.2 x 55.0	45.2 x 64.5
11	10\5	1.1	8.6	15.1	75.3	90.3	18.4	19	27.1 x 41.3	41.6 x 55.7	54.1 x 54.5	49.2 x 65.4
12	12\9	0.0	3.1	9.4	87.5	66.1	12.9	16	-	44.7 x 51.5	55.6 x 52.7	49.4 x 65.5
13	13\3	1.5	9.2	2.3	86.9	58.2	17.6	16	29.3 x 41.2	41.5 x 56.9	55.1 x 55.2	47.6 x 65.1
14	14\9	5.4	12.2	6.8	75.7	69.5	3.2	18	27.6 x 45.9	45.6 x 52.2	55.0 x 51.3	47.1 x 62.6
15	15\7	0.0	11.1	16.7	72.2	82.1	4.2	11	-	44.7 x 55.2	51.2 x 55.9	46.6 x 65.8
16	16\1	0.0	22.2	22.2	55.6	59.2	5.9	24	-	46.2 x 55.5	50.1 x 54.6	45.5 x 65.1
17	17\7	6.5	9.7	8.1	75.8	50.6	5.1	18	25.6 x 33.0	45.4 x 51.7	52.4 x54.6	47.5 x 61.0
18	18\1	7.4	8.6	7.4	76.9	63.0	14.8	12	21.9 x 42.1	47.6 x 52.6	52.4 x 54.1	50.4 x 65.2
19	19\7	9.3	7.0	4.7	79.1	62.6	14.6	13	21.5 x 38.2	40.2 x 54.7	53.3 x 50.0	46.1 x 64.4
20	20\5	2.0	5.9	13.7	78.4	49.4	5.0	13	30.0 x 42.5	44.5 x 55.4	50.6 x 55.1	45.6 x 65.2
	Mean	**6.82**	**9.01**	**9.28**	**74.94**	**73.35**	**10.59**	**16.8**	-	-	-	-
	CV (%)	**44.77**	**6.46**	**10.68**	**6.925**	**9.934**	**65.69**	**31.42**	-	-	-	-
	S.E.	**2.159**	**0.412**	**0.701**	**3.671**	**5.009**	**4.918**	**3.773**	-	-	-	-
	C D 1%	**6.142**	**1.173**	**1.994**	**10.445**	**14.509**	**13.993**	**10.620**	-	-	-	-
	Range	**0-25**	**0-22.2**	**0.25**	**50-100**	**49.4-92.1**	**1.7**	**11**	-	-	-	-

Among the self fruitful progenies of Arka Sahan, the pollen germination varied from 33.5 to 96.9 % **(**Table 4.2.4a). Higher (96.9 %) pollen germination was recorded in progeny 29\4 followed by 4\17 and 28\6 (95.2 %) and lower (33.5 %) was observed in progeny 44\13 and 51\16 (Plate 13a).

Pollen germination in Arka Sahan unfruitful progenies ranged from 1.7 to 25.3 % with a mean of 10.59 % **(**Plate 13b). Among unfruitful progenies, maximum (25.3 %) pollen germination was recorded in 9\1 followed by 8\5 (23.5 %), while minimum (1.7 %) was observed in progeny 1\3 **(**Table 4.2.4b).

4.2.22.5 Pollen tube length (µm)

There is a noticeable difference in pollen tube length between the self-fruitful and unfruitful progenies of the Arka Sahan Custard apple **(**Plate 13a and b**)**.

The progeny 6\9 recorded a maximum (335 µm) pollen tube length followed by 19\11 (309 µm), whereas the minimum (101 µm) was found in 27\14, among self fruitful progenies of Arka Sahan **(**Table 4.2.4a).

In unfruitful progenies of Arka Sahan, the maximum (24 µm) pollen tube length was recorded in progeny 16\1 followed by 4\4 (21 µm) and the minimum (11 µm) was observed in 15\7 **(**Table 4.2.4b).

4.2.20.6 Pollen length and width (µm)

No significant difference is apparent in terms of pollen length and width between the self-fruitful and unfruitful progenies of the Arka Sahan Custard apple. However, a substantial degree of variation was observed among the individual pollen units.

Among self fruitful Arka Sahan progenies the pollen length and width in a monad, dyads, triads and tetrads varied significantly ranging from 21.3 x 20.2 to 43.5 x 47.6 µm, 41.2 x 50.4 to 49.4 x 55.3, 50.6 x 51.0 to 55.2 x 54.8 and 42.2 x 66.2 to 49.5 x 64.7 respectively **(**Table 4.2.4a).

Viable **Non- viable**

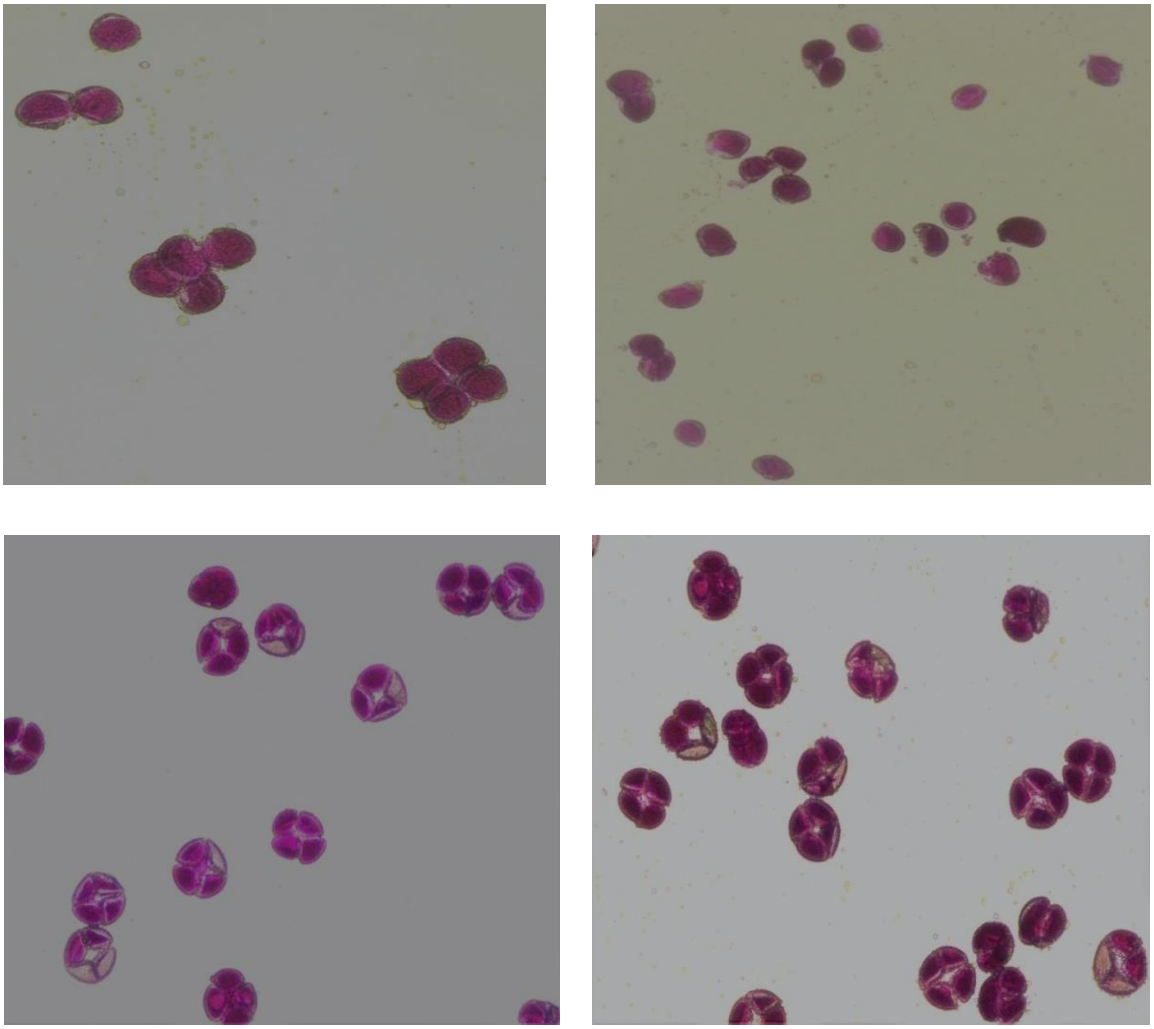


Plate 12 Pollen viability in self fruitful and unfruitful progenies

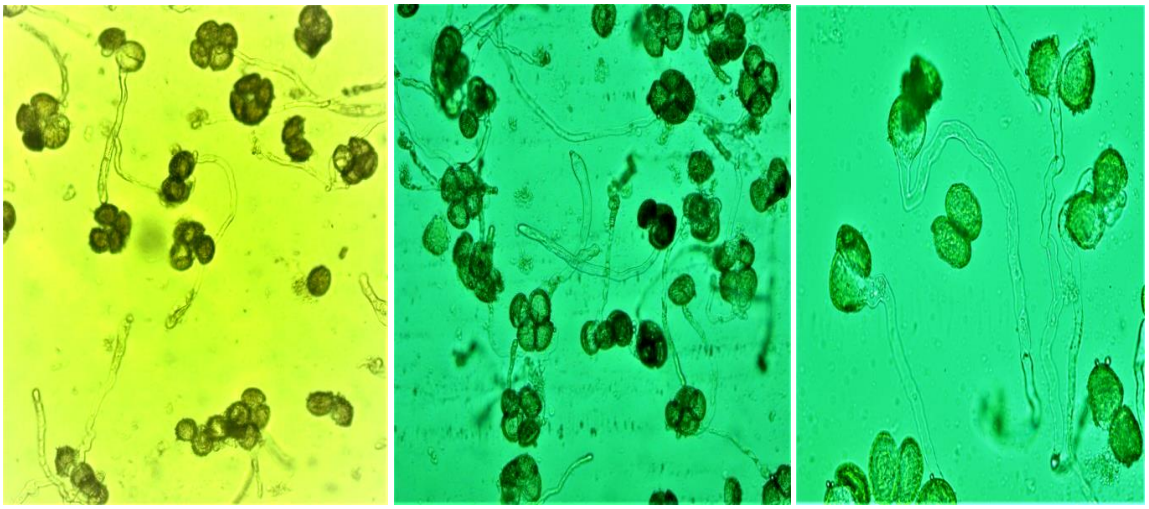


Plate 13a Pollen germination and pollen tube growth in self fruitful Arka Sahan custard apple progenies

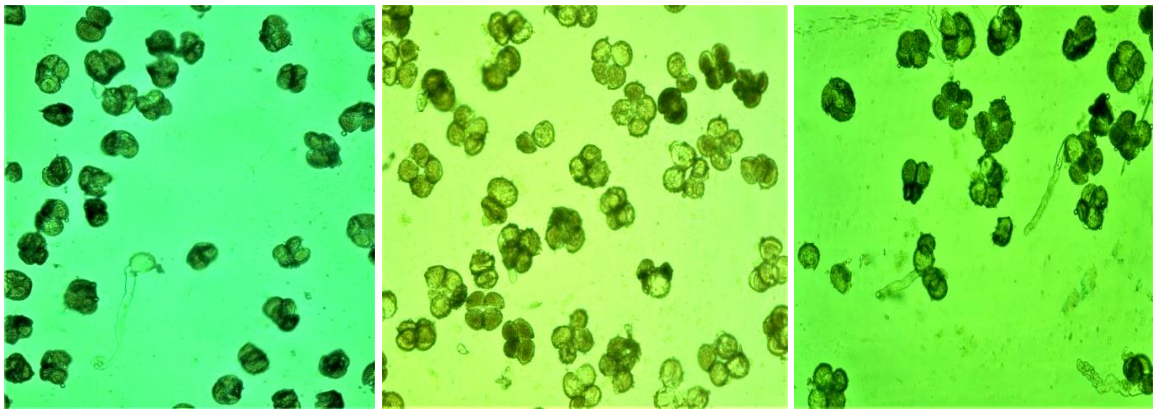
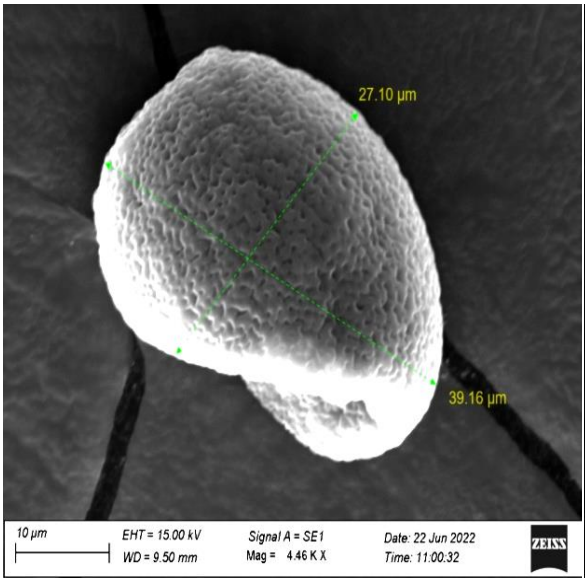
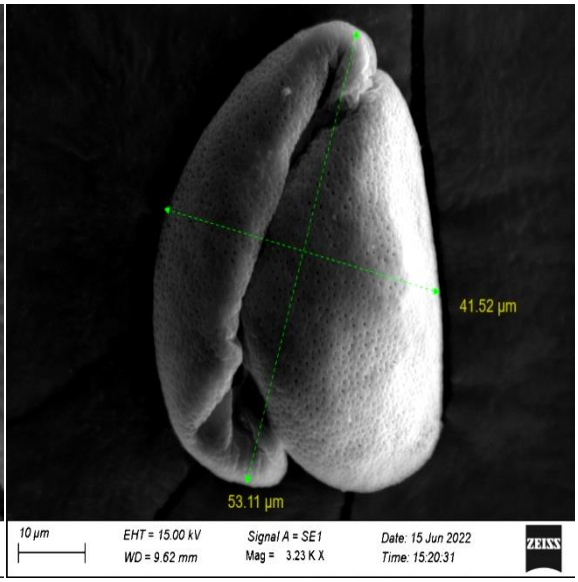


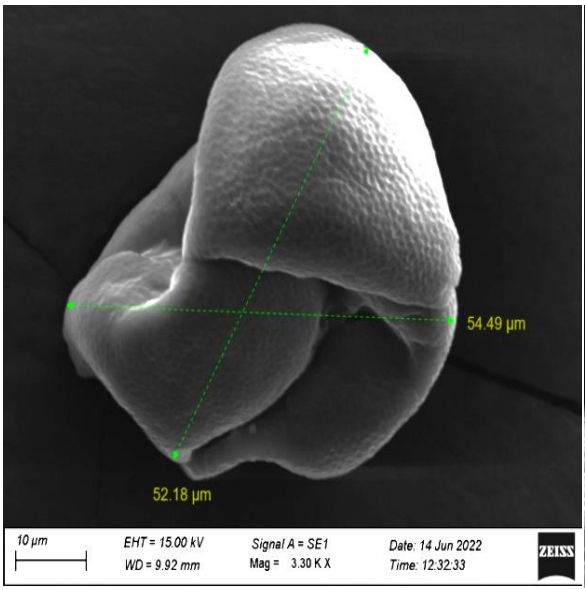
Plate 13b Pollen germination and pollen tube growth in unfruitful Arka Sahan custard apple progenies



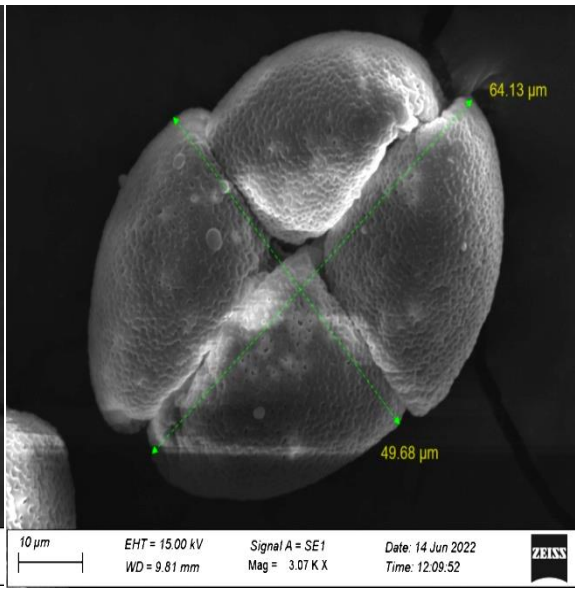
Monad



Dyad



Triad



Tetrad

Plate 14 Pollen length and width (µm)

Table 4.2.5 Significance test for self fruitful and unfruitful progenies

Floral traits	t stat @ 5%
Days required for first flowering	0.1 (NS)
Flower bud diam. (mm)	0.2 (NS)
Petal length (cm)	2.8 (S)
Petal width (cm)	0.6 (NS)
Duration of flowering	1.1 (NS)
Peduncle length (cm)	2.5 (S)
Initial angle of petal opening	6.6 (S)
Final angle of petal opening	7.8 (S)
Number of flowers per 10 cm shoot	9.4 (S)
Diameter of stigma cone(mm)	0.5 (NS)
Monads (%)	4.9 (S)
Dyads (%)	3.4 (S)
Triads (%)	1.4 (NS)
Tetrads (%)	4.5 (S)
Pollen viability (%)	4.6 (S)
Pollen germination (%)	19.9 (S)
Pollen tube length (µm)	28.2 (S)

Among unfruitful Arka Sahan progenies the pollen length and width in monads, dyads, triads and tetrads varied significantly ranging from 22.0 x 28.2 to 30.0 x 42.5 µm, 41.2 x 51.3 to 44.5 x 55.4, 51.7 x 51.4 to 55.1 x 55.2 and 40.2 x 63.2 to 51.6 x 64.4 respectively **(**Table 4.2.4b)

4.2.21 Correlation of flower and pollen traits in self fruitful Arka Sahan custard apple progenies (n=50)

Flower bud diameter was negatively influenced (-0.042) by petal length, whereas petal width exhibited a positive impact (0.237) on flower bud diameter. Furthermore, peduncle length had adverse effects on flower bud diameter, as well as petal length and width.

The diameter of the stigma cone had a direct positive effect on flower bud diameter (0.267), petal length (0.099), petal width (0.021), and peduncle length (0.151).

The initial angle of the petal opening showed a positive correlation with petal length (0.049) and peduncle length (0.004). However, it harmed the flower bud diameter (-0.016), petal width (-0.100) and the diameter of the stigma cone (-0.084).

The final angle of the petal opening displayed a significant positive correlation with the initial angle of the petal opening (0.432). Additionally, it exhibited positive associations with petal length (0.183), petal width (0.023), and peduncle length (0.085). However, it had a negative impact on the flower bud diameter (-0.113) and the diameter of the stigma cone (-0.049).

The percentage of monads exhibited a positive correlation with petal length (0.042) and the final angle of petal opening (0.053). However, it had a negative impact on flower bud diameter (-0.129), petal width (-0.261), the diameter of the stigma cone (-0.189) and the initial angle of petal opening (-0.056).

The percentage of dyads showed a positive correlation with petal length (0.132), the diameter of the stigma cone (0.010), the final angle of the petal opening (0.073), and the percentage of monads (0.145). However, it had a negative impact on flower bud diameter (-0.082), petal width (-0.103), peduncle length (-0.056), and the initial angle of petal opening (-0.101).

Table 4.2.6 Correlation coefficients of flower and pollen characters in Arka Sahan custard apple progenies (n=50)

	Flower bud diam.	Petal length	Petal width	Peduncle length	Diameter of stigma cone	Initial angle of petal opening	Final angle of petal opening	Monads	Dyads	Triads	Tetrads	Pollen viability	Pollen germination	Pollen tube length	Fruit set
Flower bud diam.	1	-0.042	0.237	-0.013	0.267	-0.016	-0.113	-0.129	-0.082	0.060	0.113	-0.218	-0.219	0.023	-0.068
Petal length		1	0.000	-0.159	0.099	0.049	0.183	0.042	0.132	0.186	-0.185	0.045	-0.112	-0.108	-0.108
Petal width			1	-0.047	0.021	-0.100	0.023	-0.261	-0.103	-0.089	0.291*	-0.014	-0.024	-0.080	0.162
Peduncle length				1	0.151	0.004	0.085	-0.000	-0.056	0.087	-0.009	0.103	0.025	-0.012	-0.092
Diameter of stigma cone					1	-0.084	-0.049	-0.189	0.010	0.101	0.091	0.145	0.027	0.246	0.103
Initial angle of petal opening						1	0.432 *	-0.056	-0.101	0.136	0.036	-0.050	-0.016	-0.078	0.193
Final angle of petal opening							1	0.053	0.073	-0.048	-0.057	0.308*	0.295*	0.185	0.553*
Monads								1	0.145	-0.013	-0.825**	0.058	0.178	-0.100	0.041
Dyads									1	-0.330**	-0.491*	-0.032	-0.035	-0.144	-0.069
Triads										1	-0.260	0.049	0.059	-0.025	-0.004
Tetrads											1	-0.049	-0.144	0.164	0.006
Pollen viability												1	0.591**	-0.132	0.603*
Pollen germination													1	-0.135	0.701*
Pollen tube length														1	-0.012
Fruit set															1

Critical r value 1%=0.356 5%=0.273 * and ** indicates significant @5% and 1% level respectively

Triads exhibited a favourable correlation with traits such as flower bud diameter (0.060), petal length (0.186), peduncle length (0.087), diameter of the stigma cone (0.101), and initial angle of petal opening (0.136). On the contrary, they showed an adverse relationship with petal width (-0.089), final angle of petal opening (-0.048), monads per cent (-0.013), and notably and inversely associated with the percentage of dyads (-0.330).

Tetrads showed a notably strong positive correlation with petal width (0.291) and exhibited positive relationships with other factors such as flower bud diameter (0.113), diameter of the stigma cone (0.091) and initial angle of petal opening (0.036). Conversely, they displayed significant negative associations through monads per cent (-0.825) and dyads (-0.491). Additionally, tetrads had an adverse impact on petal length (-0.185), peduncle length (-0.009), final angle of petal opening (-0.057), and triad per cent (-0.260).

Pollen viability demonstrated a noteworthy and positive correlation with the final angle of the petal opening (0.308). It also exhibited favourable associations with petal length (0.045), peduncle length (0.103), diameter of the stigma cone (0.145), monads per cent (0.058), and triads (0.049). Conversely, it had an indirectly negative impact on flower bud diameter (-0.218), petal width (-0.014), initial angle of petal opening (-0.050), dyads per cent (-0.032), and tetrads per cent (-0.049).

Pollen germination displayed a significant positive correlation with both pollen viability (0.591) and the final angle of petal opening (0.295). Additionally, it exhibited favourable connections with peduncle length (0.025), the diameter of the stigma cone (0.027), monads per cent (0.178), and triads per cent (0.059). Conversely, there was a negative influence through flower bud diameter (-0.219), petal length (-0.112), petal width (-0.024), initial angle of petal opening (-0.016), dyads per cent (-0.035), and tetrad per cent (-0.144).

Pollen tube length demonstrated a positive correlation with flower bud diameter (0.023), diameter of the stigma cone (0.246), final angle of petal opening (0.185), and tetrads per cent (0.164). However, it had negative effects on petal length (-0.108), petal width (-0.080), peduncle length (-0.012), initial angle of petal opening (-0.078), monads

per cent (0.100), dyads per cent (-0.144), triads per cent (-0.025), pollen viability (-0.132), and pollen germination (-0.135).

The fruit set displayed significant positive associations with the final angle of petal opening (0.553), pollen viability (0.603) and pollen germination (0.603). Furthermore, it exhibited positive effects on petal width (0.162), the diameter of the stigma cone (0.103), the initial angle of petal opening (0.193), monads per cent (0.041) and tetrads per cent (0.006). Conversely, it had negative impacts through flower bud diameter (0.068), petal length (-0.108), peduncle length (-0.092), dyads per cent (-0.069), triads per cent (-0.004), and pollen tube length (-0.012) **(**Table 4.2.6**)**.

4.2.22 Effect of pollen viability and germination (%) on number of fruits per tree

Noticeable variations in pollen viability are evident among the different treatments (Table 4.2.7). The highest pollen viability (93.75%) was noted in T1 (with more than 50 fruits per tree), succeeded by T2 (with 30-50 fruits per tree) at 84.64% viability. As the number of fruits per tree decreased, pollen viability exhibited a gradual decline. The lowest pollen viability (78.55%) was recorded in T4 (with 0 fruits per tree).

Table 4.2.7 Effect of pollen viability and germination (%) on number of fruits per tree

Treatments	Pollen viability (%)	Pollen germination (%)
T1- >50 fruits per tree	93.75	88.94
T2- 30 - 50 fruits per tree	84.64	68.95
T3 -10 – 20 fruits per tree	81.15	45.45
T4 - 0 fruits per tree	78.55	10.08
F- test (P=0.05)	S	S
S E (m) ±	0.771	0.403
C D 5%	1.174	0.878
C.V. (%)(transformed values)	4.766	1.905

S- Significant at p =0.05

Substantial differences are apparent in pollen germination among the various treatments (Table 4.2.7). The highest pollen germination rate (88.94%) was documented in T1 (with more than 50 fruits per tree), with T2 (30-50 fruits per tree) following at a germination rate of 68.95%. As the quantity of fruits per tree decreased, there was a marked reduction in pollen germination. The lowest pollen germination rate (10.08%) was witnessed in T4 (with 0 fruits per tree).

4.3 Assessment of genetic relatedness between parents and Arka Sahan progenies.

Finding the molecular markers for self-fruitfulness or unfruitfulness in Annona was the intention of the present study. This trait affects the ability of a plant to produce fruits without cross-pollination or assisted pollination. The expression of this attribute depends on different factors, such as genetic, environmental, physiological, and biotic interactions. We attempted to use molecular markers to identify the genes or loci that determine self-fruitfulness or unfruitfulness in Annona.

The sixty-five SSRs specific to Annona were used to study the genetic relatedness between Balanagar, Arka Sahan and their derived progenies consisting of both self-fruitful as well as unfruitful.

Table 4.3.1 SSR markers with annealing temperature and application size

S. No.	Locus	Forward and reverse (5^I-3^I)	Annealing temperature (°C)	Application size (bp)
1	LMCH 1	F- CTCTTCAAAGGTACGACTTC R- TTGAGAAAAGGATAAGGATT	55	290-304
2	LMCH 2	F- CATTAACAGAGCATCAAAAT R- AGATTGAGAAGTCGTACCTT	52	156-175
3	LMCH 3	F- TCTGTGAAAATACTCTCGTA R-TCTCCACTGAATAATCTTTAAT	53	215-238
4	LMCH 4	F- ATTAGAACAAGGACGAGAAT R- CCTGTGTCTTTCATGGAC	55	112-118
5	LMCH 5	F- CCCACTCTTCTACCCTCAAC R- CAAGTCCCTGTAAGAATCAGA	50	147-151
6	LMCH 6	F- GGCATCCTATNITCAGGTTT R- TTAAACAT TT TGGACAGACC	55	217-253

S. No.	Locus	Forward and reverse (5^{I}-3^{I})	Annealing temperature (°C)	Application size (bp)
7	LMCH 7	F- ATCACCAACACTGAATCT TA R- AATTTTTACCTGTAGACGTG	54	206-217
8	LMCH 8	F- AATTACGCAGATCACAGTAGC R- CATCTTGCCTTGCTCTCTAC	53	248-259
9	LMCH 9	F- TCAAACACGTATAGAAAACC R- TATGTGAAAGATCAAAAAGAG	52	170-171
10	LMCH 10	F- TTCT TGTTGGGAAGTATAGA R- GAAATCAATGTAGGTGTGAC	51	222-263
11	LMCH 11	F- TACCTCTCGCTTCTCTTCCT R- GATGATTAGACACAAGTGGATG	51	174-175
12	LMCH 13	F- ATACGACTAGCGGAGCAGAC R- GAGAATGTCGAGGGAGATGT	52	306-337
13	LMCH 16	F- TGAAAAATAACAAGAATGTAA R- GGATAAACAAAGCAGTAAATC	46	218-239
14	LMCH29	F- GTACCATCTTTTAGGAAATC R-TGCAATCTATGTTAGTCAC	45	189-190
15	LMCH33	F- AAGAAATGGGAGTAAATAGTG R- ACGGTTGTGAATAGTTGAGT	55	241-253
16	LMCH34	F- ATTTGACGGTGTTAAGGTGGT R- TATGTAGGAAATGACCAGGCTA	55	236-247
17	LMCH36	F- ATAGAAGATTTACCCAGGAG R- GTAAGTAGCTGATTGTTGATCT	54	198-200
18	LMCH37	F- TATCGACAACATAGAAAAGTTA R- TAGTTAAATCACATCGTATGAC	53	221-242
19	LMCH38	F- GTTAAGAACCAACAAAAGAAAT R- CCCCTCTATTCCCTCTCTAT	45	184-190
20	LMCH39	F- AATTTGTATGGTGTTGACAG R- AGTTGTAGGTGGTTTAAGTTC	52	189-190
21	LMCH40	F- ACTCAGCAAGATAAAGAATAGGG R- GAGTGCCGCTAGTCAAGATT	54	171-172
22	LMCH42	F- TTTATCATTACGAGAGTTATCA R- AAAGTTGTCCTTTTACTCCT	53	194-205
23	LMCH43	F-CTAGTTCCAAGACGTGAGAGAT R- ATAGGAATAAGGGACTGTTGAG	51	210-215
24	LMCH48	F- TTAGAGTGAAAAGCGGCAAG R-TCAAGCTACAGAAAGTCTACCG	55	158-159
25	LMCH53	F- GATGACGATGATAAGAATTT R- GTGCTCAGTTCTACACTAACT	40	117-119
26	LMCH54	F- AGTTAGTGTAGAACTGAGCAC R- GAGGAAGAAAAATAGAGGAC	41	249-251

S. No.	Locus	Forward and reverse (5^{I}-3^{I})	Annealing temperature (°C)	Application size (bp)
27	LMCH57	F- TTTTTGGGAGCTTTGCTGTT R- GAGGTCCACGTAATGAATGG	52	248-259
28	LMCH63	F- TTCCCCAAAATAATGAAATA R- ATGAAGAACCGAATACAAAA	50	285-289
29	LMCH68	F- GTTGCAAGTGGCGATAACAATA R-ATCCCTCTCGTTGACTCGTTTA	51	236-247
30	LMCH69	F- AGCTTTAGCCATGAATTAGA R-GAAAGGCTGACGAGATATAA	52	147-148
31	LMCH70	F- GAAGTTTTAGAGGCGATTCC R-TTTTGCCACTTTACTGTCAC	50	152-158
32	LMCH71	F- AGATAACACCCGCCCACTAT R-ACAACTTTTCTCCCAACCTATC	57	252-259
33	LMCH72	F- AATATGGACTTGTTGTAGTCTT R-ATATACGTTTGTTCCTGTTCT	52	161-163
34	LMCH73	F- CCAGTCCACTTATGCCTGTG R-ATCCACGTAAATAATGCAACAA	46	278-283
35	LMCH78	F- ATTTGATTGATTGATTTCCTA R-CTTTTGCTTTCTTTCACATC	50	171-183
36	LMCH79	F- GAAGCAAGTAGACACGTAGTA R-AGGGTTGGTATTTCTTTATAGT	50	212-241
37	LMCH80	F- AAAACAGAGACTAAAATGAAAT R- GAAGATATGCAAGGTATAAATC	52	214-219
38	LMCH83	F- CTCTCGTTGACTCGTTTACT R- GGTCTCTAGCCTTTACAATC	50	154-156
39	LMCH87	F- AGTTAAGACACGAGATGATAAA R-CAAGTAAAGACTGAAAGGTTG	48	133-135
40	LMCH88	F- GGGAGTTATTAGAGTGTTATTG R- AAATTAAGGATTGACTATTTCA	49	258-259
41	LMCH89	F- AATACAAATGGAGACGAATA R- GTGTCTAATACCATACATACCA	50	222-227
42	LMCH90	F- AAGAGCATTCTTGTGATCCT R- AAGTCTCAGTAGGGTTGATTT	49	221-226
43	LMCH91	F- CCTTGAGAAAGTGTCATCTAT R- ATAATCCTAGACCATAAAATTC	50	114-118
44	LMCH92	F- ATGTTGAAAAGAGCGTATAA R- GAAAAGATAGGAAAACTTATTG	49	237-239
45	LMCH93	F- GTTGACCTTGTTCTCGATCC R- CTCCCTCATGTTTTGCTTTT	52	227-228
46	LMCH96	F- AGAAGCTGGGAAACAAAACA R- ATTCTGGCTTTTAATTGAGGA	49	181-187

S. No.	Locus	Forward and reverse (5^{I}-3^{I})	Annealing temperature (°C)	Application size (bp)
47	LMCH98	F- ATACAAGAGTGATATTGATTCG R- GTCTCAGCTACTTCTCCTGA	49	129-131
48	LMCH102	F- GCTAACCATCCATTTACATA R- ATAACATTCTTTATCACCATCT	45	184-188
49	LMCH103	F- CACAATAATCAGAAAAACATCA R- GTGTCTCGTATCCCTCCATA	50	237-238
50	LMCH106	F- AACAAATGACAGGAGAGC R- ATAATGTATATGACGCTGCT	52	232-235
51	LMCH108	F- TTAGCCTCAGCCATTACTTA R- ACTCTTCAAACGATGAAAAC	55	174-182
52	LMCH109	F- TATAAAATGGGAAAGCGATCT R- CCTCAAAGAGCAATAATCAGC	49	196-203
53	LMCH112	F- TAACCCAGGATCTACAATAAT R- TTGCATACATTTTCCTATTT	52	196-207
54	LMCH114	F- AAAATGTAGTGTGAAAGATGAC R- GTCCATTCAGTTTTAAGTGC	52	202-206
55	LMCH115	F- TATAATCCATCAACACAAATAA R- TTAGATACACAGAACATACAGC	55	218-223
56	LMCH119	F- CAGAAAATTAGCAGAGGACTCA R- GTGGGTTGGGTTTTTAGGTC	60	198-202
57	LMCH122	F-AGCAAAGATAAAGAGAAGATAA R- ATCCAAGCCTATTAACAACT	50	195-201
58	LMCH127	F- TTCTCAAGTCAGGTTGAAAT R- AATAGAAGTTTAAGGAGAGGTT	50	175-177
59	LMCH128	F- CTTGTTAAAATGGCTGTTACT R- GCATTGAGCTGACATAACTC	41	262-268
60	LMCH131	F- AGAAGCACCCAGATAGTCAC R- TTGTAGCAATCTCACTTTATCA	55	183-189
61	LMCH134	F- TTCTCTCAATCCGGTACA R- GAAGAAAATGGTAGGGATG	49	85-89
62	LMCH137	F- ACTCGATTATGATTACAAATTA R- AAAGTATCCCCACATAGACT	50	157-227
63	LMCH139	F- CTATCCATCTACGCTTCAAAAT R- CTGAGTCGGTTAGACATTGAGA	52	300-310
64	LMCH142	F- TATATGCCTCAACTGAAATC R- GGAATGACCTTAAAAACTCT	50	166-168
65	LMCH144	F- GTTTGGAAGAGTCGCAGGAT R- ACTGTAAAACGCAGACCAAGAT	55	178-189

4.3.1 PCR reaction

The DNA amplification process was conducted in a reaction quantity of 16 µl. To amplify the DNA, used a Mastercycler® nexus - PCR Cycler by Eppendorf India and followed a specific profile. To prepare the reaction mixture, added 10 mM dNTP mix, 30 ng of primers, DNA - 30 ng, 4 units /µl of Taq polymerase, 15X PCR buffer and distilled water.

The mixture in a PCR machine was placed and performed a hot start at 94 °C for 3 minute. Repeated 35 cycles of the subsequent steps: denaturation at 93°C for 5 min, annealing at 40°C for 1 min, and extension at 72°C for 1:30 min. Finally, did a finishing extension at 72°C for 10 min.

4.3.2 Polyacrylamide gel electrophoresis (PAGE)

Component	Quantity
Acrylamide or Bisacrylamide 29:1 (w/w)	6 ml
5X TBE buffer	8 ml
Sterile water	40 ml
N, N.N" N – Tetramethylenediamine (TEMED)	640 µl
10 % Ammonium persulphate (APS)	525 µl
Voltage	75-80 ampere
Time	2.5-3 hr
Loading	3 µl

4.3.3 Screening of molecular markers for polymorphism

A total of 65 genomic SSRs were utilized to assess polymorphism in the genotypes of Arka Sahan and Balanagar parents, as well as their derived progenies. Except for two SSR markers, all the others successfully generated reliable and reproducible amplified products (Table 4.3.1). Among the amplified SSRs, only two markers, namely LMCH-38

and LMCH-102, exhibited heterozygosity and polymorphism (Plate 15**).** The size of the amplified fragments for LMCH-38 ranged from 190bp to 184bp in Arka Sahan, to 184bp in Balanagar **(**Plate 17**)**. Similarly, for LMCH-102, the fragment sizes ranged from 188bp and 184bp in Arka Sahan, and 184bp in Balanagar (Escribano *et al.,* 2009). These two polymorphic SSRs were further employed to map loci associated with self-fruitfulness among the progenies, which were categorized as self-fruitful and self-unfruitful based on phenotypic data. The bulked segregant analysis did not reveal any polymorphism between the bulks, indicating a lack of variation within the analyzed loci **(**Plate 16**)**. A majority of the SSR markers exhibited monomorphic banding patterns in the parents during genotyping, suggesting a high degree of homozygosity in both the parents and their progenies.

Furthermore, to explore any potential variability among the hybrid progenies, the top 100 self-fruitful and self-unfruitful trees were selected based on phenotypic data. However, all the progenies displayed a monomorphic banding pattern across all the SSR markers, indicating a lack of variability within the tested SSR loci. Therefore, a larger number of SSR markers are required to investigate self-fruitfulness and identify linked molecular markers for the analysis of self-fruitfulness in Annona.

The limited polymorphism observed among the SSR markers used to genotype the parents and progenies of Arka Sahan and Balanagar indicate a high level of genetic similarity and homozygosity. Additionally, the lack of variability within the tested SSR loci suggests the need for more SSR markers to effectively study self-fruitfulness and identify molecular markers associated with this trait in Annona,

Plate 15 Amplification pattern of progenies with SSR primer

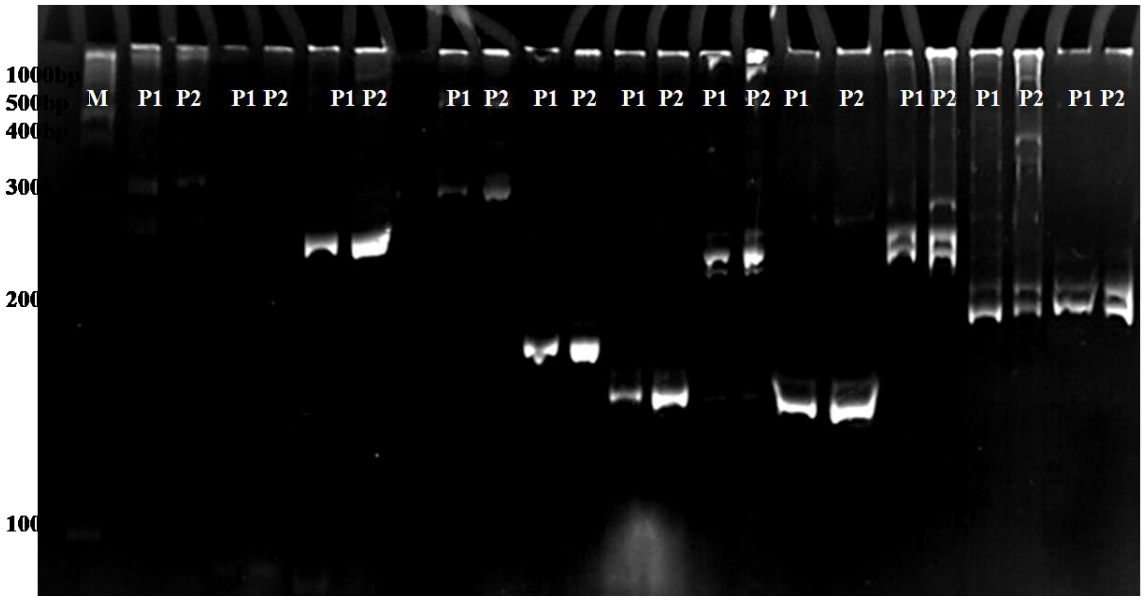


Plate 16 Bulked segregant analysis of self fruitful and unfruitful progenies

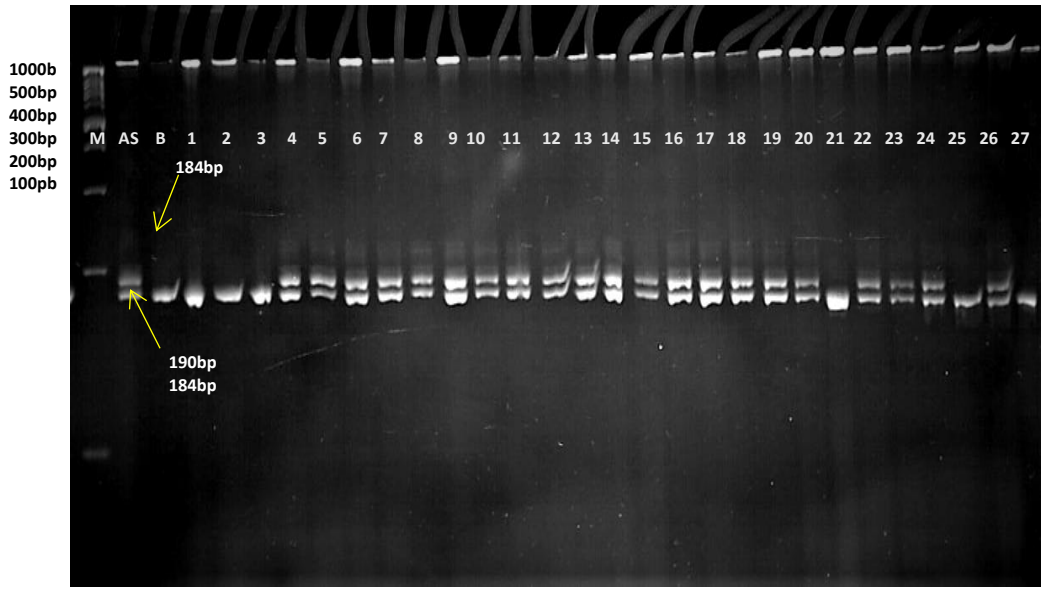


Plate 17 Amplification pattern of progenies with SSR primer LMCH38

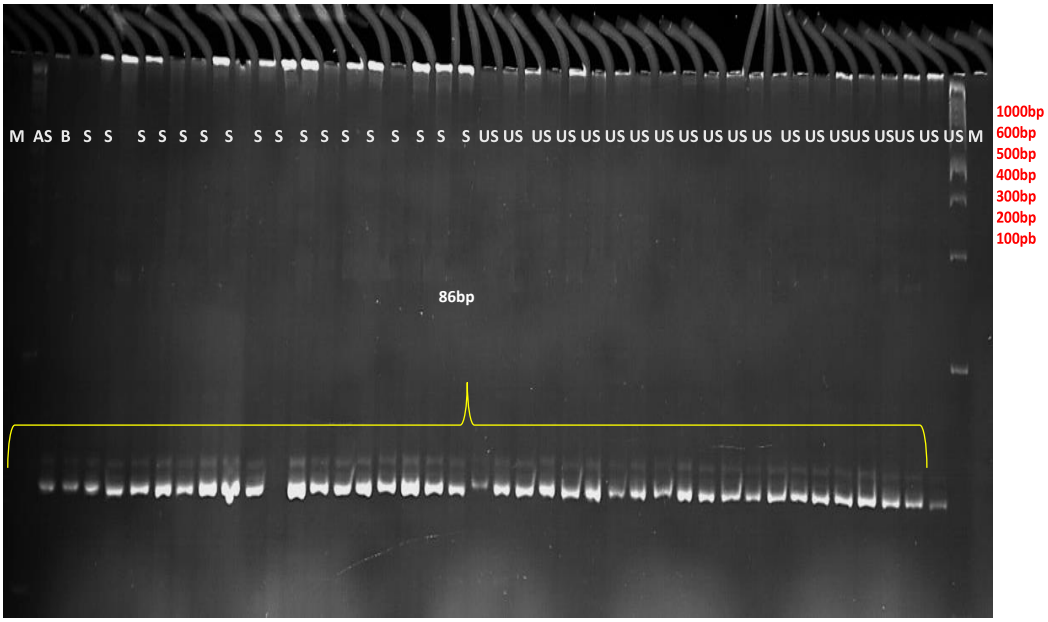


Plate 18 Amplification pattern of progenies with SSR primer LMCH 128

DISCUSSION

CHAPTER 5 DISCUSSION

Custard apple holds significant promise for advancing arid horticulture in India in the future. The genetic diversity and adaptability of custard apple plants to various climatic and soil conditions make them a valuable candidate. There is potential for enhancing their productivity, quality and resistance to pests and diseases as well as their nutritional and medicinal properties through breeding and genetic engineering.

Arka Sahan is an interspecific custard apple that was developed by the ICAR-Indian Institute of Horticultural Research (IIHR) in Bengaluru. It is a hybrid of Island Gem (*Annona atemoya* Hort.) and Mammoth (*A. squomosa L.)*

Arka Sahan, among the custard apple varieties in India, stands out as highly promising. Its versatility allows for both fresh consumption and processing into an array of products, including juices, jams, candies, and ice creams, among others. Moreover, it holds the potential to be exported to foreign markets, contributing to income generation for both farmers and the nation.

Arka Sahan's significance is underscored by its exceptional attributes: it boasts a remarkable yield potential of 12 tonnes per hectare, a substantial pulp recovery rate of 70%, and an impressive total soluble solids (TSS) content of 30°B. Additionally, it contains fewer seeds, with just 9 per 100 grams of pulp, making it a standout choice. It extended shelf life of 6 days further adds to its appeal. While it demonstrates resilience against drought conditions, it does require assisted pollination for a successful fruit set.

The objective is to enhance the fruit set percentage and incorporates favourable horticultural traits by breeding Arka Sahan with the commercial variety Balanagar, thereby yielding improved offspring.

5.1 To evaluate the progenies of Arka Sahan x Balanagar for growth, yield, quality and self fruitfulness

Morphological characterization serves as an initial and straightforward standardized approach for assessing genetic diversity in crops. It often serves as the preliminary step preceding more in-depth studies, such as biochemical or molecular analyses. This characterization relies on visual attributes (Hoogendijk and Williams, 2001).

5.1.1 Growth parameters

A total of 1113 progenies of Arka Sahan with Balanagar were characterized for plant height, growth habit and leaf traits like leaf length, leaf width and leaf shape. The analysis of data and further evaluation of progenies have been taken up with the objective of selecting progenies having maximum desirable traits. The discussion on various traits in these progenies aredescribed here under;

Morphological indicators, such as plant height, growth habit and leaf characteristics (including length, width, and shape) were measured in progenies resulting from the crossbreeding of Arka Sahan with Blanagar. The observed variations were particularly on plant height exhibited a wide range of heights, ranging from 0.8 cm (38/17) to 4.2 (45/6 and 51/9), growth habits were identified among the progenies, namely erect (524 progenies) and spreading (589 progenies), leaf shape with elliptic (69 progenies), ovate (119 progenies) and lanceolate (925 progenies) shapes being observed, leaf length varied significantly, spanning from 6.9 cm (31/16) to 28.7 cm (28/13) and leaf width also showed substantial variation, ranging from 3.3 cm (24/4, 24/20, 31/16, and 37/17) to 9.9 cm (20/17) (Table 4.1.1). These findings indicate that hybridization was successful in introducing considerable variability in these vegetative traits. The observed variations in vigour and less vigour among the progenies hold promise for utilization in breeding programs. Hybridization has effectively created the in these vegetative traits, offering valuable prospects for improving annona quality and yield. As such, these traits are suggested as potential selection criteria for enhancing annona breeding programs, as highlighted in studies by Vinay *et al.* (2017) and Anushma *et al*. (2021).

When considering fruit related parameters, the average annual number of fruits per tree exhibits a wide range in 222 self fruitful regular bearers, spanning from as few as a single fruit (23/19) to 64 fruits (42/12). The individual fruit weight also displays significant variability, with weights ranging from 52.0 g (4/6) to a substantial 473.0 g (25/8). Additionally, the yield per tree varies substantially, encompassing values as low as 0.07 kg (39/12) and as high as an impressive 19.22 kg (10/3) (Table 4.1.2). These variations in fruit production and yield are influenced by several factors, including flower production, pollination, fruit set, and fruit drop. Some species of annona may even require manual pollination to ensure adequate fruit set. Consequently, the number of fruits per tree can fluctuate greatly, ranging from just a few to potentially hundreds, depending on the specific annona species and variety under consideration, as documented in research by Hiwale, 2015 and Vinay and Chithiraichelvan (2015).

The average fruit length was recorded at 7.5 cm; however, it exhibited a range from 6.0 cm in progenies 7/16 and 30/16 to 9.1 cm in progeny 10/3. Similarly, the average pulp recovery was found to be 57.8%, with variations observed from a low of 44.9% in progeny 34/2 to a high of 68.6% in progeny 10/3 (Table 4.1.3). These findings underscore the genetic diversity within the atemoya progenies and highlight the potential for targeted breeding efforts to enhance desirable fruit characteristics. The study conducted by Ledesma *et al.*, (2007) evaluated 56 self-fertile progenies of atemoya to assess their fruit anatomical and qualitative traits. The research revealed notable variations among the progenies in these traits, suggesting the potential for the selection of superior genotypes for breeding purposes.

5.1.2 Biochemical characteristics

A significant variation was observed in total soluble solids content ranging from 24.5°(B) in the progenies (26/7, 28/7, and 51/17) to 31°(B), indicating variations in sugar content and fruit sweetness (Tabe 4.1.4). Similar results were reported by Jnapika *et al.* (2021). Total sugars ranged from 22.30 mg/100g (progeny 17/23) to 30.03 mg/100g (13/1) while reducing sugars exhibited a range from 15.31% (17/23) to 23.43% (21/9). Non-

reducing sugars showed significant variability from 3.78% (34/19) to 8.27% (3/13), consistent with findings in soursop reported by Enkeblia (2013).

Total antioxidant activity also exhibited wide variation, ranging from 81.12 mg AEAC/100g (26/15) to 95.72 mg AEAC/100g (26/7). This variation reflects differences in the fruits' ability to scavenge free radicals and mitigate oxidative stress. These biochemical traits of Arka Sahan Custard apple fruits serve as crucial indicators of their quality, nutritional value, and antioxidant potential.

The data provided underscore the importance of custard apple fruits in terms of their health benefits due to their high phenolic compound content, which serves as natural antioxidants protecting against oxidative stress and chronic diseases (Nam *et al.*, 2017). Total phenol content notably ranged from 69.03 mg gallic acid equivalents/100g (21/9) to 79.23 mg gallic acid equivalents/100g (50/16). It's worth noting that phenolic content varies across Annona species and ripening stages, with custard apple (*Annona squamosa*) fruits ranging from 23.2 to 27.8 mg/g dry weight and soursop (*Annona muricata*) fruits ranging from 17.7 to 42.2 mg/g dry weight (Dominguez *et al.*, 2019).

Annona fruits and leaves contain diverse flavonoids, including flavanols, flavones, flavonols, and anthocyanins. In the progenies studied, the total flavonoid compounds exhibited significant variation, ranging from 20.10 mg catechin equivalents/100g (28/10) to 24.15 mg catechin equivalents/100g (31/15 and 53/25), consistent with findings reported by Bhardwaj *et al.* (2020) in Annona. The research revealed significant variations in these traits among the progenies, attributed to their highly heterozygous nature (Kumar *et al*., 2018).

Overall, these findings highlight the rich diversity in biochemical traits among Arka Sahan Custard apple progenies and underscore the potential health benefits associated with their consumption.

5.1.3 Phenotypic and genotypic coefficient of variation

Among the progenies, the phenotypic and genotypic coefficient of variation (PCV) for various characters ranged from 33.79 to 62.99 and 8.88 to 18.63 (Table 4.1.5a and 5b). In the present investigation, the phenotypic coefficient of variation was greater than the corresponding genotypic coefficient of variation for all the characters indicating the importance of environment in expression of characters. It also indicates that phenotypic variability is a reliable measure of genetic variability. High values of PCV with corresponding high values of GCV were recorded for pedicel length, seed weight, number of flakes with seed and moderate values of PCV and GCV recorded for number of fruits per tree, average fruit weight, fruit length, fruit width, pedicel weight, peel weight, pulp weight, number of flakes without seed, TSS (°B), acidity per cent, TSS: acidity, yield per tree which indicates that there exists high genetic variability and better scope for improvement of these characters through selection. The results are in consonance with the findings of (Jnapika *et al*., 2021) on the Custard apple, Dinesh and Vasugi (2010) and Patel *et al*. (2015) in guava, who observed a high phenotypic coefficient of variation compared to corresponding genotypic coefficient of variation (GCV) for most of the traits studied and indicated the presence of additive gene action in the inheritance of these traits. From the foregoing discussions, it is clear that these characters offer good scope for selection in Arka Sahan custard apple.

5.1.4 Heritability

The genotypic coefficient of variation does not offer full scope to estimate the variation and therefore, estimation of heritability becomes necessary. The variability existing in a population is the total of heritable and non-heritable components.

The heritability of various characters of Arka Sahan custard apple progenies was estimated using the genotypic coefficient of variation (GCV) and the phenotypic coefficient of variation (PCV). The GCV measures the variation among genotypes, while the PCV measures the variation among phenotypes. The ratio of GCV to PCV gives the broad-sense heritability (H^2), which reflects the additive and non-additive genetic effects.

The higher the H^2, the more closely the phenotype reflects the genotype and the more responsive the trait is to selection.

The results showed that H^2 values varied from 5.01 to 88.82 for various characters of Arka Sahan custard apple progenies. High values of H^2 (>80%) were observed for average fruit weight these traits are mainly determined by genetic factors and have low environmental influence. Therefore, they can be easily improved by selection based on phenotypic performance. Moderate values of H^2 (40-80%) were observed for pulp weight, pulp recovery, TSS (°B) and yield per tree. These traits are influenced by both genetic and environmental factors and may require more accurate methods of measurement and evaluation. Low values of H^2 (<40%) were observed for fruit width, peel weight and number of flakes without seed (Table 4.1.5b). These traits are highly affected by environmental factors and have high experimental errors. Therefore, they are not suitable for selection based on phenotypic performance alone. Low heritability means that most of the variation in a trait among individuals is due to environmental factors, rather than genetic factors (Rawandoozi *et al*., 2021) reported in Peach found that most of the traits had low to moderate heritability (Rathava *et al*., 2021) low to moderate heritability and genetic advance for fruit yield and its component traits, suggesting non-additive gene action in brinjal and it also found that some traits had significant genotype by environment interaction, meaning that their expression varied depending on the environmental conditions.

The study of heredity and variation in custard apple is important for understanding the genetic diversity and potential of this crop, as well as for developing improved varieties with desirable traits.

5.1.5 Genetic advancement

The estimates of heritability are useful to plant breeders as they provide the basis for selection on phenotypic performance. However, for more reliable and maximum genetic information, heritability estimates coupled with genetic advances should be considered. Genetic advancement is the improvement over the base population that can potentially be made from the selection of a character. In the present study, the genetic

advance as per cent mean ranged from 0.12 to 72.12 among Arka Sahan custard progenies (Table 4.1.5b). High values of genetic advance as a percentage of the mean (> 20 %) were obtained in the present study for average fruit weight, peel weight and pulp weight. Similarly, grapevine (Wang *et. al*., 2023) and banana (Rai and Shekhawa 2014), reported low heritability and genetic advance for some traits, such as fruit quality and stress tolerance, which are influenced by environmental factors or non-additive gene action. From the results presented, it is observed that seed weight and number of flakes with seed higher estimates for phenotypic coefficient of variation than genotypic coefficient of variation, genetic advance as per cent mean and heritability indicating the presence of additive gene action in the inheritance of these traits and simple selection would be highly rewarding for improving these characters. Hence, direct selection may be followed for the improvement of Arka Sahan Custard apple progenies for these characters.

5.1.6 Contribution of various traits to genetic diversity

The number of fruits per tree, fruit width, peduncle weight and seed content contributed maximum towards diversity in Arka Sahan custard apple progenies. Hence, these need to be considered while attempting to custard apple crop improvement.

In this study, we evaluated the variability in 20 custard apple progenies derived from Arka Sahan and measured various traits related to fruit quality such as number of fruits per tree, fruit width, peduncle weight, seed content and pulp content (Kumar *et al.*, 2018). Jagadev *et al*. (1991) observed that the character that contributed maximum to the divergence should be given greater emphasis for selection.

5.1.7 Cluster analysis of Arka Sahan Custard apple progenies

The genetic diversity of custard apple (*Annona squamosa*) is essential for its improvement and conservation. In this study, we used the data collected from 56 self-fruitful progenies of Arka Sahan, a popular variety developed by ICAR-IIHR, to assess the genetic distance based on fruit quality traits. We used the Origin Pro 9.8 package to perform cluster analysis and generate six groups of progenies.

The results showed that the progenies were grouped based on fruit characters, such as number of fruits per tree, fruit weight, fruit length, fruit width, peduncle weight, seed content, pulp content, TSS, acidity, and ascorbic acid. Cluster VI and Cluster V had the most desirable horticultural traits, such as a high number of fruits per tree and high fruit weight. Cluster VI had 1 progeny with an average of 56 fruits per tree and 356 g of fruit weight. Cluster V had 6 progenies with an average of 40 fruits per tree and 275.0 g of fruit weight (Table 4.1.7). These two clusters also had high values for fruit length, fruit width, pulp content, and TSS. The study revealed that there is a significant genetic distance among the custard apple progenies derived from Arka Sahan. The cluster analysis can help in identifying the superior progenies for selection and breeding programs (Kumar *et al*., 2018). The selected progenies can also be evaluated for their adaptability and consumer acceptability in different regions. The clusters with maximum genetic distance must be chosen as parents in the hybridization. Crossing between the genotypes separated by higher genetic distance will produce appropriate transgressive segregants with a better opportunity for selection of superior genotypes in the following generations as reported by Jalikop (2005) in pomegranate.

5.1.8 Principle component analysis of Arka Sahan Custard apple progenies

Principal Component Analysis (PCA) is a form of multivariate analysis that illustrates various axes of differentiation and quantifies the amount of variation each of these axes explains (Rao, 1952). PCA validates the group patterns identified through cluster analysis. The advantage of using PCA over cluster analysis lies in its ability to reduce the dimensionality of the dataset by creating significant principal components that capture the maximum variability among the offspring or data points. In PCA, the original variables are transformed into a set of linear expressions known as principal components, which collectively account for the majority of the observed variation. To perform PCA for different traits or characteristics, the correlation matrix method was employed. The loading values associated with each character in the principal components represent the weights that define the character's contribution to the respective principal components. Furthermore, the signs of these loading values (+/-) indicate the direction of their contribution, similar to regression coefficients.

The principal component analysis sorted out only significant principal components out of the 14 traits studied. The contribution of the main characters for variance was easily identified by the characters loaded on the PC-1 with high loading values. PCA facilitates the in-depth analysis of genetic diversity. The PCA biplot can be used to classify Arka Sahan Custard apple progenies and visualize the relationship among the progenies. The distribution of progenies in the PCA based on the PC-1 and PC-2 showed variations among the progenies.

The analysis thus identified the maximum contributing variables viz., number of fruits per tree significantly loaded in PC-1, while fruit weight loaded in PC-2, contributing more towards variability. The above characters were positive across the two axes indicating their importance as components of genetic divergence among the studied characters. Negative values for the principal components for pulp recovery, seed content, number of flakes without seed, and peel content contribution towards total divergence of Arka Sahan Custard apple progenies (Table 4.1.10). Majumder *et al.* (2013), in their study of 60 mango genotypes found that the weight of harvested fruits per plant, number of fruits per plant, per cent of the flowering shoot, percentage of perfect flower and fruit weight were some of the important traits responsible for genetic divergence in the characters studied. Krishnapillai and Wijeratnam (2016) reported that PC-1 explained 34.2% of variations, the components being fruit length, breadth, thickness and weight, whereas, PC-2 showed 21.8% variations with the parameters of leaf length, leaf breadth and inflorescence length in mango. Saifullah *et al.* (1999) reported that fruit per primary branch, TSS, seed diameter, spine density and yield per plant played a major role in both axes for determining the genetic divergence of jackfruit. The results of the present study are in line with the findings of Kumari *et al*. (2018) on guava

5.1.9 Correlation of fruit quality characters in Arka Sahan custard apple progenies

Among the various characteristics examined, the number of fruits per tree (0.708), fruit weight (0.752), fruit length (0.595), fruit width (0.426), and the number of flakes without seeds (0.679) displayed a statistically significant positive correlation with yield per tree. On the other hand, peel content (-0.106) and seed content (-0.077) demonstrated a

non-significant negative association with yield per tree (Table 4.1.11). Additionally, these two characteristics exhibited non-significant positive associations with pedicel length (0.216), pedicel weight (0.090), and pulp recovery (0.149). Similar findings were observed by Paull and Duarte (20110, Lleras *et al.* (2020) and Morton (1987).

5.1.10 Gene action for TSS

Progenies with a phenotypic ratio of moe than 30 (°B) 63 individuals were observed, while the expected value was 65 (Table 4.1.12). The close alignment between observed and expected values suggests that the gene action for this particular trait might be additive or have a simple genetic basis. Progenies with a phenotypic ratio of less than 30 (°B) 159 individuals were observed and the expected value was 156. Again, the close match between observed and expected values indicates that the trait's inheritance may be following a simple Mendelian inheritance pattern (Rodrigues *et. al*., 2023) F2 generations consistent with a single recessive allele being responsible for the seedless trait in *A. squamosa* considering the 3:1 segregation hypothesis.

These findings suggest that the observed phenotypic ratios align well with the expected ratios based on the gene action being studied. The calculated chi-square test result further supports the conclusion that there is no statistically significant difference between the observed and expected frequencies, indicating that the gene action does not significantly deviate from the expected pattern.

5.2 To study the floral biology in self fruitful and unfruitful Arka Sahan progenies

The analysis and subsequent evaluation of 70 progenies resulting from the cross between Arka Sahan and Balanagar were conducted with the specific goal of identifying progenies that exhibit 50 self-fruitful and 20 unfruitful characteristics. In this context, a comprehensive assessment of various traits in these progenies was undertaken. The discussion below outlines these traits: flowering time, days required for first flowering, flower bud diameter, petal outer and inner colour, petal length and width, peduncle length, initial and final angle of petal opening, number of flowers per 10 cm shoot, anthesis time, anther dehiscence, diameter of stigma cone, stigma receptivity, pollen shape and surface,

pollen units, pollen viability, pollen germination, pollen tube length and pollen length and width. The aim is to select progenies that meet the criteria of 50 being self-fruitful and 20 being unfruitful. This comprehensive assessment of these traits will aid in identifying the most suitable progenies for the desired outcome.

Significant variations were observed in several traits among the progenies. For Petal length, self-fruitful progenies exhibited a range of 0.6 to 3.8 cm (Table 4.2.1a and 4.2.1b), while unfruitful progenies showed a narrower range of 1.7 cm to 2.6 cm. For peduncle length, self-fruitful progenies displayed a range of 1.0 to 3.1 cm, while unfruitful progenies had a range of 1.0 cm to 2.7 cm. It's worth noting that similar observations regarding trait variations, particularly in *A. cherimola*, were made by Agustin in their study published in 2006. These findings underscore the importance of understanding and documenting trait variability within plant progenies for comprehensive breeding and genetic studies.

The initial angle of petal opening varies among self-fruitful progenies, ranging from 10º to 30º, while unfruitful progenies tend to have a narrower range of 10º to 15º. As for the final angle of petal opening, self-fruitful progenies display a broader range of 35^0 to 75^0, whereas unfruitful progenies exhibit a more limited range of 20^0 to 50^0 (Table 4.2.2a and 4.2.2b). These beetles gain access to the floral chamber through gaps between the petals, where they consume nectar and pollen. Additionally, they facilitate cross-pollination by transferring pollen from anthers to stigmas. The size and shape of the floral chamber also play a critical role; larger and wider chambers can accommodate more beetles, allowing them to move freely inside, thus increasing the likelihood of successful pollen transfer (Saunders, 2012; Gottsberger, 1989). Smaller and narrower chambers may restrict the entry and movement of the beetles, reducing pollination success (Dao *et al*., 2023).

The count of flowers per 10 cm shoot exhibited variability within self-fruitful progenies, ranging from 1 to 10 flowers, whereas, in unfruitful progenies, it spanned a narrower range of 1 to 4 flowers (Table 4.2.2a and 4.2.2b). A parallel observation was made in the Abdel-Razik Annona cultivar by El-Rouby *et al.,* in 2008. These findings

indicate that self-fruitful progenies tend to have a broader range of flower numbers compared to unfruitful progenies, implying that they possess more floral resources and increased prospects for pollination and successful fertilization.

Anthesis time in self-fruitful progenies tended to bloom in the early morning, while unfruitful progenies typically bloomed from the afternoon to the evening. For anther dehiscence, anthers in self-fruitful progenies dehisced in the early morning, while in unfruitful progenies, this occurred from the afternoon to the evening. Reduction in pollen grain water potential, thus contributing to performance during germination (Herrero and Dickinson, 1981; Pring and Tang, 2004). These significant differences in these traits provide valuable insights into the characteristics of the studied progenies. These variations may affect the availability and attractiveness of the flowers to the beetles, as well as their exposure to other potential pollinators or predators (Dao *et al*., 2023). In sugar apple (*Annona squamosa*) and its interspecific hybrid Arka Sahan, anthesis time was observed from flowers that reached anthesis between 1200–1400 h in both species. However, there was a lack of synchronization in flowering between the two species, which affected the availability of pollen for assisted pollination (Chander *et al*., 2023). Thakur and Singh (1965b) recorded that dehiscence took place throughout the day in Annona.

No significant variations were detected in the following characteristics: flowering time, which consistently spanned from March to July. A similar observation was reported by Hiwale in 2015 in custard apple. Mendes *et al.* (2017) observed that the onset and duration of reproductive development in *A. squamosa* varied with pruning times, and the accumulation of degree days was also lower in the period of no rainfall in the region. Days required for first flowering and the duration for the first flowering event remained stable, with a range of 22 to 24 days.

The flower bud diameter of the plant species studied was found to be relatively consistent, ranging from 6.0 to 9.5 mm (Table 4.2.3a and 3b). This indicates that there is little variation in the size of the buds among different individuals or populations of the same species. This suggests that the flower bud diameter of this species is relatively stable and may have a low adaptive value. The petal outer colour and petal inner colour of the

plant species studied were also found to be consistent, belonging to the yellow-green group 145B and 150D, respectively. Alternatively, the yellow-green colour may be a result of the presence of pigments such as carotenoids or flavonoids that have antioxidant or photoprotective functions (Koski and Galloway (2020). The petal outer colour and petal inner colour did not show any significant variation across different individuals or populations of the same species. This indicates that there is no strong selection pressure for changing the petal colour in this species.

The petal width of the plant species studied ranged from 0.5 to 1.5 cm, which is relatively narrow compared to other flowering plants. The petal width may affect the amount of light reflected by the petals, the visibility of the floral guides, and the accessibility of the nectar and pollen to the pollinators. However, in this study, the petal width did not show any significant correlation with any of these factors. This suggests that the petal width of this species is relatively stable and may have a low adaptive value.

The duration of flowering remained consistently within a range of 73 to 87 days. In a study conducted by Debora *et al.*, in 2017, it was reported that the period from pruning to the conclusion of flowering lasted for 70 days. The diameter of the stigma cone remained consistently within the range of 2.0 mm to 4.5 mm. In a separate study by Kishore *et al.*, in 2012, the size of the stigma in *Annona squamosa* was reported to be 1.36 × 1.08 mm. Regarding stigma receptivity, it consistently spanned a period of 4 to 5 days. Gonzalez and Cuevas, in 2011, observed that the ovules remained viable for no less than 32 hours, and stigmas remained receptive for 28 hours in *A. cherimola*. In these specific traits, no significant variations or differences were observed among the progenies.

In Annona, one of the major challenges in the cultivation of Annona fruit crops is the low and erratic fruit set and retention, which affects the yield and quality of the fruits. Several factors influence the fruit set and retention of annona fruit crops, such as pollination, temperature, humidity, plant growth regulators, nutrition and pests and diseases.

The fruit set percent of self fruitful Arka Sahan custard apple progenies is generally low and variable, ranging from 4.55% to 11.66%. Low fruit set of 8.6% and below 6% have also been reported by Martin *et al*. (2019) and Thakur and Sing (1965a). The low fruit set of annona fruit crop is mainly attributed to the poor pollination efficiency due to the protogynous nature of the flowers, which have a short female phase and a long male phase, resulting in temporal asynchrony between pollen release and stigma receptivity (Lora *et al*., 2009). Moreover, the pollination of Annona flowers depends on insects such as beetles and thrips, which are not very effective or abundant in some regions (Lora *et al.*, 2009). Therefore, hand pollination or artificial pollination with plant growth regulators has been suggested as a way to improve the fruit set of the Annona fruit crop (Pujari *et al.*, 2021). Fruit retention (80.13 to 89.39 %) was observed among the self fruitful progenies of Arka Sahan custard apple. According to some studies, the fruit retention percentage in custard apple can range from 14.48% to 85.53% (Pujari *et al.*, 2021; Butani *et al.*. 2020). The time taken for fruit maturity in annona fruit crops varies depending on the species, cultivar, climatic conditions, and cultural practices. In our study, the time taken for fruit maturity ranges from 121 to 129 days after flowering.

Significant differences were observed in several pollen-related characteristics between self-fruitful and unfruitful progenies. Aggregate pollen-like monads per cent in self-fruitful progenies ranged from 1.8% to 57.1%, while unfruitful progenies showed a range of 0% to 25%. Dyads per cent in self-fruitful progenies displayed percentages ranging from 0% to 45.8%, whereas unfruitful progenies ranged from 0% to 22.2%. Tetrads per cent in self-fruitful progenies had percentages ranging from 20% to 90.3%, while unfruitful progenies had a range of 50% to 100% (Table 4.2.4a and 4b). Pollen grains in many Annona species exist as monads, which are single, isolated pollen grains. These monads are relatively small and have a simple structure (Gibernau *et al*., 2001. Annona belongs to the Annonaceae family, which has many genera that produce groups of pollen grains, often four (tetrads), but sometimes two (dyads) or three (triads) and one (monad) (Su and Saunders 2003 and Jalikop and Kumar, 2007)

Pollen viability in self-fruitful progenies exhibited viability percentages ranging from 88.45% to 98.4%. where as unfruitful progenies had viability percentages spanning

from 49.4% to 92.1%. Incompatible or inviable pollen may result in reduced or failed fertilization, leading to low fruit set or seed abortion (Jalikop and Kumar, 2007)

Pollen germination in self-fruitful progenies showed germination percentages varying from 33.5% to 96.9%, while unfruitful progenies had germination percentages ranging from 1.7% to 25.3%. Pereira *et al.,* (2014), in an evaluation of germination percentages in "Red" and "Thai Lessard" sugar apple cultivars in the state of Florida, reported lower germination percentages of 26.5% and 35.6%, respectively. Pacini *et al.,* (2006) observed that carbohydrate composition is interconverted according to environmental conditions; thus, pollen grains that are released partially hydrated enable a rapid pollen tube emission because the rehydration phase is shorter than in the partially dehydrated pollen (Nepi *et al.,* 2001; Franchi *et al.,* 2002). The success of *in vitro* germination of pollen grains depends on several endogenous and exogenous factors such as plant nutritional status, time and method of pollen grain collection, photoperiod, environmental variations, incubation period and composition of the medium of culture (Alves Rodrigues *et al.*, 2018; Chagas *et al.*, 2010; Ramos *et. al*. 2008; Soares *et al.*, 2008; Souza, Souza *et. al.*, 2014). It is also important to emphasize that the culture medium factor is specific for each species (Dafni *et al*., 1999), so this is a component that must be rigorously studied for successful *in vitro* germination

Pollen tube length of self-fruitful progenies, pollen tube length ranged from 101 µm to 335 µm, while in unfruitful progenies, it varied from 11 µm to 24 µm. These substantial variations in these pollen characteristics suggest important distinctions between the self-fruitful and unfruitful progenies in terms of their reproductive processes. This result suggests that pollen tube length is a reliable indicator of fruitfulness in this hybrid plant and that it is affected by genetic and epigenetic factors that regulate the growth and guidance of the pollen tube. Previous studies have shown that pollen tube length can vary widely among different plant species and that it can be modulated by mechanical properties of the stigma papillae Sankaranarayanan and Kessler 2020, as well as by molecular signals from the pistil Hartman *et al*., 2014. Therefore, further investigations are needed to elucidate the underlying mechanisms that determine the pollen tube length and fruitfulness in this hybrid plant.

No significant differences were observed in terms of pollen shape among the progenies. Two distinct shapes were noted: elliptic with one or two furrows on the proximal face, and boat-shaped. The furrows on these grains could be monosulcate or disulcate, depending on their number. In the case of dyads and tetrads, no specific shapes were identified. Among tetrads, three shapes were identified: isobilateral, decussate, and tetrahedral. The formation of tetrads in Annona is related to the type of cytokinesis (cell division) during pollen development. There are three basic types of cytokinesis in angiosperms: simultaneous, successive, and intermediate (Lora *et al*., 2009; Li and Xu, 2019; Su and Saunders, 2003; Pinto *et al.*, 2005).

Additionally, there were no significant differences observed in pollen surface characteristics, which could be either verrucate or smooth. The pollen grains in Annona are inaperturate, isopolar and radially symmetrical, with four basic patterns of exine sculpturing: rugulate, verrucate, scabrate and psilate (Su and Saunders 2003). Furthermore, in the context of aggregate pollen, the percentage of triads ranged from 0% to 40%. There is no defference was observed in pollen length and width.

5.2.1 Correlation of flower and pollen characters in self fruitful Arka Sahan custard apple progenies

These findings suggest that fruit set is positively influenced by factors such as the final angle of petal opening, pollen viability, and pollen germination, while it is negatively affected by traits like flower bud diameter, petal length, peduncle length, and certain pollen characteristics (Table 4.2.6).

Studies on floral biology, fruit set and fruit drop of different genotypes of jamun (*Syzygium cumini* Skeels): evaluates the floral biology, fruit set and fruit drop of 10 jamun genotypes. The paper reports that there was a wide variation among the genotypes in terms of flowering time, pollen viability; stigma receptivity, fruit set and fruit drop (Singh *et al*., 2019)

5.3 Assessment of genetic relatedness between parents and progenies

Several important findings related to the genetic diversity and polymorphism within a specific plant species, Annona, particularly in the context of two varieties or cultivars, Arka Sahan and Balanagar. The study found that there is limited genetic polymorphism among the SSR (Simple Sequence Repeat) markers used to genotype both the parents and progenies of Arka Sahan and Balanagar. Polymorphism refers to the presence of different genetic variations or alleles at a specific genetic locus. In this case, the SSR markers showed limited variation among the studied individuals, indicating that these individuals share a high degree of genetic similarity. The limited polymorphism observed suggests that Arka Sahan and Balanagar are genetically similar to each other. This could indicate that they might share a common genetic background or have undergone extensive inbreeding, leading to a high level of genetic similarity. High genetic similarity can have implications for breeding programs and the overall genetic health of a population.

The present study also indicates a high level of homozygosity among the tested individuals. Homozygosity refers to the presence of identical alleles at a specific genetic locus. High homozygosity can be an indicator of inbreeding within a population. It can have both positive and negative consequences, depending on the trait of interest. The study found a lack of variability within the tested SSR loci. This means that the specific genetic markers examined did not show much diversity among the individuals tested. This lack of variability can limit the utility of these markers for certain genetic studies or breeding programs. One of the main implications of the study is the need for additional SSR markers to effectively study self-fruitfulness and identify molecular markers associated with this trait in Annona. In other words, to better understand the genetic basis of self-fruitfulness in these cultivars and potentially improve breeding efforts, more diverse and informative genetic markers are required. In summary, the study suggests that Arka Sahan and Balanagar exhibit a high level of genetic similarity and homozygosity, which may have implications for breeding and genetic studies. To address these limitations and advance research on self-fruitfulness and other traits in Annona, it is recommended to use a broader set of SSR markers to capture more genetic diversity and variability among the studied individuals. This would provide a more comprehensive understanding of the genetic basis

of the traits of interest. Using SSR markers, Ahmad *et al.* (2020) investigated the genetic diversity and self-incompatibility of 50 date palm genotypes. They focused on how molecular markers can help study the ability or inability of plants to produce fruits by themselves. Similar research was done by Saitwal *et al*. (2017) who utilized SSR and ISSR markers to examine the genetic diversity and characterization of Annona genotypes collected from various regions of Maharashtra, India. They found that ISSR and SSR markers were useful in differentiating *A. squamosa* and *A. atemoya* species and identifying unique amplicons for future crop improvement. Another study by Pico *et al*. (2020) developed 22 polymorphic SSR loci for *A. deceptrix*, an endangered species endemic to Ecuador. These studies indicate the potential of using molecular markers to study self-fruitfulness or unfruitfulness in plants.

SUMMARY AND CONCLUSION

CHAPTER 6 SUMMARY AND CONCLUSION

The present investigation entitled “Evaluation and characterization of Arka Sahan Custard apple progenies for self fruitfulness” was conducted in the Division of Fruit Crops, ICAR-Indian Institute of Horticultural Research (ICAR-IIHR), Bengaluru during 2020-2023 with the following objectives;

- To evaluate the progenies of Arka Sahan x Balanagar for growth, yield, quality and self-fruitfulness
- To study the floral biology in self-fruitful and unfruitful Arka Sahan progenies
- Assessment of genetic relatedness between parents and progenies

The study was carried out with progenies developed by crossing Arka Sahan with Balanagar, a total of 1113 progenies were evaluated for self-fruitfulness, morphological and biochemical traits and also to determine the differences for self-fruitful and unfruitful progenies. Studied the relationship between parents and progenies through molecular markers. The study also was aimed at assessing the extent of genetic diversity by cluster analysis, Principal Compound Analysis (PCA). The salient features of the experimental findings are summarized below under the following heads.

6.1 Evaluation of Arka Sahan Custard apple progenies

6.1.1 Growth parameters

The morphological characterization in 1113 progenies of custard apple from the Arka Sahan and Balanagar revealed that the progenies have a wide range of variation in vegetative traits and self-fruitfulness. The average plant height was 2.71 m, but some progenies were as low as 0.8 m or as high as 4.2 m. The progenies also differed in their growth habit, with 524 having an erect habit and 589 having a spreading habit. The leaf shape varied among the progenies, with 69 having an elliptic pattern, 119 having an ovate pattern, and 925 having a lanceolate pattern. The leaf length and width also showed variation, ranging from 6.9 to 28.7 cm and from 3.3 to 9.9 cm, respectively.

6.1.2 Fruit and yield traits of Arka Sahan Custard apple progenies

Among the 1113 progenies studied, self-fruitfulness and regularity were observed to be minimal. This suggests that the majority of the progenies may require cross-pollination or specific conditions for fruit production, and there may be irregularities in fruiting among them. Out of the 222 progenies of the Arka Sahan Custard apple, 56 were identified as having stable self-fruitfulness and good horticultural traits. Additionally, 50 progenies exhibited good horticultural traits. These selected progenies were further analyzed for various fruit traits. The 56 progenies with stable self-fruitfulness and good horticultural traits were selected on the progenies with more than 30 fruits per tree, more than 220.0 g fruit weight along with high TSS (>24°B). This analysis likely provided insights into the internal structure and composition of the fruits, which can be crucial for understanding fruit quality. The average number of fruits per tree was 19.48, but some progenies had only one fruit while others had up to 64 fruits. The fruit weight also varied greatly, from 52.0 g to 473.0 g, with an average of 168.42 g. The yield per tree and the estimated yield per hectare also showed significant differences among the progenies, ranging from 0.07 to 19.22 kg and from 0.03 to 7.96 tons per hectare, respectively. The progeny 10\3 exhibited the highest for each trait on yield attributes. The study aims to identify the self fruitful and best-performing progenies of custard apple for further evaluation and selection.

The evaluation of Arka Sahan Custard apple progenies revealed promising traits related to fruit quality and yield. The successful hybridization process introduced valuable variability, and the study highlights the importance of selecting and further studying progenies with stable traits for potential cultivation and breeding purposes. Additionally, the biochemical diversity observed among the progenies indicates the potential for developing custard apple varieties with distinct and high chemical profiles. Further research and breeding efforts in this direction may have a significant impact on custard apple production and quality.

6.1.3 Fruit qualitative traits

The progenies of Arka Sahan had different fruit characteristics. The length of the fruits varied from 6.0 cm to 9.1 cm, with the longest fruit found in progeny 10\3. The width of the fruits ranged from 4.5 cm to 8.0 cm, with an average of 6.76 cm. The widest fruit was also in progeny 10\3. The weight of the pulp in the fruits was between 109.5 g and 243.8 g, with the highest pulp recovery (69%) in progeny 10\3 as well. The percentage of seeds in the fruits was from 0.9 % to 7.7 %, with a mean of 3.32 %. The more seeds were in progeny 25\12. The number of seedless flakes per fruit was from 29.5 to 58.0, with a mean of 37.71. The most seedless flakes were in progeny 10\3 too.

6.1.4 Biochemical characteristics in fruits of Arka Sahan progenies

The progenies of Arka Sahan had different biochemical traits. The average soluble solids in the progenies were 28.6°B, with the highest value of 32°B in progeny 13\1. The acidity in the progenies ranged from 0.22 % to 0.33 %, with the most acidic progeny being 10\3. The total sugars in the progenies varied from 22.30 mg/100g to 30.03 mg/100g, with a mean of 26.84 mg/100g. The sweetest progeny was 13\1. The total antioxidant activity in the progenies was between 81.12 mg AEAC/100g and 95.72 mg AEAC/100g. The most antioxidant-rich progeny was 26\7. The total phenolic compounds in the progenies were from 69.03 mg gallic acid equivalents /100g to 79.23 mg gallic acid equivalents /100g. The most phenolic-rich progeny was 50\16. The total flavonoid compounds in the progenies were from 20.10 mg catechin equivalents/100g to 24.15 mg catechin equivalents/100g, with a mean of 22.296 mg catechin equivalents/100g. The most flavonoid-rich progeny was 31\15.

6.1.5 Genetic variability studies

Genetic variability studies revealed that the range of PCV was 8.43 to 62.99 and GCV was 5.03 to 33.79 for various characters. The higher PCV value than GCV for the number of fruits per tree, seed content, and number of flakes with seed and pulp recovery indicated the importance of the environment in the expression of characters. The estimates of heritability ranged from 5.01 to 88.82 and genetic advance as per cent mean ranged from 1.04 to 37.39 for various characters. High heritability coupled with high genetic advance

was recorded for average fruit weight and pulp weight indicating the role of additive gene action in governing the inheritance of these traits, which can be improved by simple selection.

6.1.6 Relative contribution and cluster analysis

Diversity in Arka Sahan progenies was highly contributed by the number of fruits per tree, fruit weight, length, pulp content and number of seeds per fruit. Among 56 progenies, 6 clusters were generated. The highest inter-cluster value was recorded between clusters V and VI. Based on these studies, crosses may be made between the progenies of clusters that are far apart genetically to obtain new recombinants in custard apple since the magnitude of heterosis depends largely on the degree of genetic diversity of parents. On the other hand, the minimum inter-cluster value recorded between cluster IV and II progenies of Arka Sahan indicated almost parallel diversity among the progenies included in these clusters.

6.1.7 Principal component analysis

Principal component analysis (PCA) recognized principal components (PCs) with eigenvalues of more than one which contributed more than 99 per cent. The analysis identified the maximum contributing variables viz., number of fruits per tree and fruit weight significantly loaded in PC 1 and PC 2, contributing more towards variability. The above characters were positive across the two axes indicating their importance as components of genetic divergence among the studied characters. Negative values for both the principle components for pulp recovery and seed content indicated the lowest contribution towards the total divergence of Arka Sahan progenies of custard apple.

6.1.8 Gene action for TSS

The test was conducted to analyze the gene action that affects the phenotypic ratio of the total soluble solids (°B) in custard apple fruits. The observed frequencies of progenies with >30 (°B) and ≤30 (°B) were compared with the expected frequencies based on a 1:3 ratio. The chi-square test was used to test the null hypothesis that there is no difference between the observed and expected frequencies. The p-value of the test was

0.4040, which is higher than the significance level of 0.05. Therefore, the null hypothesis was not rejected, and it was concluded that the gene action does not deviate significantly from the expected pattern.

6.2 Floral traits in self-fruitful and unfruitful Arka Sahan progenies

The progenies of Arka Sahan had different flowering characteristics. The flowering time of both self-fruitful and unfruitful progenies was from March to July after pruning, and the minimum time was 22 days for both. The flower bud diameter was similar for both self-fruitful and unfruitful progenies, ranging from 6 to 9.5 mm. The outer colour of the petals was also similar for both, belonging to the yellow-green group 145B and 150 respectively. The petal length was different for self-fruitful and unfruitful progenies, varying from 0.6 to 3.8 cm and 1.7 to 3.0 cm respectively. The petal width was similar for both, ranging from 0.5 to 1.5 cm. The duration of flowering was similar for both, varying from 73 to 87 days. The peduncle length was different for self-fruitful and unfruitful progenies, ranging from 1.0 to 3.1 cm and 1.0 to 2.7 cm respectively. The initial and final angle of petal opening was different for self-fruitful and unfruitful progenies, ranging from (10°to 30° and 10° to 15°) and (35°to 80° and 20° to 50° respectively. The number of flowers per 10 cm shoot was different for self-fruitful and unfruitful progenies, ranging from 1 to 10 flowers and 1 to 4 flowers respectively. The timing of anthesis and anther dehiscence was different for self-fruitful and unfruitful progenies, with most of them occurring in the early morning and afternoon to evening respectively. The diameter of the stigma cone was similar for both self-fruitful and unfruitful progenies, ranging from 2.0 to 4.5 mm. The stigma reactivity was low two days before anthesis, reached its peak on the day of anthesis, and declined gradually until two days after anthesis.

6.2.1 Pollen morphology

The progenies of Arka Sahan had different pollen characteristics. The shape of the pollen grains was consistent for both self-fruitful and unfruitful progenies. The monads had two shapes: elliptic with one or two furrows on the proximal face, and boat-shaped. The furrows could be monosulcate or disulcate, depending on their number. The dyads and triads had no specific shapes. The tetrads had three shapes: isobilateral, decussate, and

tetrahedral. The percentage of monad, dyad and triad pollen grains was different for self-fruitful and unfruitful progenies. The self-fruitful progenies had a wide range of monads (1.8 to 57.1 %), dyads (0 to 45.8 %), and tetrads (20 to 90.3 %). The unfruitful progenies had a narrow range of monads (0 to 25 %), dyads (0 to 22.2 %), and tetrads (50 to 100 %). There was no significant difference in triads (0 to 40 %) and pollen viability (49 to 92 %) for both self-fruitful and unfruitful progenies. Pollen germination was different for self-fruitful and unfruitful progenies, with higher values for self-fruitful progenies (33.5 to 96.9 %) than for unfruitful progenies (1.7 to 25.3 %). Pollen tube length was also different for self-fruitful and unfruitful progenies, with longer tubes for self-fruitful progenies (101 to 335 µm) than for unfruitful progenies (11 to 24 µm). There was also a difference in pollen length and width for both self-fruitful and unfruitful progenies.

6.3 Assessment of genetic relatedness between parents and Arka Sahan progenies

Genotyping results showed that the majority of the SSR markers displayed monomorphic banding patterns in both parents, indicating a high degree of homozygosity. However, two specific markers, LMCH-38 and LMCH-102, were heterozygous and polymorphic between the parents but did not show variability within the progeny generation at these loci. This genetic information can be valuable for understanding the inheritance patterns and genetic diversity.

Conclusion

The present study on ‘Evaluation and Characterization of Arka Sahan custard apple Progenies for Self fruitfulness’ was successful for finding a self fruitful progeny with good fruit quality. The selected progenies had more fruits per tree and higher fruit yield than the Arka Sahan hybrid. Out of 1113 progenies evaluated for self fruitfulness, 56 stable self fruitful progenies were selected for further evaluation. Among them, after sacrificing all and rigorous evaluation , the progeny 10\3 and 14\4 were promising compared to Arka Sahan for high TSS, more pulp recovery and fewer seeds. Progenies 1\1 and 50\16 were promising compared to Balanagar.

Principle component analysis identified the number of fruits per tree, fruit weight, and fruit width and fruit length as the major contributing variables towards variability in Arka Sahan custard apple progenies.

The flowering and pollen characteristics of the progenies of Arka Sahan are important indicators of their self fruitfulness and fruit quality. The self-fruitful progenies have higher petal length, initial and final angle of petal opening, number of flowers per 10 cm shoot, pollen germination and tube length, which are essential for successful pollination and fertilization. The self-fruitful progenies also have more monads and dyads, which are more viable and functional than tetrads. The unfruitful progenies have lower petal length, initial and final angle of petal opening, number of flowers per 10 cm shoot, pollen germination and tube length, which hinder their pollination and fertilization. The unfruitful progenies also have more tetrads, which are less viable and functional than monads and dyads. Therefore, the flowering and pollen characteristics can be used to select the best progenies of Arka Sahan for self fruitfulness and fruit quality improvement.

The genotyping results offer a glimpse into the complexity of genetic inheritance within the study population. While most markers indicate a high degree of homozygosity in both parents, the presence of polymorphic markers highlights the potential for genetic diversity within specific regions of the genome. Understanding these patterns can be instrumental in future breeding efforts, as it provides insights into the inheritance of particular genetic traits and the potential for selective breeding to enhance desired traits within the population. Further research and analysis are warranted to unravel the underlying mechanisms influencing the observed patterns of genetic diversity and inheritance.

Future line of work

1. Multiplication and Performance Evaluation: Once promising progenies need to be multiplied to create a sufficient number of individuals for evaluation. These progenies are assessed for various traits, including yield, fruit quality, and stability of self-fruitfulness.

2. Screening for Pest and Disease Resistance: Pests like fruit flies, mealy bugs, and diseases like anthracnose can devastate crops. Screening progenies for resistance involves exposing them to these stressors and observing their response.

3. Marker-Assisted Selection for Self-Fruitfulness: Identifying tightly linked markers to self-fruitfulness can expedite the breeding process by allowing for precise selection of individuals with this desirable trait.

ABSTRACT

ABSTRACT

Evaluation and Characterization of Arka Sahan Custard apple Progenies for Self fruitfulness

Knowledge about the extent of self-fruitfulness in Custard apple is vital for developing coherent strategies for future gains in productivity and quality. A total of 1113 progenies displayed substantial diversity in vegetative traits, growth habits, and leaf morphology. Plant height ranged from 0.8 m to 4.2 m, with an average of 2.71 m. Growth habits were classified as erect (524 progenies) or spreading (589 progenies), and leaf shapes included elliptic (69 progenies), ovate (119 progenies), and lanceolate (925 progenies), with varying leaf lengths (6.9 to 28.7 cm) and widths (3.3 to 9.9 cm). In the assessment of fruit traits and yield characteristics among these 1113 progenies, limited (222 progenies) self-fruitfulness and regular fruiting were observed, Among the progenies, 56 were identified as possessing stable self-fruitfulness and favourable horticultural attributes. These selected progenies underwent further analysis. The progenies displayed considerable variation in fruit attributes, with fruit length ranging from 6.0 cm to 9.1 cm, and the widest fruit observed in progeny 10\3. Fruit pulp weights varied from 109.5 g to 243.8 g, with progeny 10\3 featuring the heaviest pulp. Seed percentages ranged from 0.9% to 7.7%, with the highest seed count in progeny 25\12. Biochemically, the progenies demonstrated diversity, with an average total soluble solids content of 28.6 °Brix, reaching a peak of 32 °Brix in progeny 13\1. Acidity levels ranged from 0.22% to 0.33%, with progeny 10\3 being the most acidic. Total sugar content varied from 22.30 mg/100g to 30.03 mg/100g, with progeny 13\1 emerging as the sweetest. Antioxidant activity 95.72 mg AEAC/100g, with progeny 26\7 exhibiting the highest antioxidant content. Total phenolic compounds varied from 69.03 mg gallic acid equivalents/100g to 79.23 mg gallic acid equivalents/100g, with progeny 50\16 being the richest in phenolic compounds.

A higher PCV indicates greater phenotypic diversity, while a higher GCV suggests the presence of genetic diversity. Heritability estimates provide insights into the degree of inheritance of specific traits, with values ranging from 5.01 to 88.82 for different traits. Genetic advance as a percentage of the mean measures the potential for genetic improvement. It ranged from 1.04 to 37.39 for various traits, indicating the scope for selecting and breeding for desirable traits.

The flowering traits and pollen morphology in progenies derived from the Arka Sahan custard apple variety, with a particular focus on distinguishing between self-fruitful

and unfruitful traits. The flowering period for both groups spanned from March to July. Flower bud diameter exhibited similarity, ranging from 6 to 9.5 mm. However, petal length varied, with self-fruitful progenies ranging from 0.6 to 3.8 cm and unfruitful progenies from 1.7 to 3.0 cm, while petal width remained similar (0.5 to 1.5 cm). Notable differences included peduncle length, with self-fruitful progenies ranging from 1.0 to 3.1 cm and unfruitful progenies from 1.0 to 2.7 cm. The initial and final angles of petal opening showed disparities, with self-fruitful progenies spanning 10° to 30° and 10° to 15°, respectively, while unfruitful progenies ranged from 35° to 80° and 20° to 50°. The number of flowers per 10 cm shoot differed, with self-fruitful progenies exhibiting 1 to 10 flowers and unfruitful progenies showing 1 to 4 flowers. Anthesis and anther dehiscence occurred at varying times, predominantly in the early morning and afternoon to evening, respectively. Stigma cone diameter remained similar, measuring 2.0 to 4.5 mm, while stigma reactivity reached its peak on the day of anthesis, gradually declining over two days afterwards. Pollen morphology analysis revealed consistent shapes for pollen grains, including elliptic monads with one or two furrows on the proximal face, and boat-shaped monads. The furrows could be monosulcate or disulcate. Dyads and triads exhibited no specific shapes, though tetrads manifested as isobilateral, decussate, or tetrahedral. Self-fruitful progenies exhibited a broad range of monads (1.8 to 57.1%), dyads (0 to 45.8%), and tetrads (20 to 90.3%), while unfruitful progenies displayed a narrower range of monads (0 to 25%), dyads (0 to 22.2%), and tetrads (50 to 100%). Triads (0 to 40%) and pollen viability (49 to 92%) showed no significant difference between the two groups. Pollen germination was notably higher in self-fruitful progenies (33.5 to 96.9%) compared to unfruitful progenies (1.7 to 25.3%). Additionally, self-fruitful progenies exhibited longer pollen tube lengths (101 to 335 µm) compared to unfruitful progenies (11 to 24 µm). Differences in pollen length and width were also observed in both self-fruitful and unfruitful progenies.

The research also addressed the issue of unfruitfulness in annona and highlighted factors contributing to lower fruit set. These factors included anthesis timing, anther dehiscence, initial and final angle of petal opening, and pollen traits like aggregated pollens and poor pollen germination. Genetic relatedness analysis using SSR markers identified homozygosity in parents, which is essential information for breeding programs and found two polymorphic markers, LMCH-38 and LMCH-102, with remarkable inheritance patterns in the progeny generation. The findings can inform future breeding programs aimed at enhancing productivity and quality in this fruit crop.

Keywords: Custard apple; self fruitful; diversity; polymorphism; SSR

सारांश

स्व:फलोत्पादकता के लिए अर्का सहन सीताफल संतति का मूल्यांकन एवं लक्षण-वर्णन

सीताफल में स्व:फलोत्पादकता की सीमा का ज्ञान भविष्य में उत्पादकता और गुणवत्ता में वृद्धि हेतु योग्य रणनीतियों के विकास के लिए महत्वपूर्ण है। एक हज़ार एक सौ तेरह संततियों ने वानस्पतिक लक्षणों, विकास की प्रकृति और पत्तों की आकारिकी में पर्याप्त विविधता प्रदर्शित की। पौधे की ऊँचाई 0.8 मीटर से 4.2 मीटर तक होती है, जिसका औसत 2.71 मीटर होता है। विकास की प्रकृति को सीधा (524 संततियाँ) या फैलने वाली (589 संततियाँ) के रूप में वर्गीकृत किया गया था, और पत्ती का आकार दीर्घवृत्त (69 संततियाँ), अंडाकार (119 संततियाँ), और भालाकार (925 संततियाँ) था, पत्ती की लंबाई (6.9 से 28.7 से.मी.) और चौड़ाई (3.3 से 9.9 से.मी.) अलग-अलग थी। इन 1113 संततियों के बीच फलों के गुणों और उपज की विशेषताओं के आकलन में, सीमित (222 संततियों) स्व-फलोत्पादन और नियमित फलन को देखा गया। संततियों में से, 56 को स्थिर स्व-फलोत्पादक और अनुकूल बागवानी विशेषताओं वाले के रूप में पहचाना गया। इन चयनित संततियों का आगे विश्लेषण किया गया। संततियों ने फल की विशेषताओं में काफी भिन्नता प्रदर्शित की, फल की लंबाई 6.0 से.मी. से 9.1 सेमी तक थी, और संततियों में सबसे चौड़ा फल 10\3 देखा गया। फलों के गूदे का वजन 109.5 ग्रा. से 243.8 ग्रा. तक था, जिसमें संतति 10\3 में सबसे भारी गूदा था। बीज प्रतिशत 0.9% से 7.7% तक था, 25\12 संतति में बीज संख्या सबसे अधिक थी। जैव-रासायनिक रूप से, औसत कुल घुलनशील ठोस सामग्री 28.6º ब्रिक्स के साथ संततियों ने विविधता दर्शाई , जिसमें संतति 13\1 में 32º ब्रिक्स के साथ सबसे अधिक थी। अम्लता का स्तर 0.22% से 0.33% तक था, संतति 10\3 सबसे अधिक अम्लीय थी। चीनी की कुल मात्रा 22.30 मि.ग्रा./100 ग्रा. से 30.03 मि.ग्रा./100 ग्राम के बीचथी, जिसमें संतति 13\1 सबसे मीठी के रूप में उभरी। प्रतिऑक्सीकारक गतिविधि 95.72 मि.ग्रा. एईएसी/100 ग्रा. तक थी, जिसमें संतति 26\7 में उच्चतम प्रतिऑक्सीकारक मात्रा पाई गई। कुल फेनोलिक यौगिक 69.03 मि.ग्रा. गैलिक एसिड समकक्ष/100 ग्रा. से 79.23 मि.ग्रा. गैलिक एसिड समकक्ष/100 ग्रा. तक थे, संतति 50\16 फेनोलिक यौगिकों में सबसे समृद्ध है।

उच्च पीसीवी अधिक फेनोटाइपिक विविधता को इंगित करता है, जबकि एक उच्च जीसीवी आनुवंशिक विविधता की उपस्थिति को दर्शाता है। आनुवंशिकता-अनुमान विशिष्ट लक्षणों की विरासत के स्तर में अंतर्दृष्टि प्रदान करते हैं, जिसमें विभिन्न लक्षणों का मान 5.01 से 88.82 तक होते हैं। मध्यमान के प्रतिशत के रूप में आनुवंशिक उन्नति आनुवंशिक सुधार की क्षमता को मापती है। यह विभिन्न लक्षणों के लिए 1.04 से 37.39 तक था, जो वांछनीय लक्षणों के चयन और प्रजनन की गुंजाइश को दर्शाता है।

सीताफल की अर्का सहन किस्म से प्राप्त संततियों में फूलों के लक्षण और पराग आकारिकी, स्व:फलोत्पादन और अफलन लक्षणों के बीच अंतर समझाने पर विशेष ध्यान देते हैं। दोनों समूहों के लिए फूल आने की अवधि मार्च से जुलाई तक रही। कली के व्यास में समानता देखी गई, जो 6 से 9.5 मि.मी. तक थी। हालाँकि, पंखुड़ी की लंबाई अलग-अलग थी, स्व-फलोत्पादक संततियाँ 0.6 से 3.8 से.मी. तक और अफलित संततियाँ 1.7 से 3.0 से.मी. लंबी थीं, जबकि पंखुड़ी की चौड़ाई समान (0.5 से 1.5 से.मी.) रही। उल्लेखनीय अंतरों में

डंठल की लंबाई के अंतर भी शामिल हैं, जिसमें स्व-फलोत्पादक संततियाँ 1.0 से 3.1 से.मी. तक और अफलित संततियाँ 1.0 से 2.7 से.मी. तक लंबी होती हैं। पंखुड़ी खुलने के आरंभिक और अंतिम कोणों में असमानताएं दिखाई दीं, जिसमें स्व-फलोत्पादक संततियाँ क्रमशः 10° से 30° और 10° से 15° तक फैली हुई थीं, जबकि अफलित संततियाँ 35° से 80° और 20° से 50° तक फैली हुई थीं। प्रति 10 से.मी. टहनी पर फूलों की संख्या अलग-अलग थी, स्वयं-फलोत्पादक संततियों में 1 से 10 फूल और अफलित संततियों में 1 से 4 फूल दिखाई दिए। परागोद्भव और परागकोष का विघटन अलग-अलग समय पर हुआ, मुख्य रूप से क्रमशः सुबह और दोपहर से शाम तक। स्टिग्मा कोण का व्यास समान रहा, जिसकी माप 2.0 से 4.5 मि.मी. थी, जबकि स्टिग्मा की प्रतिक्रियाशीलता परागोद्भव के दिन अपने चरम पर पहुंच गई, दो दिनों के बाद धीरे-धीरे कम हो गई। पराग के आकृति विज्ञान विश्लेषण से पराग कणों के सुसंगत आकार का पता चला, जिसमें समीपस्थ मुख पर एक या दो खांचे वाले अण्डाकार मोनाड और नाव के आकार के मोनाड शामिल हैं। खाँचे मोनोसल्केट या डिसलकेट हो सकते हैं। डयाड और ट्रयाड ने कोई विशिष्ट आकार प्रदर्शित नहीं किया, हालांकि टेट्राड समद्विबाहु, चतुष्क या चतुष्फलकीय के रूप में देखे गए हुए। स्व-फलोत्पादक संततियोंक ने मोनैड (1.8 से 57.1%), डायाड (0 से 45.8%), और टेट्राड (20 से 90.3%) के बारे में बड़ा अंतर दिखाया, जबकि अफलित संततियों ने मोनैड (0 से 25%), डायाड (0 से 22.2%), और टेट्राड (50 से 100%) के बारे में कम अंतर दिखाया । ट्रयाड (0 से 40%) और पराग व्यवहार्यता (49 से 92%) ने दोनों समूहों के बीच कोई महत्वपूर्ण अंतर नहीं दिखाया। स्व-फलोत्पादक संततियों (33.5 से 96.9%) में पराग का अंकुरण अफलित संततियों (1.7 से 25.3%) की तुलना में काफ़ी अधिक था। इसके अतिरिक्त, स्व-फलोत्पादक संततियों ने अफलित संततियों संतानों (11 से 24 μm) की तुलना में पराग नलिका की अधिक लंबाई (101 से 335 μm) दिखाई। स्व-फलोत्पादक और अफलित संततियों में पराग की लंबाई और चौड़ाई में भी अंतर देखा गया।

इस अनुसंधान में सीताफल में अफलन की समस्या को भी दर्शाया गया और कम फल-स्थापन में योगदान करने वाले कारकों को उजागर किया गया। इन कारकों में परागोद्भव का समय, परागकोष का विघटन, पंखुड़ी खुलने के प्रारंभिक और अंतिम कोण, और एकत्रित पराग और कम पराग-अंकुरण जैसे कारक शामिल थे। एसएसआर मार्करों का उपयोग करके आनुवंशिक संबंध विश्लेषण में जनकों में समयुग्मजता की पहचान की गई, जो प्रजनन कार्यक्रमों में कार्यक्रमों के लिए महत्वपूर्ण जानकारी है और संतति-उत्पादन में उल्लेखनीय विरासत स्वरूप सहित दो बहुरूपी मार्कर, एलएमसीएच-38 और एलएमसीएच-102, की पहचान की गई। यह अनुसंधान इस फल की उत्पादकता और गुणवत्ता को बढ़ाने के लक्ष्य के साथ भविष्य के प्रजनन कार्यक्रमों मदद कर सकता है।

मुख्य शब्द: सीताफल; स्व-फलोत्पादकता; विविधता; बहुरूपता; एसएसआर

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CHAPTER 7 BIBLIOGRAPHY

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APPENDICES

APPENDIX-I

Meteorological observations during August, 2019 to March, 2023 at ICAR-IIHR, Bengaluru

			January	February	March	April	May	June	July	August	September	October	November	December
2019	Temperature (^{0}C)	Max.	29.06	31.68	34.60	35.49	34.34	30.91	29.70	27.97	28.59	28.89	28.74	27.20
		Min.	9.62	14.80	17.89	20.42	21.73	21.30	20.87	20.55	20.58	19.74	18.05	16.70
	Relative Humidity (%)	8.30am	85.43	71.72	64.90	69.87	78.73	82.43	83.31	87.54	89.20	89.92	86.97	88.22
		1.30pm	33.40	35.79	29.30	33.73	47.50	62.20	62.92	75.32	70.77	72.25	60.57	67.29
	Evaporation (mm)	evaporation	4.59	5.90	7.49	7.26	6.37	5.81	5.24	4.41	3.63	4.11	3.84	3.08
	Wind speed, (km/h)	wind speed	3.69	4.86	4.41	4.23	4.54	6.30	9.10	8.02	6.10	3.56	4.00	5.23
	Rainfall, (mm)	rainfall	0.50	5.70	0.00	14.35	76.75	43.35	23.83	99.45	103.73	162.10	7.60	1.35
2020	Temperature (^{0}C)	Max	30.15	31.48	33.63	34.36	34.52	31.20	29.07	27.99	28.29	27.88	27.45	26.81
		Min.	14.22	15.56	18.21	19.36	21.30	20.78	20.61	20.21	20.00	19.26	17.41	15.45
	Relative Humidity (%)	8.30am	84.52	77.04	73.24	75.60	81.66	95.00	91.42	89.58	90.93	89.21	87.33	90.01
		1.30pm	46.73	38.68	38.16	43.67	50.39	74.53	73.43	72.83	77.50	68.27	63.20	60.17
	Evaporation (mm)	evaporation	4.37	5.70	6.77	6.77	6.12	4.50	3.96	3.40	3.41	2.99	3.08	3.07
	Wind speed (km/h)	wind speed	3.95	4.98	4.44	4.51	4.14	6.89	5.59	6.48	4.87	3.95	4.27	4.80
	Rainfall (mm)	rainfall	0.00	0.00	3.23	52.00	37.15	42.50	112.00	47.73	148.98	75.75	9.60	6.95
2021	Temperature (^{0}C)	Max.	27.60	29.66	33.27	33.99	31.77	29.49	28.98	29.29	29.34	29.22	26.28	27.72
		Min.	15.25	13.28	13.93	19.43	21.34	20.28	20.20	19.81	19.67	19.52	19.03	14.61
	Relative Humidity (%)	8.30 am	89.42	82.57	67.77	77.30	84.35	85.90	80.55	80.48	78.23	79.52	86.70	78.32
		1.30 pm	57.65	38.43	27.65	39.47	58.87	65.73	59.23	54.81	54.80	59.48	66.67	50.87

			January	February	March	April	May	June	July	August	September	October	November	December
	Evaporation (mm)	evaporation	3.55	5.29	8.42	6.66	5.31	4.11	3.45	3.73	3.89	3.37	2.33	2.70
	Wind speed (km/h)	wind speed	4.55	4.59	4.67	4.32	5.43	6.57	5.13	4.56	4.52	1.89	2.38	2.08
	Rainfall (mm)	rainfall	12.10	15.20	0.00	50.10	122.00	99.30	197.70	66.65	85.35	267.20	311.00	0.00
2022	Temperature (^{0}c)	Max.	29.11	31.58	33.36	34.93	31.62	30.73	28.43	28.91	29.29	28.61	27.03	26.93
		Min.	13.78	13.02	14.72	18.82	19.83	19.70	20.08	19.70	19.12	17.65	16.05	14.68
	Relative Humidity (%)	8.30 am	74.23	69.18	58.56	64.70	77.06	78.47	83.94	84.10	78.97	80.87	81.47	80.39
		1.30 pm	46.90	36.34	31.95	34.47	54.87	52.73	63.35	62.58	57.83	56.00	55.20	52.68
	Evaporation (mm)	evaporation	3.49	5.16	6.26	6.00	4.51	4.90	3.46	4.21	4.28	3.85	3.06	3.09
	Wind speed (km/h)	wind speed	2.57	2.93	3.61	2.63	3.55	3.98	5.10	4.39	3.29	1.77	2.03	2.24
	Rainfall, (mm)	rainfall	0.58	0.00	5.85	87.70	218.40	203.15	122.60	224.20	225.80	302.50	37.20	75.90
2023	Temperature (^{0}C)	Max.	28.04	1.35	32.08	33.93	-	-	-	-	-	-	-	-
		Min.	10.58	0.76	15.01	18.18	-	-	-	-	-	-	-	-
	Relative Humidity (%)	8.30am	78.85	0.18	70.43	74.58	-	-	-	-	-	-	-	-
		1.30pm	35.83	7.66	34.00	36.25	-	-	-	-	-	-	-	-
	Evaporation (mm)	evaporation	4.33	0.22	6.78	7.09	-	-	-	-	-	-	-	-
	Wind speed (km/h)	wind speed	2.75	0.26	3.51	2.84	-	-	-	-	-	-	-	-
	Rainfall (mm)	rainfall	0.00	0.00	23.70	2.65	-	-	-	-	-	-	-	-

Promising progenies

10\3

- ✓ Number of fruits per tree - 56
- ✓ A Average fruit weight is -355.5 g
- ✓ 31°B TSS
- ✓ No. seeds- 8-9/100 g
- ✓ Pulp recovery - 68.6 %

14\4

- ✓ Number of fruits per tree - 55
- ✓ A Average fruit weight is -275.0 g
- ✓ 31°B TSS
- ✓ No. seeds- 7-8/100 g
- ✓ Pulp recovery - 66.5 %

1\1

- ✓ Number of fruits per tree - 45
- ✓ A Average fruit weight is -270.0 g
- ✓ 30°B TSS
- ✓ No. seeds- 8-9/100 g
- ✓ Pulp recovery - 57.6 %

50\16

- ✓ Number of fruits per tree - 40
- ✓ A Average fruit weight is -339.0 g
- ✓ 31°B TSS
- ✓ No. seeds - 12-13/100 g
- ✓ Pulp recovery – 49.9 %