

**STUDIES ON GENETIC VARIABILITY AND CHARACTERIZATION
OF CUSTARD APPLE (*Annonasquamosa*L.) GENOTYPES IN
NORTHERN BASTAR OF CHHATTISGARH**

Ph. D. Thesis

By

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**DEPARTMENT OF HORTICULTURE
COLLEGE OF AGRICULTURE
INDIRA GANDHI KRISHI VISHWAVIDYALAYA
RAIPUR (Chhattisgarh)**

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**STUDIES ON GENETIC VARIABILITY AND CHARACTERIZATION
OF CUSTARD APPLE (*Annonasquamosa*L.) GENOTYPES IN
NORTHERN BASTAR OF CHHATTISGARH**

Thesis

Submitted to the

Indira Gandhi Krishi Vishwavidyalaya, Raipur

by

Jeevan Lal Nag

**IN PARTIAL FULFILMENT OF THEREQUIREMENTS
FOR THEDEGREE OF**

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in

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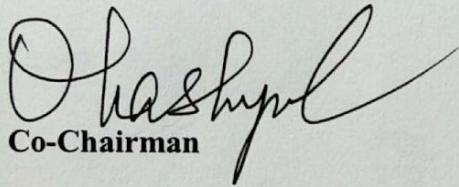
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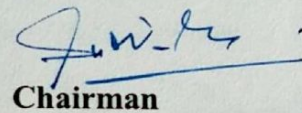
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CERTIFICATE-I

This is to certify that the thesis entitled “**Studies on genetic variability and characterization of custard apple (*Annona squamosa* L.) genotypes in Northern Bastar of Chhattisgarh**” submitted in partial fulfilment of the requirement for the degree of “**Doctor of Philosophy in Agriculture**” of the Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.), is a record of the bonafide research work carried out by **Mr. Jeevan Lal Nag** under our guidance and supervision. The subject of the thesis has been approved by Student’s Advisory Committee and the Director of Instructions.

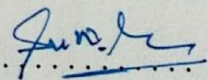
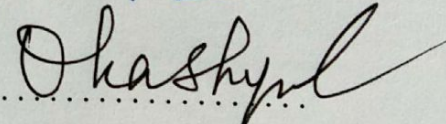
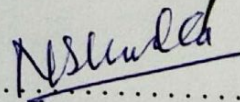
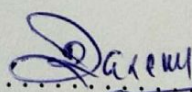
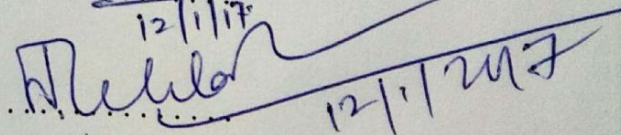
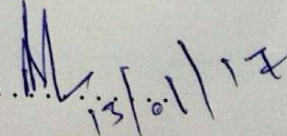
No part of the thesis has been submitted for any other degree or diploma has been published/ published part has been fully acknowledged. All the assistance and help received during the course of the investigation have been duly acknowledged by him.


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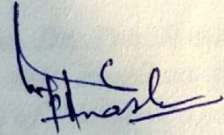
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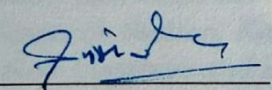
This is to certify that the thesis entitled “**Studies on genetic variability and characterization of custard apple (*Annona squamosa* L.) genotypes in Northern Bastar of Chhattisgarh**” submitted by **Mr. Jeevan Lal Nag** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.), in partial fulfilment of the requirements for the degree of **Doctor of Philosophy in Agriculture** in the Department of Horticulture has been approved by the External Examiner and Student’s Advisory Committee after oral examination.

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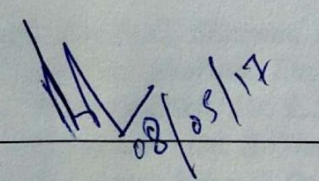

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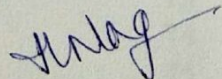

(JEEVAN LAL NAG)

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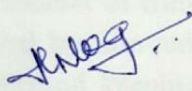
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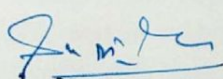
LIST OF ABBREVIATIONS

ACC	1-aminocyclopropane-1-carboxylic acid
ANOVA	Analysis of Variance
CD	Critical Difference
cm	Centimetre
°C	Degree Celsius
d.f.	Degrees of freedom
E	Environment
<i>et al.</i>	et alia or /others
EFE	Ethylene forming enzyme
Fig.	Figure
g	Gram
G	Genotype
GCV	Genotypic Coefficient of Variation
HCl	Hydrochloric Acid
h ²	Heritability
ha	Hectare
hrs	Hours
IGKV	Indira Gandhi Krishi Vishwavidyalaya
kg	Kilogram
MDW	Methanol Dichloromethane Water
m	Metre
m ²	Square metre
mm	Millimetre
NS	Non-Significant
q	Quintal
RBD	Randomized Block Design
RH	Relative Humidity
SMW	Standard Meteorological Weeks
TSS	Total Soluble Solids
Viz.	Namely

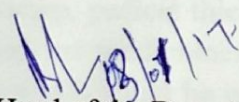
THESIS ABSTRACT

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- b) **Full Name of the Student** : Jeevan Lal Nag
- c) **Major Subject** : Horticulture
- d) **Name and Address of the Major Advisor** : Dr. S.N. Dikshit (Professor)
Department of Fruit Science
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- e) **Degree to be awarded** : Doctor of Philosophy in Agriculture (Horticulture)


Signature of the Student


Signature of Major Advisor

Date:.....13/01/17


Signature of Head of the Department

ABSTRACT

The present study entitled “**Studies on genetic variability and characterization of custard apple (*Annona squamosa* L.) genotypes in Northern Bastar of Chhattisgarh**” was carried out at the College of Agriculture and Research Station, Kanker, Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh) during 2013-14 and 2014-15. Sixty custard apple genotypes were selected for evaluations which were found *in-situ seedling* as wild seedling plants. Investigation was carried out at Antagarh, Bhanupratappur, Charama, Durgkondal, Kanker, Koylibeda, and Narharpurblocks of district-Kanker, (Chhattisgarh) India. Experimental materials comprised 10 years old 60 genotypes of custard apple and experiment was laid out under Randomized Complete Block Design (RCBD) with four replications. The study was conducted with the objectives to estimate the genetic variability, heritability, genetic advance, character association, path analysis and genetic diversity for selection of super genotypes. Observations on twenty important for quantitative traits *viz.*, number of alternate leaf, length of leaf(cm), number of flowers per branch, days to 50 % maturity, total number of fruits, fruit width (cm), length of fruit(cm), fruit weight(g), length of pedicel(cm), pedicel thickness(mm), length of pericarp(cm), weight of pericarp(g), seed length(mm),

number of seeds per fruit, seed width(mm), weight of seed(g), weight of pulp(g), weight of areole(g), number of fruits per tree, fruit yield per plant(kg) and 10 qualitative traits viz., total soluble solids(° Brix), total sugar(%), reducing sugar(%), non-reducing sugar(%), acidity (%), storage life, pulp ratio, pulp:seed ratio, peel percentage and fruit yield per plant (kg) were recorded on one plants and three reproductive samples from each replication were randomly collected for analysis.

Analysis of variance revealed presence of sufficient amount of variability. Relative magnitude of phenotypic co-efficient of variation was higher than the genotypic co-efficient of variation. The high GCV and PCV were observed for pulp weight and qualitative character viz., pulp-seed ratio and keeping days.

The highest heritability estimates were observed for the traits pulp weight followed by areole weight, fruit weight, length of pericarp, weight of pericarp, pedicel thickness, fruit length, length of pedicel, total number of fruits, fruit yield per plant and qualitative traits pulp:seed ratio followed by non-reducing sugar, total sugar, fruit yield per plant, reducing sugar, acidity and keeping days. High heritability coupled with high genetic advance as percentage of mean was found for pulp weight, areole weight, fruit weight, weight of pericarp, pedicel thickness, length of pericarp and length of pedicel, which indicated the predominance of additive gene action in the expression of these characters which could be utilized through selection. Traits like fruit yield per plant, total sugar, pulp:seed ratio, reducing sugar and total soluble solid, which indicated the predominance of additive gene action in the expression of these characters which could be utilized through selection for improvement in these characters.

The genotypic and phenotypic correlation coefficient revealed that the number of alternate leaf showed highly significant positive correlation with characters number of flowers per branch, total number of fruits, fruit width, fruit length, fruit weight, length of pedicel, pedicel thickness, length of pericarp, weight of pericarp, pulp weight, areole weight, number of fruit per tree and fruit yield per plant. Whereas, character total soluble solids exhibited highly significant positive correlation with total sugar per cent, reducing sugar, keeping days, pulp ratio, pulp:seed ratio, peel percent and fruit yield per plant at both the levels, hence due importance should be given to these traits while selecting high-yielding custard apple genotypes.

Path coefficient analysis of fruit yield per plant revealed that reducing sugar had highest positive direct effect relationship with fruit yield per plant followed by pulp:seed ratio, peel per cent and non-reducing sugar. Genetic divergence for fruit yield and its components in custard apple of quantitative traits in both year cluster analysis for fruit yield and quality traits were estimated separately.

For quantitative characters, all genotypes were grouped into 8 clusters using non-hierarchical Euclidean cluster analysis. For fruit yield parameters, maximum

number of genotypes were grouped into cluster III and VI (12 genotypes in each) followed by cluster V (10) and cluster VII (9). The minimum number of genotypes were found in cluster I (3) followed by cluster VIII (4). A promising genotypes for most of the traits was found in cluster I, *i.e.*, genotype IGCA-21, therefore, it can be selected as parent for further research programme to improve fruit yield and attributing traits. Next promising genotypes are IGCA-21, IGCA-3, IGCA-11, IGCA-1, IGCA-4, IGCA-2, IGCA-10 and IGCA-22 for fruit yield per plant from cluster I, II, III, IV, V, VI, VII and cluster VIII, respectively. For qualitative traits, all genotypes were grouped into 8 clusters using non-hierarchical Euclidean cluster analysis. For qualitative parameter, maximum number of genotypes were grouped into cluster VIII (14) followed by cluster III (12). Clustering pattern of genotypes recognized that there is no influence of ecological location on divergence because parental populations were collected from different ecological area. Result showed that in cluster I, genotype IGCA-21 is promising for most of the qualitative traits; therefore, it can be selected as parent for further research programme to improve fruit quality traits. Next promising genotypes are IGCA-21, IGCA-11, IGCA-4, IGCA-2, IGCA-3, IGCA-12, IGCA-13 and IGCA-10 are most promising for pulp-seed ratio and peel percentage from cluster I, II, III, IV, V, VI, VII and cluster VIII, respectively. These results indicated the existence of sufficient variability among genotypes and there are better chances of improvement either through selection or through hybridization by getting heterosis and these genotypes can be used in breeding programme to get useful heterotic combinations. Promising genotypes of custard apple may be directly involved in multiplication of genotypes to develop a high yielding genotype of custard apple in Chhattisgarh.

शोध-सारांश

अ) शोध शीर्षक	:	“छत्तीसगढ़ के उत्तर बस्तर में सीताफल (एनोना स्क्युमोसा) के जीनोटाइप में अनुवांशिक विविधता एवं गुणों का अध्ययन”
ब) विद्यार्थी का पूरा नाम	:	जीवन लाल नाग
स) प्रमुख विषय	:	उद्यानिकी
द) प्रमुख सलाहकार का नाम व पता	:	डॉ. एस. एन. दीक्षित (प्राध्यापक) फल विज्ञान विभाग, कृषि महाविद्यालय इं.गां.कृ.वि.वि., रायपुर (छ.ग.)
इ) सम्मानित की जाने वाली उपाधि	:	पी.एच.डी. (कृषि) उद्यानिकी
	:	विद्यार्थी का हस्ताक्षर
	:	विभागाध्यक्ष के हस्ताक्षर
प्रमुख सलाहकार का हस्ताक्षर		
दिनांक : 13/01/17	:	

सारांश

वर्तमान अध्ययन विषय “छत्तीसगढ़ के उत्तर बस्तर में सीताफल (एनोना स्क्युमोसा) के जीनोटाइप में अनुवांशिक विविधता एवं गुणों का अध्ययन” कृषि महाविद्यालय एवं अनुसंधान केंद्र कांकेर (छ.ग.), इं.गां.कृ.वि.वि., रायपुर (छ.ग.) खरीफ 2013-14 एवं खरीफ 2014-15 में मूल्यांकन स्वस्थाने साठ सीताफल के जीनोटाइप को वरण कर जांच किया गया था जो जंगली रूप में अथवा प्राकृतिक आवास पर उपस्थित थे। यह अध्ययन अंतागढ़, भानुप्रतापपुर, चारामा, दुर्गकोंदल, कांकेर, कोयलीबेड़ा, एवं नरहरपुर विकासखण्ड जिला कांकेर छ.ग. राज्य, भारत में किया। इसके अध्ययन दस साल पुराने सीताफल पेड़ों पर किया गया। अध्ययन सामग्री में साठ जीनोटाइप को लेकर यादराच्छिक ब्लॉक अभिकल्पना के साथ चार प्रतिरूप में लिया गया था। इस अध्ययन का मुख्य उद्देश्य अनुवांशिकी विविधता, वंशागतित्व, अनुवांशिकी प्रगति सह सम्बंध गुणांक, पाथ गुणांक एवं अनुवांशिकी विभिन्नता विश्लेषण करना था। जिसका अवलोकन में बीस मात्रात्मक लक्षण जैसे एकांतर पत्तियों की संख्या प्रति शाखा, पत्ति की लम्बाई, फूलों की संख्या प्रति शाखा, 50 प्रतिशत परिपक्वता, कुल फलों की संख्या प्रति पौधा, फलों की चौड़ाई, फलों की लम्बाई, फलों का वजन, डण्डल की लम्बाई, डण्डल की मोटाई, पैरीकार्य की लम्बाई, पैरीकार्य का वजन, बीज की लम्बाई, कुल बीजों की संख्या प्रति फल, बीजों की चौड़ाई, बीज का भार, गुदे का वजन, छिलके का भार प्रति फल, फलों की संख्या प्रति वृक्ष, फलों की उपज प्रति वृक्ष, और दस गुणात्मक लक्षण जैसे कुल घुलनशील टोस, कुल शर्करा का मात्रा, अपचायक शर्करा, अन-अपचायक शर्करा, अम्लता, भण्डारण क्षमता, गुदे का अनुपात, गुदा बीज अनुपात,

विविधता गुणांक, गुदे का भार पर अधिक अवलोकन किया गया । गुणात्मक लक्षण गुदे बीज का अनुपात और भण्डारण दिनों की संख्या के लिये अवलोकन किया गया। उच्च वंशागतित्व गुदा का भार प्रति फल, छिलके का भार प्रति फल, फलों का वजन , पैरीकार्य की लम्बाई, पेडिसिल का मोटाई, पैरीकार्य की चौड़ाई, फूल की लम्बाई, पेडिसिल का लम्बाई, कुल फलों की संख्या प्रति पेड़ । और गुणात्मक लक्षण , गुदा बीज का अनुपात, अन-अपचायक शर्करा, कुल शर्करा, फल का उपज प्रति पेड़, अपचायक शर्करा, अनुमापन अम्लता एवं भण्डारण दिनों की संख्या पर अवलोकित किया गया। उच्चतम अनुवांशिक प्रगति औसत प्रतिशत के रूप में फल का उपज और अन्य घटकों में सीताफल के पेड़ों में मात्रात्मक लक्षण के लिये उच्चतम वंशागतित्व साथ ही साथ उच्च अनुवांशिक प्रगति प्रतिशत में गुदा का वजन, छिलका का भार, फल का भार, पैरी कार्य का वजन, पैडिसिल का मोटाई, पैरीकार्य की लम्बाई और पैडीसील का लम्बाई दर्शाता है कि इनके अभिव्यक्ति के लिये अतिरिक्त जीन ईकाई परिलक्षित करती है। जिसके कारण इन लक्षणों का उपयोग फसल सुधार के लिये चयनित कर उपयोग किया जा सकता है और मात्रात्मक लक्षण फलों का उपज प्रति वृक्ष, कुल शर्करा, गुदा बीज अनुपात, अपचायक शर्करा एवं कुल विलेय ठोस यह दर्शाता है कि इनके अभिविलय के लिये अतिरिक्त प्रभावी जीन परिलक्षित करती है जिसके कारण इन गुणात्मक लक्षणों को उपयोग गुणों को सुधार या विकास के लिये जायेगा। इस प्रकार उच्च उत्पादन वाले सीताफल कि जीन प्रारूप का चयन करते समय उपरोक्त लक्षणों को उचित, माध्यम दिया जाना चाहिये ।

इसी प्रकार जीन प्रारूप एवं लक्षण प्रारूप मात्रात्मक लक्षणों के लिये सह-संबंध गुणांक का अवलोकन किया गया, एकांतर पत्तियों की संख्या प्रति शाखा, धनात्मक सह-संबंध के लिये उच्च सार्थकता । साथ ही साथ अन्य लक्षण फूलों की संख्या, कुल फलों की संख्या, फल की चौड़ाई, फल की लम्बाई, फल का भार, पेडिसिल का लम्बाई, पेडिसिल की मोटाई, पैरीकार्य की लम्बाई, पैरीकार्य की चौड़ाई, गुदा का भार, छिलका का भार, फलों की संख्या प्रति पेड़, फल का उपज प्रति पेड़ दोनों के लिये दोनों स्तर पर जीन प्रारूप एवं लक्षण प्रारूप के लिये सार्थक एवं सकारात्मक पाया गया गुणात्मक लक्षणों के लिये कुल विलेय ठोस, कुल शर्करा, अपचायक शर्करा, भण्डारण दिनों की संख्या, गुदा का अनुपात, गुदा बीज का अनुपात, छिलका का प्रतिशत, फल का उपज प्रति पेड़ दोनों के लिये दोनों स्तर पर जीन प्रारूप एवं लक्षण प्रारूप के लिये सार्थक एवं सकारात्मक अवलोकित किया गया । इसलिये इन महत्वपूर्ण लक्षणों का वरण सीताफल की उच्च उपज के लिये जीनोटाइप का चयन किया जाना चाहिये। पाथ गुणांक विश्लेषण का अध्ययन विभिन्न गुणात्मक लक्षणों के उपर फल उपज प्रति पेड़ के साथ सकारात्मक प्रभाव एवं प्रत्यक्ष प्रभाव एवं संबंधता अपचायक शर्करा का उच्च एवं सकारात्मक पाया गया। साथ ही साथ फल बीज अनुपात , छिलका का प्रतिशत एवं अन-अपचायक शर्करा का भी फल उपज प्रति पौधा के साथ सार्थक एवं सकारात्मक परिणाम प्राप्त हुये। जिनका हम सीधे तौर पर लाइनो का वरण कर अन्य प्रजनक कार्यक्रम में उपयोग किया जा सकता है।

इसी प्रकार अनुवांशिक विभिन्नता फल उपज और अन्य घटकों के सीताफल के उपर मात्रात्मक लक्षणों का अध्ययन दो वर्षों तक गुच्छ विश्लेषण फल उपज और गुणात्मक लक्षणों के लिये अलग से अध्ययन किया गया। मात्रात्मक लक्षण के सभी जीनोटाइप के आठ गुच्छों को प्रयोग श्रेणी बंध इक्विलिजियन गुच्छ विश्लेषण फल उपज एवं अन्य मानकों के साथ फल उपज प्रति पेड़ अधिकतम अधिक संख्या में जीन प्रारूप गुच्छ (III) एवं (VI) अधिकतम बारह-बारह जीन प्रारूप एवं अन्य गुच्छ (V),(X), गुच्छ (VII) और (IX) जीन प्रारूप में भाग लिया इसी प्रकार इसके कम संख्या में जीन प्रारूप गुच्छ एक में तीन एवं आठ में चार जीनोटाइप भाग लिये। आशा जनक जनन द्रव्य को गुच्छ के आधार पर जीन प्रारूप का फल उपज प्रति पेड़ और अन्य घटकों के लिये सीताफल का अध्ययन किया गया परिणामस्वरूप गुच्छ एक के जीन प्रारूप आई.जी.सी.ए.-21 सभी लक्षणों के लिये आशा जनक परिणाम प्राप्त हुये इस गुच्छ के जीन प्रारूपों का वरण अनुसंधान कार्यक्रम में ले सकते हैं। जिसका उपयोग फल उपज एवं अन्य घटकों के लिये किया जा सकता है। जीन प्रारूप आई.जी.सी.ए.-21, आई.जी.सी.ए.-3, आई.जी.सी.ए.-11, आई.जी.सी.ए.-1, आई.जी.सी.ए.-4, आई.जी.सी.ए.-2, आई.जी.सी.ए.-10 और आई.जी.सी.ए.-22 आशा जनक एवं

महत्वपूर्ण फल उपज प्रति पौधा जो कि गुच्छ I, II, III, IV, V, VI, VII और गुच्छ VIII के लिये उपयोगी है । इसी कारण गुणात्मक लक्षणों के कारण सभी जीन प्रारूपों आठ गुच्छ का उपयोग श्रेणी बंध इक्वीलिडियम गुच्छ विश्लेषण किया गया । गुणात्मक मानको अधिकतम संख्या के जीन प्रारूप के समुह में गुच्छ आठ में से चौदह जीनो टाइप गुच्छ तीन में बारह जीनों टाइप भाग लिये । जीन प्रारूपों के स्वरूप में गुच्छ को परिस्थितिक स्थिति का कोई प्रभाव नहीं पड़ा क्योंकि जनको की संख्या विभिन्न पारिस्थितिक स्थितियों में पाये गये थे । गुच्छ के विचारशील एवं आशा जनक जनन द्रव्यों को गुच्छ में सीताफल के गुणात्मक लक्षणों का प्रभाव देखने को मिला परिणात्मक गुच्छ एक में जीन प्रारूप आई.जी.सी.ए.-21 में आशा जनक सभी गुणात्मक लक्षणों का वरण जनको का उपयोग पादप प्रजनन में फल की गुणवत्ता में एवं उन्नत किस्म को विकास में करेंगे। जीन प्रारूप आई.जी.सी.ए.-21, आई.जी.सी.ए.-11, आई.जी.सी.ए.-4, आई.जी.सी.ए.-2, आई.जी.सी.ए.-3, आई.जी.सी.ए.-12, आई.जी.सी.ए.-13, एवं आई.जी.सी.ए.-10 गुदा बीज अनुपात और छिलका का अनुपात प्रति वृक्ष में गुच्छ I, II, III, IV, V, VI, VII एवं गुच्छ VIII में भाग लिये। समूहों एवं आनुवांशिक संरचना का नियंत्रण पादप प्रजनन रखता है । प्रजनन विधि परिवर्तन प्राकृतिक समूहों में आनुवांशिक विचलन त्वरित किया जाता है ।

सीताफल मुख्य रूप से पर-परागण फल है इसलिये वातावरणीय विभिन्नता एवं परिस्थितियों को प्रजनन कार्यक्रम में परिवर्तन कर देता है। इन प्रमाणों के जीन प्रारूपों के बीच पर्याप्त परिवर्तनशीलता का संकेत मिलता है जिससे फसल सुधार में इसका योगदान हो सकता है साथ ही साथ और संकरण कार्यक्रम में जीन प्रारूपों का उपयोग संकर ओज संयोजन को पाने के लिये वृक्ष प्रजनन कार्यक्रम में इस्तेमाल किया जा सकता है।

CHAPTER - I INTRODUCTION

Custard apple (*Annona squamosa* L.), also known as *Sitaphal* or *Sharifais* is an important dryland fruit crop of India and belongs to family 'Annonaceae' having chromosome number $2n = 14$. The fruit tree belongs to tropical climate and is native of tropical America and surrounding regions. *Annona* means year's harvest and *squamosa* means scaly referring to the scale like structure of the fruit surface. Custard apple tree has been naturalized in the Deccan plateau due to its hardy nature and hence, it is an important dryland fruit crop. It is cultivated in Maharashtra, Gujarat, Madhya Pradesh, Andhra Pradesh, Chhattisgarh, Karnataka, Bihar, Orissa, Assam and Tamil Nadu. Besides India, it is common in China, Phillipines, Egypt and Central Africa. In India, it is presently grown in an area of about 29.87 thousand hectares with a production of 228.37 MT and the average productivity is 765 q/ha and it ranges from 673 q/ha in Andhra Pradesh to 685 q/ha in Maharashtra (2014-15). Chhattisgarh and Maharashtra occupies 55.74 per cent of the total area in the country, whereas Gujarat occupies 5.34 thousand hectare and the average productivity is 768 q/ha (Chandra, 2010).

Chhattisgarh, state of India occupies an area of approximately 7.990 thousand hectare with an annual production of 39.73 metric tones having the productivity of 497.25 q/ha under custard apple. In the range of forest scattered across Jagdalpur, Beejapur, Dantewada, Kanker, Dhamtari, Rajnandgaon, Durg, Jashpur, Surguja and Bilaspur districts, only Kanker district is blessed with natural biodiversity of the custard apple. Its wild land races are found distributed all along as a natural stand over an area of about 7.20 thousand hectare with an annual production of 35.60 MT having the productivity of 494.45 q/ha (Anon., 2013).

Custard apple is a small, semi or late deciduous, much branched shrub or small tree 3 to 8 metres tall with a broad, open crown or irregularly spreading branches and a short trunk, not buttressed at base. Branches with light-brown bark and

visible leaf scars; inner bark light-yellow and slightly bitter; twigs become brown with light-brown dots. Custard apple being very hardy, survives well under drought, salinity and marginal soil conditions. It grows very well even on shallow soils.

The ill-smelling leaves are deciduous, oblong or narrow lanceolate with conspicuous veins. Thin, simple, alternate leaves occur singly, 5 to 17 cm long and 2 to 6cm wide rounded at the base and pointed at the tip (oblong-lanceolate), pale- green on both surfaces and mostly hairless with slight hairs on the underside when young. The sides sometimes are slightly unequal and the leaf edges are without teeth, inconspicuously hairy when young. Leaf stalks are 0.4 to 2.2 cm long, green, sparsely pubescent. The greenish-yellow flowers arise at an extra axillary position, in drooping clusters, are fragrant, slender, with 3 outer fleshy, light-green externally and pale-yellow with a dark-red or purple spot on the inside at the base and flowers never fully open.

Flower solitary or in short lateral clusters of 2.4 to 2.5 cm long, greenish-yellow on a hairy, slender 2 cm long stalk. Three green outer petals, purplish at the base, oblong, 1.6 to 2.5 cm long, and 0.6 to 0.75 cm wide, three inner petals reduced to minute scales or absent. It is a very numerous stamens; crowded, white, less than 1.6 cm long; ovary light-green. Styles white, crowded on the raised axis. Each pistil forms a separate tubercle (small rounded wart like protuberance), mostly 1.3 to 1.9 cm long and 0.6 to 1.3 cm wide which matures into the aggregate fruit. The flowers have numerous stamens and carpels. Its flowering coinciding with maximum moisture availability during rainy period makes, it quite at home under stress conditions and flowers are pollinated by sap feeding beetle (nitidulid beetles).

The fruit of custard apple (*Annona squamosa*) has delicious whitish pulp, and is popular in tropical markets. The fruits composed of loosely cohering carpels forming a squamose or tuberculated surface. Aggregate and soft fruits form from the numerous and loosely united pistils of a flower which become enlarged and mature into fruits which are distinct from fruits of other species of genus and more like a giant raspberry instead. Custard apple produces single crop in a year during September to

December in Central India and maturing fruits turn light-green. The inter-areole space widens, the fruit turn creamy-white. The round or heart-shaped greenish yellow, ripened aggregate fruit is pendulous on a thickened stalk, 5 cm to 10 cm in diameter with many round protuberances and covered with a powdery bloom. Fruits are formed of loosely cohering or almost free carpels the ripened pistils (Morton, 1987).

The pulp is white-tinged yellow, edible and sweetly aromatic. It has a thick, creamy-white layer of custard like, somewhat granular, flesh beneath the skin surrounding the concolorous moderately juicy segments. Each carpel containing a single, hard, smooth, shiny, dark-brown or black, glossy seed, oblong, smooth, less than 1.3 to 1.6 cm long (Nath *et al.*, 2008). Actual seed counts have been found 55 to 60. A pointed, fibrous, central core, attached to the thick stem, extends more than halfway through the fruit and possessing pleasant flavour, custard apple fruits are utilized for ice cream making (Maurya and Singh, 2006).

Once the above nutritional and medicinal qualities of dietary importance were realized, there has been considerable awareness about the consumption of custard apple in the world. The immature fruits, seeds, leaves and roots are of considerable medicinal values both in Aurvedic and Yunani systems of medicine. Custard apple is full of vitamin C anti-oxidants, which helps to combat many diseases and also enhances the immune system. Eating custard apple is helpful in curing many diseases and disorders. The fruit is good for heart, skin and bone and maintains blood pressure. Custard apple is also helpful in curing of boils, ulcers and gum related problems. The leaves of this fruit work against cancer, bark can be used in case of toothache, and gum pain. However, the most important advantages of custard apple are healthy heart, beneficial in pregnancy, improve eye vision, cure arthritis, fighting fatigue and protects against anaemia.

The edible portion or pulp is creamy or custard like, granular, with a good blend of sweetness, possessing pleasant flavor and mild aroma have a universal liking, being rich in carbohydrates 23.0 g per100 g fruits. The fruit is reported to have moisture 70.5 g, protein 1.6 g, fat 0.4 g, minerals 0.9 g, fiber 3.1 g, calcium 17.0 mg,

phosphorous 47.1 mg, iron 1.5 mg, thiamine 0.07 mg, riboflavin 0.17 mg, niacin 1.30 mg, Vitamin C 37.0 mg and energy 104Kcal Gopalan *et al.*, (1987) and Singh, (1995).

Shedding off leaves during stress conditions is another associated escape mechanism which offers ample scope for cultivation of custard apple in arid regions. There is no well organized orcharding of this crop. Hence, the custard apple fruits yield is a complex character and therefore, the knowledge of association and cause and effect relationship of yield component traits with yield would help in formulation of effective selection schemes (Baskaran and Muthiah, 2007). Grouping of genotypes based on the inherent genetic diversity is also helpful to find out the linkage of association. Diverse genotypes are always used to exploit heterosis in plant breeding programme.

The evolution of custard apple through natural and human selection in diverse elevation zones and under different cropping systems with involvement of honey bees being the carrier of cross pollination has resulted in a wide variety of locally adapted landraces. These landraces have evolved over years to fit into local cropping patterns and diverse end uses and represent a wide range of patterns of crop diversity. The knowledge of patterns of genetic variation of a crop species in any given region or country is very important for planning future germplasm exploration missions and thereafter it's efficient utilization in crop improvement programme. Assessment of genetic variability for yield and its components is useful to predict the extent of improvement possible for fruits yield and other important characters.

Selection of superior genotypes depends on the phenotypic expression. Often selection based on phenotypic performance does not lead to expected genetic advances mainly due to presence of G x E interactions as well as undesirable association between the component characters. A clear understanding and knowledge of association and contribution of various yield components directly and indirectly needed to undertake selection programme for obtaining high yielding genotypes (Salunke *et al.*, 1995). The estimate of genetic parameter and association of characters are very useful in understanding the nature and magnitude of genetic variability

available in the breeding material. Diverse genotypes are always used to exploit heterosis and generate variability in plant breeding programme.

The heritability estimates and genetic advance proved to be the important parameters for isolating the desirable genotypes. Heritability provides information on contribution of genotypic variance to the corresponding phenotypic variance while, genetic advance reflects genetic architecture of any population. High genetic advance associated with high heritability gives an idea of true heritable traits for better selection during breeding programme.

The measurement of phenotypic, genotypic and environmental correlations between yield and its components has basic and foremost endeavors to find out guidelines for plant selection. The magnitude and direction of correlation offers an idea for future improvement in concerned traits. In situations where more variables are included in correlation studies, the indirect association becomes complex and the path analysis is proved to be useful tool in finding out the direct and indirect causes of association.

Yield is a complex character, influenced by environmental fluctuations. Therefore, direct selection for yield as such will not be reliable and fruitful. Hence, selection criteria based on yield components would be helpful in selection suitable plant types. The knowledge of inter-relationship between yield components and the relative weightage that should be given to different yield components to obtain maximum gain is therefore the most important. Thus constructions of selection indices will be helpful to discriminate desirable genotypes on the basis of their phenotypic performance (Paul and Bajpai, 2000).

Kanker district of Chhattisgarh state holds promise in availability of diverse genotypes of custard apple and exists in the form of landraces, hence there exists a lot of scope to identify promising genotypes. Till date no systematic collection and evaluation of custard apple cultivars has been carried out in Chhattisgarh. Thus, there is an urgent need for collection, characterization and evaluation of high-yielding genotypes which can be successfully grown on commercial scale in Chhattisgarh.

Hence, in view of the above, the present investigation entitled “**Studies on genetic variability and characterization of custard apple (*Annona squamosa* L.) genotypes in Northern Bastar of Chhattisgarh**” was planned to be undertaken with following objectives:-

1. To evaluate and characterize *in-situ* performance and yield-attributing characters of custard apple genotypes.
2. To identify high-yielding genotypes of custard apple of quality fruits.
3. To find out the genetic divergence and association analysis of custard apple genotypes for fruit yield and other traits.
4. To study the post -harvest quality attributes in custard apple genotypes.

CHAPTER -II

REVIEW OF LITERATURE

The cultivation of custard apple in India was started primarily as an unorganized sector around the hilly areas while some organized farmers also grow in border plants like live fencing to protect orchards from grazing animals and subsequently realizing commercial significance of the fruits, it has emerged as one of the important minor fruit plants in horticulture sector. Slowly India has realized the commercial relevance of custard apple and it has emerged as a very sweet drought resistant fruit. *Annona squamosa* is a small, deciduous, much branched shrub or small tree 3 to 8 metre tall with a broad, open crown or irregularly spreading branches and short trunk, not buttressed at base. The sugar apple fruit is pale-green in colour and the pulp is typical of the Annonaceae family, creamy-white, fragrant and sweet. The fruit contains numerous black seeds which are ellipsoid to obovoid, 1-1.4 cm in size while, flowers are yellowish green. *Annona squamosa* can be grown at an altitudes upto 2,000 metre and does well in hot dry climates; at much lower altitudes than many of the other fruit bearers in its family.

The considerable research efforts are being attached to custard apple from the times when it became important commodity in the national and international market. Multifarious strategic research attempts are for realizing the higher yield in this crop to meet the ever increasing global demand for its delicious, nutritious and their all parts are used as medicine (Kumar *et al.*, 2005). India was the first country to initiate systematic research in custard apple improvement at Fruit Research Station, Sangareddy, Andhra Pradesh and Fruit Research Station, Maharashtra and Fruit Research Station Udaypur, Rajasthan. In the recent years, considerable research efforts are also being made in America, Brazil, South Africa and China. Timely renewed research approaches and breeding objectives coupled with advent of modern research techniques have been facilitating the researchers in their efforts to understand the genetic strength and physiological behavior of the crop.

Keeping this in view, the available review and literature pertaining to the different aspects of the present investigation entitled “**Studies on genetic variability**

and characterization of custard apple (*Annona squamosa* L.) genotypes in Northern Bastar of Chhattisgarh” has been reviewed under the following heads:

- 2.1 Evaluation of genotypes
- 2.2 Flowering behaviour
- 2.3 Assessment of genetic variability
- 2.4 Character association
- 2.5 Genetic divergence
- 2.6 Physico-chemical characters of fruits
- 2.7 Keeping quality (Shelf life)

2.1 Evaluation of genotypes

The objectives broadly aimed at developing new high-yielding commercial varieties with such characters as desired tree height and spreading of canopy (dwarf / semi dwarf canopy), fruit weight(450-500g), fruit size with higher pulp-seed ratio and lower number of seed (30-35), seeded pericarp, seedless pericarp, keeping quality, resistance / tolerance to biotic (mealy bug) and abiotic stress (fruit cracking, moisture stress and climate changes). Literature pertaining to the evaluation of genotypes relevant to the present investigation has been reviewed.

George and Nissen (2002b) concluded that the mean marketable yields of custard apple (*Annona squamosa* X *A. cherimola*) cv. African Pride were 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. Sugar apple rootstock exhibited dwarfing characteristics but could not be recommended owing to susceptibility to *Pseudomonas solanacearum*.

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. The trees are

hardy, withstanding temperatures of 2.7 °C without injury. Average fruit weight (250 g) is twice that of other cultivars and the flesh has a high soluble solids content.

George and Nissen (2002a) 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. Overall fruit set was not adversely affected by drought. Drought also increased the number of fruits harvested per tree by 47% compared with well-watered controls. This response was mainly due to the increase in number of flower per tree. Drought reduced average fruit size by 11% possibly due to effects on cell division in the first 4-6 weeks after fruit set or on net carbon assimilation. In summary, mild to moderate drought during the flowering period and fruit set increased flowering without adversely affecting fruit set, but decreased fruit size of the custard apple cv. African Pride in subtropical Australia.

George and Nissen (2002b) revealed that the five methods of controlling tree size, viz., growth retardant (foliar-sprayed and trunk-injected paclobutrazol), root-restriction bags, cherimoya rootstock and sugar apple (*Annona squamosa*) interstock, were evaluated for their effects on growth, yield and fruit quality of custard apple (*Annona spp.* hybrid cv. African Pride) in subtropical Australia (Queensland). Compared with trees on their own roots, sugar apple interstock was highly effective in dwarfing 'African Pride' trees, reducing tree canopy volume by 72-90%. Root-restriction bags (woven fiber glass) proved to be only partially effective in controlling tree size due to growth of major roots through the seams. Compared with trees on their own roots, cherimoya rootstock alone and sugar apple interstock increased fruit weight per unit canopy volume by a maximum of 3 and 5 fold, respectively. Sugar apple interstock reduced the severity of fruit disorders 'woodiness' and 'brown pulp' by about 75 and 50%, respectively.

Liu and Chen (2002) observed that the temperature affects the growth, pollination and fruit development of *Annona spp.* The optimum temperature for growth and fruiting of cv. African Pride is 17-22 °C and growth is retarded if the

temperature decreases to 4-5 °C. *Annona cherimola* is suitable for cooler tropical regions.

Girwani *et al.* (2011) identified high-yielding cultivars in custard apple (*Annona squamosa* L.) with quality and shelf life. Under an *Annona* improvement programme, six existing promising hybrids were evaluated at the Fruit Research Station, Sangareddy. Hybrid-1 (17/4 Atemoya x Balanagar) was earliest to mature. Maximum fruit weight (250 g) was recorded in Hybrid-1 (17/4 Atemoya x Balanagar) followed by Hybrid-6 (15/3 Red Sitaphal x Atemoya) (225 g) and Hybrid-4 (1/6 British Guinea x Atemoya) (220 g). Among all the hybrids, maximum number of fruits per tree (94) was recorded in Hybrid-1 (17/4 Atemoya x Balanagar) followed by Hybrid-6 (15/3 Red Sitaphal x Atemoya) (67). The TSS ranged from 22 to 28 ° Brix and was found to be maximum in Hybrid-2 (15/2 Red Sitaphal x Pond apple), while the seed content per fruit was also minimum (20) in this hybrid. Based on overall performance, the Hybrid-1 (17/4 Atemoya x Balanagar) and Hybrid-3 (15/3 Red *Sitaphal x Atemoya*) and Hybrid-2 (15/2 Red Sitaphal x Pond apple) were found to be excellent in quality with pleasant aroma, smooth pulp texture with less seed, good sugar acid blend and shelf life.

Kulkarni *et al.* (1997) reported that during 1991-92, the effects of cultural methods (irrigation or mulching) and gibberellins (50 or 100 ppm), NAA (20 or 30 ppm) or 2,4-D (15 or 30 ppm) on the yield and quality of custard apples (*Annona reticulata*) were investigated in Rahuri, (M.S.). In terms of average fruit weight, the best results were obtained using irrigation (148.0 g), followed by mulching (138.8 g) and controls (137.0 g). Fruit composition was not significantly affected by the treatments.

Keny *et al.* (2010) revealed that the six traits were evaluated in the first cropping season (mean number of seeds per fruit, mean weight of the pericarp, pulp, pedicel, seeds per fruit and the whole fruit), while five traits were evaluated in the first three cropping seasons (mean fruit length and width, total number of fruits ha⁻¹, mean fruit weight (in both types of analyses), and fruit yield in kg ha⁻¹).

Hashmi and Pawar (2012) evaluated at Agricultural Research Communication Centre, Karnal (Haryana) and reported the suitability of custard apple (*Annona squamosa* L.) fruits for organized farming on the basis of different physical and chemical characteristics such as fruit weight, number of seeds, seed weight, rind yield and pulp yield, TSS, pH, acidity, total sugar and ascorbic acid. The results revealed that custard apple growth in organized orchards resulted in comparatively higher pulp yield and better chemical properties, justifying its suitability for commercial exploitation.

2.2 Flowering behaviour

Flowering behavior is very important for fruit setting in custard apple because *Annona* is a cross-pollinated due to protogynous and flowering occurs in last week of June and up-to last week of July. The flower has numerous stamens carpel's and pollinated by nitidulid beetles.

Kumar *et al.* (1977) reported that the custard apple plants, cv. Sahebganj were observed to flower from March to August, the maximum flowering being in April and May. Buds developed into flowers in 35 days. Fruit set was low (8%) and started in August, when the climatic conditions were optimal. Maximum anthesis was between 5.30 p.m. and 5.30 a.m. and dehiscence was maximum between 11.30 a.m. and 2.30 p.m. The highest pollen germination (16-25%) was obtained in 20% sucrose-agar solution.

Sahoo *et al.* (2000a) found that in custard apple, the flowering season commences in February and continued up to September. The flowers are borne mostly in new flushes after shedding of older leaves. Anthesis occurred from 02.30 hr to 18.30 hr with a peak period between 05.30 and 06.30 hr. Dehiscence of pollen began 10 hours after flower opening and continued for only 2 hours. The stigmas were receptive from one day prior to anthesis till 2-3 days after anthesis indicating a protogynous condition. The pollen grains were round to ovate in shape. Very little variation was recorded in flowering behavior of green and red fruited types.

Sahoo *et al.* (2000b) investigated the custard apple (*Annona squamosa* L.) pollen morphology, pollination and fruit set under the northeast climatic conditions and results observed that the average pollen grain size from March to August ranged between 53.15 and 53.82 micro m in the green type and between 47.82 and 48.26 micro m in red type. The maximum pollen grain diameter was observed in July in both types. The viability of pollens varied from 42.30 to 93.33% in the green type and 45.10 to 93.75% in the red type. The highest pollen viability was recorded from June to August in both varieties. Fruit set by open pollination was ~3.33% and fruit set by controlled self pollination was only 0.75%.

Pritchard and Edwards (2006) studied the low natural pollination rates which produce few and poorly formed fruits in commercial orchards of the custard apple (*Annona squamosa* x *A. cherimola*) cultivar *Hillary White* on the Atherton Tablelands, North Queensland, Australia. Supplementary pollination, using either pollen type, significantly increased overall fruit production and fruit quality above natural levels. However, pollen source from cv. African Pride trees produced significantly larger and more symmetrical fruits than pollen from cv. *Hillary White*. Increased quality was not at the expense of quantity. There was no difference in mean fruit yield between flowers treated with pollen from either variety. These results indicated that using cv. African Pride pollen had greater economic returns for growers through the production of a higher proportion of 'best' quality fruits.

2.3 Assessment of genetic variability

The critical assessment of nature and magnitude of variability in the germplasm stock is one of the important prerequisites for formulating effective, meaningful breeding programmes, as crop improvement of any crop depends on extent of variability and heritability of economically important characters, though, under the relative influence of the environment on their expression.

The planning and success of any crop improvement programme mainly depends on genetic variability and its magnitude present in a population. Statistics has offered various analytical techniques to assess the available variability. The genotypic and phenotypic coefficients of variation allow to estimates the extent of variability

present in material under investigation and also play an important role in improvement of existing cultivar and searching for superior genotypes. The choice of genetically diverse parents for hybridization is an important feature of crop improvement programme for getting desirable sergeants. The genetic variability for various traits in custard apple has been studied by several workers.

The genetic variability in relation to environmental variability was worked out by Fisher (1936). Wright (1921), Lush (1940), Warner (1952) and Johnson *et al.* (1955) suggested the techniques for estimation of components of genetic variability.

Heritability estimate provides the information regarding the amount of transmissible genetic variation to total variation and determines genetic improvement and response to selection. It also suggests the relative role of genetic factors in expression of phenotypes and acts as an index of transmissibility of particular trait into its off springs however; knowledge of heritability alone does not help in formulating concrete breeding programme.

Heritability is the quantitative statement of the relative importance of heredity and environment. The partitioning of phenotypic variation in genetic and environmental variation was done by Fisher (1936). Thereafter, different methods for the estimation of heritability have been refined by several workers.

Lush (1940) defined the heritability in broad sense as the ratio of genetic variance to the phenotypic variance (total variance). Mather (1949), Kaul (1967) Reddy and Heyne (1968) have given different methods of estimating heritability.

Genetic advance refers to the improvement in mean genotypic value of selected plants over parental population. Thus, it is the measurement of genetic gain under selection. Therefore, the success of genetic advance under selection solely depends on three main factors *viz.*, existing genetic variability, heritability and selection intensity applied (Allard, 1960).

Cliff (1977) elucidated that the maturity of fruit coincided with first week of November to first week of December. The landraces exhibited variability in different traits which are of worth consideration for breeding programme.

Islam *et al.* (1991) reported that 27 *Annona squamosa* landraces were collected from 8 districts of Bangladesh during summer 1989, and the fruit measured for quantitative and qualitative characters. Considerable variation between landraces was found for fruit weight, fruit size, edible portion, °Brix and taste. Overall, accessions CA022, CA001 and CA017 were superior to others genotypes.

Jagtap and Kokate (1991) observed that the fruits were measured for physical and chemical characters as well as texture of pulp, palatability and seed number. Five promising genotypes (P36, P42, D77, Y72 and D90) were selected for future improvement by clonal propagation. During 1987-88, a number of trees were selected from the private orchard of the Forest Department of Maharashtra State University and the hilly area of Pemgiri village, Sangamner Taluka, Ahmednagar district.

Shete *et al.* (1991) screened a large population of open-pollinated seedling progeny of custard apple (*Annona squamosa*) during the fruiting season of 1988 at Rahuri (M.S.). Data were collected on eight physico-chemical characters in 24 promising types of 137 ten year old superior type seedling originally, selected seedling 25 as the most outstanding selection is recommended for further testing.

George *et al.* (1999) reported that the objective of this breeding programme 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), low susceptibility to blemish and high level of self-pollination, eliminating the need for labour intensive and expensive hand-pollination. A conventional breeding programme using poly crosses of 11 of the best, advanced selections (Hillary White, Martin, Paxton, MHRS Gold, MHRS Red, Palethorpe, R11-T3; R11-T4; R11-T6; Ruby Queen, Bullock's Heart) has been initiated. The breeding programme occurred to develop seedless cultivars by first producing tetraploids either through gamma irradiation or colchicine and then crossing to diploids to produce seedless triploids. In resultant introduced red and pink skin-coloured germplasm (*A. reticulata* and *A. reticulata* x *A. cherimola* hybrids) from Florida, and crosses to transfer skin colour genes into the best of the Australian selections and varieties are currently being developed.

Carvalho *et al.* (2000) studied 91 genotypes of the IPA gene bank evaluated in 1992-97 for growth and yield characteristics under irrigation in the Moxoto River Valley. In which the heights of the 10 most promising genotypes ranged from 4.3 to 5.5 m at 7-years-old. During the 6 crop years studied, highest mean annual yields were obtained from IPA18.2, IPA17.2 and IPA17.3 (11.73, 10.58 and 10.56 kg/tree, respectively). The average number of fruits/tree for these genotypes was also high (54.5, 45.8 and 49.8, respectively). Fruit ripening occurred mainly from January to August, with peaks in January and July.

Wang *et al.* (2001) conducted trials with custard apple (*Annona reticulata*) cv. African Pride grafted onto *A. squamosa*, *A. reticulata* and *A. montana* and planted in December 1997. Grafting compatibility, growth, bearing and hardiness of the trees were investigated in December 1999. The trees grafted onto *A. squamosa* performed best, giving a graft survival of 96.2%, production per tree of 3.85 kg and an average fruit weight of 457.4 g. The trees were also less damaged by a temperature of 3 °C in winter.

Saulo *et al.* (2006) evaluated eight fruits each of 30 genotypes of the species characterized by length and fruit diameter, fruit mass, pulp mass, seed mass, rind mass and receptacle mass, pulp yield, number of seeds, thickness of the rind, pH, total soluble solids, total titratable acidity, vitamin C, TSS/Acidity ratio, moisture, ash content, total, reducing and non-reducing sugars. Results were evaluated by descriptive statistics (mean, standard deviations and coefficient of variation) and statistical multivariate analysis, by grouping techniques and main component analysis. The genotypes were clustered in 10 genetically divergent groups, which allowed the selection of promising genotypes. The highly variable traits fruit pulp, rind mass and number of seeds contribute to differentiation of the evaluated genotypes.

Keny and Paulo (2010) concluded that selection based on simple correlation estimates may not be convenient, since not always a cause and effect relationship can be verified between two traits. Positive correlations were obtained between number of seeds and seed weight, and between number of fruits and yield. The greatest direct effects were obtained for pulp weight on fruit weight and for mean number and weight

of fruits on fruit yield. The most important indirect effects were obtained for number of seeds and pericarp weight, obtained via pulp weight, on fruit weight, and for fruit length and width, obtained via mean fruit weight, on fruit yield.

Bhatnagaret *al.* (2012) reported that the variations in shape (round and cordate), fruit colour (yellowish green, light green, pale green), pulp colour (pale white, creamy white) and areole shape (rounded, rounded and fused, mummiform) of custard apple fruits were observed. The areoles were prominent and the rind was leathery in the landraces collected from Dara and Baran sites. The areoles were rounded and smooth in Baran and Kota landraces and were faintly demarcated. Among the seven landraces, the landraces from Baran site had an attractive rind colour. The pulp colour in it varied from pale white to creamy white. The maximum pulp weight of 47.0g was observed in landrace collected from Baran site. Maximum TSS was observed in landraces collected from Kelwara and Rajsamand sites (18.1°Brix) followed by those from Baran site (17.9 °Brix). Existence of variability in landraces indicates ample scope for improvement of *annonas* found adapted under sub mountaineous tracts of Aravalli hills.

2.4 Character association

Understanding the nature and extent of the associated relationship of the quantitative characters among the germplasm accessions greatly facilitates the simultaneous improvement of several characters in a genotype in selection operations. Correlation studies also reveal the genetic barriers, if any, which are going to hurdle the enhancement of the genotype. Many yield components and growth parameters have been extensively studied by many fruit breeders for effective selections or using germplasm material.

Knowledge about interrelationship between yield and yield-contributing characters facilitates the choice of efficient breeding method to be adopted and selection of parents for crop improvement programme. Correlation coefficient is a statistical measure which is used to find out the degree and direction of relationship between two and more variables. The phenotypic correlation coefficient helps in determining selection index whereas, genotypic correlation coefficient provides a

close measure of association between characters which may be useful for overall improvement of the crop.

Correlation coefficient analysis was used to measure interrelationship among various traits and determine the component character on which selection can be based for genetic improvement in the yield, which is not a unitary character but depends on the development of various plant characters. Contribution of each character towards increase in yield varies from crop to crop. Some of them have substantial contribution while other has merged. Hence, correlation helps in finding out the association between different characters and measures the strength of relationship between two variables.

The original concept of correlation was represented by Galton (1888) and he suggested the need of coefficient of correlation to describe the degree of association between variables. Later, the theory of correlation was developed by Pearson (1904). Thereafter, Searle (1961) described the mathematical implications of correlation at phenotypic, genotypic and environmental levels.

The magnitude of relationship between various plant characters that determines the component characters on which selection can be made for improvement in yield and quality parameters. Genotypic correlation is the inherent association between the two variables. It may be either due to pleiotropic action of genes or linkage. If the correlation between yield and a character is due to the direct effect of the character, it reflects a true relationship between them and selection can be practiced for such characters in order to improve yield. If the correlation is mainly due to indirect effect of the character through another component trait, the breeder has to select for the trait through which the indirect effect is expected. A great yield response is obtained when the character for which indirect selection is practiced which in turn, has a high heritability and positive correlation with yield.

Various workers have extensively studied genotypic and phenotypic correlations of various yield-attributes with fruit yield as well among themselves in Custard apple.

The information on the extent of association between the yield and other yield-contributing characters is important to bring the simultaneous improvement in associated traits. Although, knowledge of phenotypic correlation of agronomic characters with yield in custard apple is indispensable in the characterization of component influences on manifesting the characters, these associations yet do not provide explicit information on the relative importance of direct and indirect effects of each component character on yield of custard apple.

With the increase in number of variables, it becomes imperative to measure the contribution of each variable towards the observed correlation. Therefore, partitioning of the observed correlation coefficients into components of direct and indirect influences provide perceptions in the characterizations of more complex traits like yield. Under such circumstances “path coefficient analysis” which partitions the correlation coefficients, provides precise information on the direct and indirect effects in order to perceive the most influencing characters to be utilized as selection criteria in Custard apple breeding programmes.

Path coefficient analysis has been extensively used in Custard apple for genetic improvement of yield. Some of the studies made by various workers to assess the correlation, path effects of different yield-attributing characters are reviewed here:

Deshmukh *et al.* (2001) revealed that majority of the farmers had adopted recommended custard apple cultivation technology. Relational analysis showed that variables like education, occupation, family size, land holding, and annual income had significant positive relationship with adoption of custard apple technology. This finding resulted from a questionnaire survey involving a sample of 120 farmers in Aurangabad district, Maharashtra, India, in 1995-96 to examine the relationship between adoption of custard apple (*Annona reticulata*) technology and the characteristics of custard apple growers.

Joshi *et al.* (2003) found that the custard apple is vegetatively propagated (*Annona squamosa*) by shield and patch budding and by softwood grafting. Bud sprout percentage of shield and patch budding increased with the increase in temperature and relative humidity. The number of leaves was negatively correlated

with bud take percentage in patch budding but was positively correlated with bud sprout percentage in shield budding. Direct associations were observed among bud sprout percentage in softwood grafting, mean scion length in softwood grafting, and final success percentage in patch budding and softwood grafting. The mean scion length in softwood grafting was positively associated with the number of leaves in shield and patch budding and in softwood grafting. Sunshine hours was negatively correlated with bud take percentage in shield and patch budding, bud sprout percentage in shield and patch budding, days required for sprouting in patch budding, and final success in shield budding. Rainfall was positively correlated with bud take percentage in shield and patch budding, bud sprout percentage in shield and patch budding, and final success in shield budding. However, it was negatively correlated with mean scion length in shield and patch budding and in softwood grafting, number of leaves in shield budding, and number of leaves in patch budding.

Lima *et al.* (2004) observed the leaf area (y), length (l) and width (w) of 20 half-sibling progenies of custard apple tree (*Annona squamosa*) and to fit regression equations of the type $y=a+bx$, where $x=l,w$, that will allow y to be estimated based on l and w . Leaf area was measured with an automatic measuring device and leaf dimensions were determined with a ruler. All values of b were different from zero. Differences occurred only in 11% of the 190 possible comparison pairs between progenies, for the estimates of b . No differences were observed between progenies in terms of leaf length, width and area. In view of this fact, the equation $y=0.72x$ ($R^2=0.77$) was fitted for all progenies.

Mariguele and Silva (2010b) estimated simple and partial coefficients of correlation, as well as to divide their effects into direct and indirect using path analysis for custard apple tree traits. Twenty half-sibling progenies were evaluated in a randomized block design with five replicates and plots consisting of four plants. Six traits were evaluated in the first cropping season (mean number of seeds per fruit and mean weight of the pericarp, pulp, pedicel, seeds per fruit, and the whole fruit), while five traits were evaluated in the first three cropping seasons (mean fruit length and width, total number of fruits ha^{-1} , mean fruit weight (in both types of analyses), and fruit yield in $kg\ ha^{-1}$). The results of this work led to the conclusion that selection

based on simple correlation estimates may not be convenient, since not always a cause and effect relationship can be verified between two traits. Positive correlations were obtained between number of seeds and seed weight and between number of fruits and yield.

Mariguele and Silva (2010a) reported that the selection based on simple correlation estimates may not be convenient, since not always a cause and effect relationship can be verified between two traits. Positive correlations were obtained between number of seeds and seed weight and between number of fruits and yield. The greatest direct effects were obtained for pulp weight on fruit weight and for mean number and weight of fruits on fruit yield. The most important indirect effects were obtained for number of seeds and pericarp weight, obtained via pulp weight, on fruit weight and for fruit length and width, obtained via mean fruit weight, on fruit yield.

2.5 Genetic divergence

Availability of sufficient genetic diversity in the germplasm collection, which the breeder is handling, is the basis of breeding program. The assessment of genetic divergence in the present investigation is based on the phenotypic divergence of the genotypes. Literature pertaining to the genetic diversity relevant to the present investigation has been reviewed.

The choice of genetically diverse parents for hybridization is an important feature of any crop improvement programme for getting desirable segregates. The multivariate analyses based on Mahalanobis D^2 analysis are used for divergence analysis. The D^2 analysis classifies the genotypes into relatively homogeneous groups in such a way that, within the cluster diversity is minimized and between clusters diversity is maximized. The respective genotypes from diverse clusters can be utilized in breeding programme. Therefore, the study on genetic divergence on available genotypes under the environment where it is to be exploited is essential for successful utilization of germplasm resources for the development of superior varieties in Custard apple. Literature available on genetic divergence estimates for different characters in custard apple tree (*Annona squamosa*) is reviewed here.

Mahalanobis (1928) reported that D^2 statistics was used for assessing the genetic divergence between different population.

Rao (1974) studied the genetic diversity of the genus *Annona* which has 5 spp. with edible fruits the custard apple (*Annona squamosa*), cherimoya (*A. cherimola*), bullock's heart (*A. reticulata*), sour sop (*A. muricata*) and atemoya, which is a natural hybrid between the custard apple and cherimoya. The custard apple and cherimoya are valued more than the other spp. The transportability and storage life of these fruits are low. Preservation for short periods in the form of jam and other products has been successful. General use of these fruits is making in ice cream, confectionery and certain milk products.

George *et al.* (2005) found the genetic diversity of the selecting new types and gaining an understanding of the inheritance of desirable traits in custard apple. Inter-varietal crosses were made between the best selections of custard apple and the main commercial cultivars such as KJ Pinks, Maroochy Gold, Palethorpe and Maroochy Yellow. Inter-specific crosses were made between four different species, *Annona cherimola* (cherimoya), *A. squamosa* (sugar apple), *A. reticulata* (Bullocks Heart) and *A. diversifolia* (Ilama). Fifteen advanced selections from the breeding programme were examined at six evaluation sites throughout Queensland and northern New South Wales. The programme has successfully developed hybrids with red skin colour and pink internal flesh. Red skin colour was found to be controlled by either a single or double recessive genes.

Liu ShiBiao (2000) assessed the genetic divergence of the *Annona squamosa* cultivar African Pride which performed very well in the area of Zhanjiang, China. It was highly adapted to the various soils and performed best in sandy-loam soil. The trees were much more hardy than other *A. squamosa* cultivars (resistant to 0.5 °C). The fruits matured mainly in September to November, and were large, weighing 326 g on average, with white, tender flesh with a sugar content of 18.3%, 400 micro g ascorbic acid/g, a very sweet flavour, and had very good eating quality and good transport quality.

Samal *et al.* (2002) assessed the genetic divergence of twenty cultivars of cashew. Observations on eight important characters like numbers of laterals and flowering laterals per square meter, length of panicle, sex ratio, number of nuts per panicle, nut weight, shelling percentage and yield per plant were recorded. The dendrogram based on main data showed clusters at appropriate phenol levels indicating that the entries were broadly classified into four clusters at 70 per cent phenol level, seven clusters at 75 per cent phenol level and at 80 per cent phenol level they were grouped into eleven clusters.

Dikshit *et al.* (2008) assessed the genetic divergence of twenty one accessions of custard apple germplasm collected during an exploration programme from six districts of Maharashtra. The physico-chemical 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/pulp ratio (37-54.2).

Mariguele and Silva(2010b) considered for the genetic divergence the greatest direct effects for pulp weight on fruit weight and for mean number and weight of fruits on fruit yield. The most important indirect effects were obtained for number of seeds and pericarp weight, obtained via pulp weight, on fruit weight, and for fruit length and width, obtained via mean fruit weight, on fruit yield of custard apple.

Jorge Andres Agustin *et al.*, (2014) considered the genetic divergence in Mexico for 14 genera and 63 species of Annonaceae distributed mainly in tropical regions of Southeast Mexico. Conservation *in situ* is sporadic, taking place in backyard gardens for soursop (*Annona muricata*), custard apple (*A. cherimola*), chincuya (*A. purpurea*) and sugar apple (*A. squamosa*) mainly. Custard apple (*A. reticulata*), ilama (*A. diversifolia*) and chincuya (*A. purpurea*) are encouraged but not multiplied. Conservation *ex situ* is held in genebanks *in vivo* or collections of work for soursop (30 collections), cherimoya (70 collections) and ilama (100 collections) only. The seeds of these species are unorthodox and conservation medium and long term is not resolved in Mexico. The growing potential for this group of fruit is high

but problems of lack of varieties, crop protection, lack of technology and small markets limit the cash crop.

2.6 Physico-chemical characters of fruits

Custard apple is no longer poor man's fruit as it fetches an even higher price than several other fruits because the fruits are very sweet, nutritious, very perishable in nature and other all parts are used as a medicine purposes.

Mazumdar (1977) compared two types of fruit of custard apple (*Annona squamosa*)with regard to berry weight, specific gravity, acidity and the content of total, reducing and non-reducing sugars and also that seeded berries were larger and had a higher sugar content.

Singh *et al.* (1977) assessed changes in the fruit size of *Annona squamosa*, at an intervals from 20th August to 18th November, and on the physical characteristics and chemical composition of mature fruits and reported that ascorbic acid content was 1.10 mg/100 g.

Chattopadhyay and Mandal (1993) reported that the number of fruits per tree, number of seeds per fruit, specific gravity and total sugar content were significantly higher, and the peel weight was lower, with 240 g/plant of each fertilizer in custard apple. Both rates of fertilizer caused a significant increase in the diameter, DM percentage, TSS, vitamin C and reducing sugar percentage, compared with the control.

Martinez *et al.* (1993) studied fruit ripening after harvesting in cherimoya and demonstrated a respiratoryclimacteric associated with rapid ethylene production. The increase in ethylene production was caused by an increase in the activities of ACC-synthase and ethylene-forming enzyme (EFE), which were very low in the freshly picked fruits, but increased rapidly over the second day e=reaching a maximum on the third day. During the climacteric there was also a low amount of 1-aminocyclopropane-1-carboxylic acid (ACC) in its conjugated form. Rind browning increased after harvesting, but this was not related to decrease in chlorophyll, since the chlorophyll level remained stable throughout the entire post harvest period. The level of browning correlated well with the Hunter L Value. The onset of ethylene

production, starch degradation, loss of firmness and acceleration of total sugar all coincide.

Pal and Kumar (1995) observed that the fruit growth and development of 10 year old *Annona squamosa* trees (cultivars Barbados Seedling and Washington-97), grown at Hesaraghatta Experimental Station (Karnataka, India), was monitored at 15 days intervals from flowering to harvest maturity (120+or-5 days after flowering) and physiological maturity (2-5 days after harvest maturity). Fruits showed a double sigmoid growth curve and exhibited climacteric respiration. Changes in fruit weight and size, the pulp-peel ratio, DM accumulation, TSS, insoluble solids, sucrose, glucose, fructose, citric acid and peel chlorophyll and vitamin and mineral contents were observed. The sugar-acid ratio and the appearance of a yellow colour in the edible pulp appeared to be reliable harvest criteria of custard apple.

Chen WeiHui (1999) evaluated the custard apple (*Annona squamosa*) fruits harvested at the normal time or 2 or 5 days earlier and then stored at 25-33 degrees C and 85-90% RH. The soluble solids content, total acids and vitamin C content of stored fruits were determined. The results showed that for immediate consumption, the best harvest date was when the fruit soluble solids content reached 15-20%. Otherwise, the harvesting should take place 2-3 days earlier, when the fruit soluble solids content reached around 10%.

Ghosh *et al.* (2001) conducted physico-chemical studies of 4 year old grafted trees of custard apple (*Annona reticulata*) cultivars Atemoya, Balanagar, Chance Seedling, Iceland Gem, Washington, and Jargham Local in West Bengal, India during the year 2000. Balanagar exhibited the highest fruit weight (300 g), fruit length (8.3 cm), fruit diameter (9.0 cm), number of seeds per fruit (35), earliest maturity date i.e. October and content of total soluble solids (27.0 ° Brix), reducing sugar (11.8%), non-reducing sugar (4.7%), total sugar (16.7%) and ascorbic acid (54.4 mg/100 g pulp). Atemoya and Chance Seedling exhibited the highest acidity (0.32%) content and number of seedless berries per fruit (48), respectively.

Girwani *et al.* (2011) reported that they identified high-yielding cultivars of custard apple (*Annona squamosa* L.) with quality and shelf life. Six existing promising

hybrids were evaluated at the Fruit Research Station, Sangareddy. Among all the hybrids, maximum TSS ranged from 22 to 28 degrees B and was found to be maximum in Hybrid-2 (15/2 Red Sitaphal x Pondapple), while the seed content per fruit was also minimum (20) in this hybrid. Based on overall performance, the Hybrid-1 (17/4 Atemoya x Balanagar) and Hybrid-3 (15/3 Red Sitaphal x Atemoya) and Hybrid-2 (15/2 Red Sitaphal x Pond apple) were found to be excellent in quality with pleasant aroma, smooth pulp texture with less seed, good sugar acid blend and shelf life.

2.7 Keeping quality (Shelf life)

Custard apple are mostly consumed as table fruit. They are also used in icecreams and other milk products and preserved as jam, jelly or other products on limited scale. Edible portion or pulp is creamy or custard like, granular with a good blend of sweetness and acidity which vary with the species. The pleasant flavour and mild aroma have a universal liking. Custard apple fruit is nutritional rich and largely valued for its taste.

Broughton (1979) revealed that the *Annona squamosa* fruits ripened normally in storage at 15 to 30 °C although fruits were susceptible to fungal attack at >25 °C. Ripening was enhanced by removal of CO₂ and by addition of O₂ to the storage atmosphere and delayed by addition of CO₂ and removal of O₂. Ethylene had no apparent effect on ripening. Fruits stored at low RH ripened faster than those at high RH. Dipping the fruits in IAA at 10⁻⁴ to 10⁻² M accelerated ripening. Levels of both ascorbic acid and glucose increased to a maximum at the climacteric, but decreased as the fruits became overripe. The stage of eating ripeness occurred at the climacteric. Recommended conditions for storing custard apple are: temperatures between 15 and 20 °C, low oxygen and ethylene tensions coupled with 10% CO₂ and 85-90% RH.

Ranganna (1986) reported that the organoleptic evaluation is overall acceptability methods for quality evaluation of fruits and vegetable in which nine point Hedonic rating test is adopted for pulp, juice, Ready to Serve (RTS), nectar,

jam, jelly and vegetable products fresh or in different interval of storages by the panel of five judges.

Rabbani and Singh (1988) concluded that the processed products were evaluated for colour, appearance, aroma, taste and overall acceptability. The product with score of '7' (like moderately) or above for overall acceptability was considered acceptable.

Batten (1990) observed that custard apple ripened most quickly and with good flavor at 28°C while ripening was slower and the quality impaired at 32°C. Fruit stored at 4°C and high humidity developed symptoms of chilling injury after 2 days, although even after 5 days at 4°C fruits ripened at 20°C with very good flavor. Fruits withstood 5 days at 8°C without detectable deterioration in appearance or flavor, but the total post harvest life of 9 days hardly better than at 12°C (8.5 days). At 12°C, fruits deteriorated in appearance after >6 days, although the flavor remained very good up to 10 days. The maximum TPHL achieved without significant damage to fruit was 9.4 days, with 6 days at 12°C followed by ripening at 20°C or 9.1 days, with 5 days at 8°C. This compares with a ripening time of 4.8 days at 20°C.

Bhadra and Sen (1997) observed that the most effective treatments for prolonging the shelf life of fruits were; brown paper wrapping, followed by dipping in gibberellic acid (GA) and polyethylene bagging + KMnO₄. Ethrel (ethephon) and hot water treatment enhanced ripening of fruits compared to the control and other treatments. The lowest fruit weight losses were recorded in polyethylene bagging + KMnO₄, perforated polyethylene bagging and brown paper wrapping treatments. GA (100 or 200 ppm), brown paper wrapping and polyethylene bagging + KMnO₄ also maintained high sugar and ascorbic acid contents and low acidity during storage for up to 10 days at 32 °C and 70-75% RH, after a variety of treatments. Some fruits were also stored at 10 °C and 85-90% RH.

Prasanna *et al.* (2000) reported that the ripening of fruits was observed on 4, 6 and 9 days of storage at 25, 20, and 15 °C, respectively. The colour of the pulp, texture, taste and flavour of ripe fruits held at 25 and 20 °C were superior, followed by fruits stored at 15 °C. At 10 °C, the fruits became hard with surface blackening, messy

pulp and less sweetness. The major changes during ripening were a continuous decrease in fruit firmness and starch content and a continuous increase in TSS and sugars, the changes being more rapid at 25 and 20 °C than at 15 and 10 °C. Custard apple fruits stored at 25 and 20°C had a clear climacteric peak whereas those stored at 15 and 10 °C did not show any distinct rise in respiration rate. Ethylene peak (2.40 micro kg⁻¹h⁻¹) coincided with the respiratory climacteric at 25°C storage, corresponding with the peaks in TSS, sugars, ascorbic acid and acidity.

Singh (2003) revealed that fruits such as papaya, banana, ber (*Zizyphus mauritiana*), guava, mango, sapota (*Manilkara zapota*), citrus fruits, custard apple (*Annona reticulata*) and pomegranate can be stored safely for certain period under ambient temperature as well as in cold storage with the help of postharvest treatment with certain ripening retardants such as fruit coating resin (Waxol), gibberellic acid (GA₃, CaCl₂, KMnO₄ and Cycocel (chlormequat) at their appropriate concentration. Ripening retardants prolong shelf life of fruits, reduce weight loss, spoilage and maintain higher percentage of marketable quality fruits up to a certain period of time thereby overcome glut in markets during peak season and give higher returns to growers and traders.

Girwani *et al.* (2011) reported that the custard apple (*Annona squamosa* L.) is delicious fruit of the tropics and has been naturalized in the Deccan plateau due to its hardy nature. Under an *Annona* improvement programme, six existing promising hybrids were evaluated for different horticultural traits from 2001 to 2006 at the Fruit Research Station, Sangareddy. All the hybrids varied in fruit shape (round, conical and cordate), fruit colour (yellowish-green, grayish-green, light green and red), pulp colour (creamy white, light pink and white), areole shape (tuberculate, hexagonal) and texture (course, soft and meaty). Time of fruit maturity varied from September 2nd fortnight and lasted till the end of December. Hybrid-1 (17/4 Atemoya x Balanagar) was earliest to mature. Maximum fruit weight (250 g) was recorded in Hybrid-1 (17/4 Atemoya x Balanagar) followed by Hybrid-6 (15/3 Red Sitaphal x Atemoya) (225 g) and Hybrid-4 (1/6 British Guinea x Atemoya) (220 g). Among all the hybrids, maximum number of fruits per tree (94) was recorded in Hybrid-1 (17/4 Atemoya x Balanagar) followed

by Hybrid-6 (15/3 Red Sitaphal x Atemoya) (67). The TSS ranged from 22 to 28 degrees B and was found to be maximum in Hybrid-2 (15/2 Red Sitaphal x Pondapple), while the seed content per fruit was also minimum (20) in this hybrid. Based on overall performance, the Hybrid-1 (17/4 Atemoya x Balanagar) and Hybrid-3 (15/3 Red Sitaphal x Atemoya) and Hybrid-2 (15/2 Red Sitaphal x Pondapple) were found to be excellent in quality with pleasant aroma, smooth pulp texture with less seed, good sugar acid blend and shelf life.

Nagaraja (2011) conducted an experiment with custard apple (*Annona squamosa*) fruits dipped in cold water for 5 min, CaCl_2 at 2% for 10 min, KMnO_4 at 4% for 10 min and smeared with mustard oil, then placed in polyethylene bags (150 and 200 gauge) with (0.5%) or without ventilation. Untreated fruits served as the control. Data were recorded on fruit specific gravity, storage life, physiological losses in weight, taste, colour, flavour and acceptability.

Nilam *et al.* (2011) revealed that the custard apple fruits treated with NAA 100 ppm as well as GA_3 50 ppm were found most effective in extending the shelf-life, respectively over control (by 1.75 and 1.42 days), while they helped in maintaining the marketability and tended to reduce the fruit weight loss. The level of acidity and ascorbic acid decreased, while reducing and total sugars increased with advancement of storage period. Application of NAA 100 ppm was more economical than other no chemicals.

Mallikarjuna *et al.* (2012) conducted an experiment during 2006-07 to assess the effect of different packages and storage systems for enhancing shelf life of custard apple fruits. They reported that the shelf life of custard apple fruits was 6 days in ventilated polyethylene package and it was by 8 days in silicon membrane and diffusion channel systems at 20 °C. At 15 °C, the storage life was increased 8 days in ventilated polyethylene followed by 10 days in silicon membrane and diffusion channel systems. The shelf life of custard apple fruits under ambient temperature in ventilated polyethylene package was 4 days and in silicon membrane and diffusion channel systems, it was 6 days compared to control which could be kept well for only 2 days under ambient temperature.

Silva *et al.* (2012) evaluated the postharvest quality of custard apple (*Annona squamosa* L.) fruits under different treatments *i.e.*, unpacked (control), individually packed in polyvinylchloride (PVC) film, or packed in expanded polystyrene trays enveloped in PVC film and tested during five periods of storage (0, 4, 8, 12, and 16 days) at 10°C. Data of mass loss, pulp hardness, soluble solids, titratable acidity, pH, vitamin C and water activity were recorded at harvest and every 4 days over the storage period. Custard apple fruits stored at 10°C and packed in PVC film had reduced mass loss. The modified atmosphere packaging also resulted in decreased loss of firmness, providing about a 12 days postharvest life. Soluble solids and total titratable acidity concentrations did not increase significantly during storage. The modified atmosphere allowed for a shelf life of 12 days at 10°C.

CHAPTER - III

MATERIALS AND METHODS

The details of experimental site, period of experiment, weather prevailed during the experimental period, materials used, methods adopted for conduction of experiment and analysis of data during the course of investigation are described in this chapter as following.

3.1 Location and period of experiment

The experiment entitled “**Studies on genetic variability and characterization of custard apple (*Annona squamosa* L.) genotypes in Northern Bastar of Chhattisgarh**” was conducted at Research cum Instructional Farm, College of Agriculture & Research Station, Singarbhat, Kanker, Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh) during two consecutive seasons *viz.*, during 2013-14 and 2014-15. Physico-chemical analysis of fruits was done in the Quality Laboratory, College of Agriculture & Research Station, Singarbhat, Kanker, Chhattisgarh.

3.2 Geographical location

The Chhattisgarh state is divided in three climatic zones *viz.*, plains of Chhattisgarh, Bastar Plateau and Northern Hills. Northern Bastar Kanker comes under Chhattisgarh plains and it is situated in the northern part of the Chhattisgarh on 20°20' N latitude and 81°32' E longitude at an altitude of 384 metre above mean sea level. The geographical information about various blocks is given in Table 3.1

Table 3.1: Geographical information about various blocks of District- Kanker

S. No.	Name of Block	District	Latitude	Longitude	Mean Sea Level (m)
1.	Antagarh	Kanker	N 20°15.245	E 081° 33.101	433
2.	Bhanupratappur	Kanker	N 20°18.297	E 081° 31.477	393
3.	Charama	Kanker	N 20°13.257	E 081° 33.855	383
4.	Durgkondal	Kanker	N 20°17.242	E 081° 31.422	432
5.	Kanker	Kanker	N 20°20.203	E 081° 32.065	384
6.	Koylibeda	Kanker	N 20°18.216	E 081° 31.429	330
7.	Narharpur	Kanker	N 20°11.550	E 081° 31.910	437

3.3 Agro-climatic conditions

Northern Bastar, Kanker comes under moist, sub-humid agro-climatic region of Chhattisgarh. The northern Bastar of Chhattisgarh received high rainfall coupled with comparatively lesser temperature and higher humidity. The average annual rainfall of this region is 1380 mm, most of which (85%) is received from third week of June to mid September and remaining distributed during February, March, May and October. May is the hottest and January is the coolest month of the year. The maximum temperature goes as high as 42 °C during the May (summer) and minimum as low as 12°C during January. The atmospheric humidity is high from June to October. The climatic condition of the region is mild round the year and is favorable for cultivation of custard apple. The meteorological observations during the period of investigation have been presented in Appendix I, II and shown in Fig 3.1 and 3.2

3.4 Experimental soils

The *in-situ* custard apple genotypes were found wild-growing in forest land, farmer's rice bunds and road side in the plains of Chhattisgarh. The soil type of the experimental site was silt-clay in texture with pH varying from 5.5 to 6.2. Nitrogen and potassium content of the soil is medium, while phosphorus level is medium to low. The relevant physico-chemical properties of the soil are given in Table 3.1

For soil analysis, randomly collected soil samples from 4 to 5 places upto a depth of 15 cm in the field were thoroughly mixed to make a composite soil sample. The composite sample was analyzed in Krishi Vigyan Kendra, Kanker, for soil physico-chemical properties.

3.5 Experimental materials

Sixty custard apple genotypes of about 8 to 10 year age were selected *In-situ* for investigation, which were found as wild seedling plants on forest land and rice bunds. Investigation was carried out at Antagarh, Bhanupratappur, Charama, Durgkondal, Kanker, Koylibeda and Narharpur blocks of District- Kanker (Chhattisgarh). The details of the custard apple genotypes selected for the study are given in Table 3.2. The experimental site is depicted in.

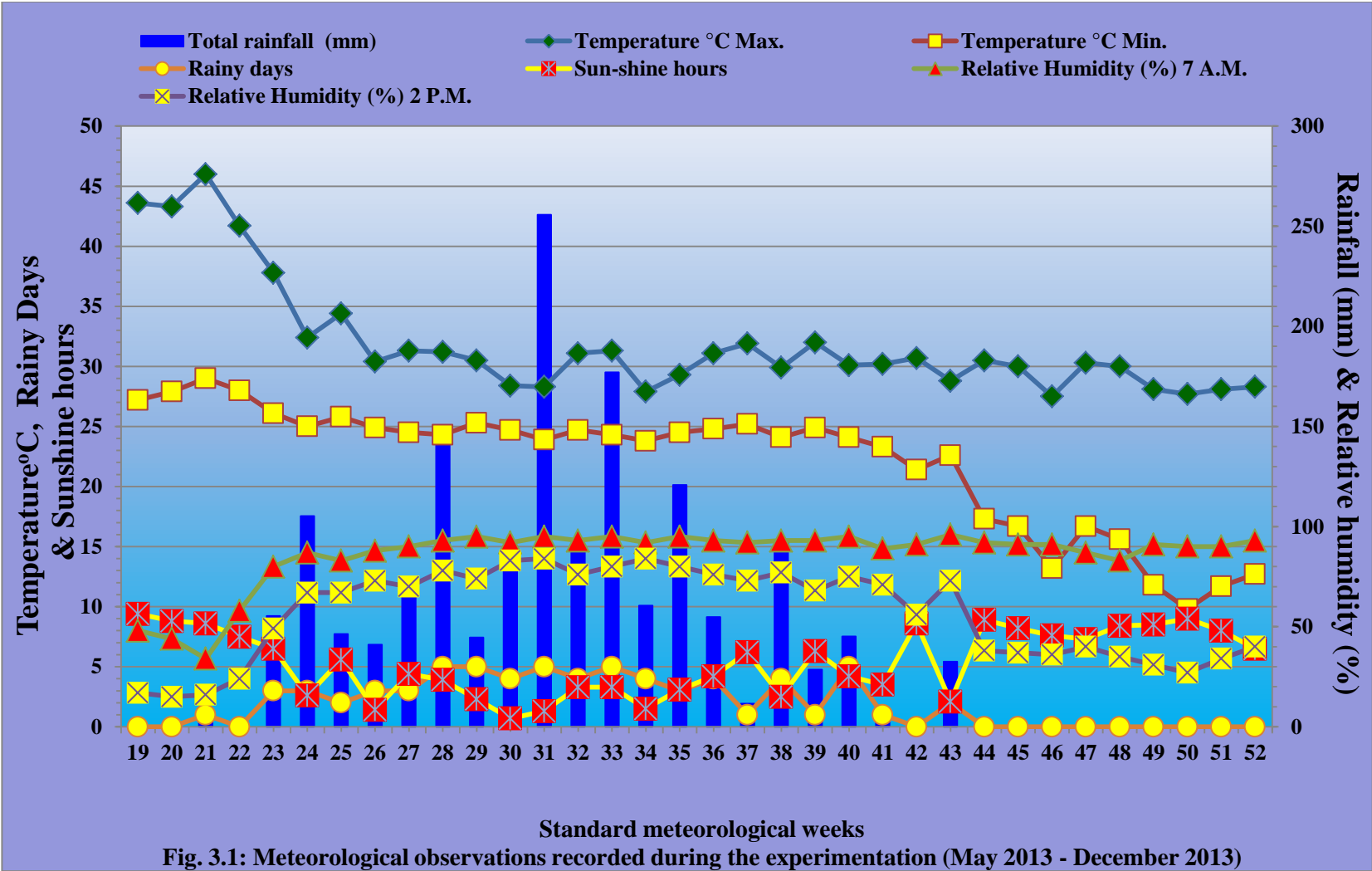
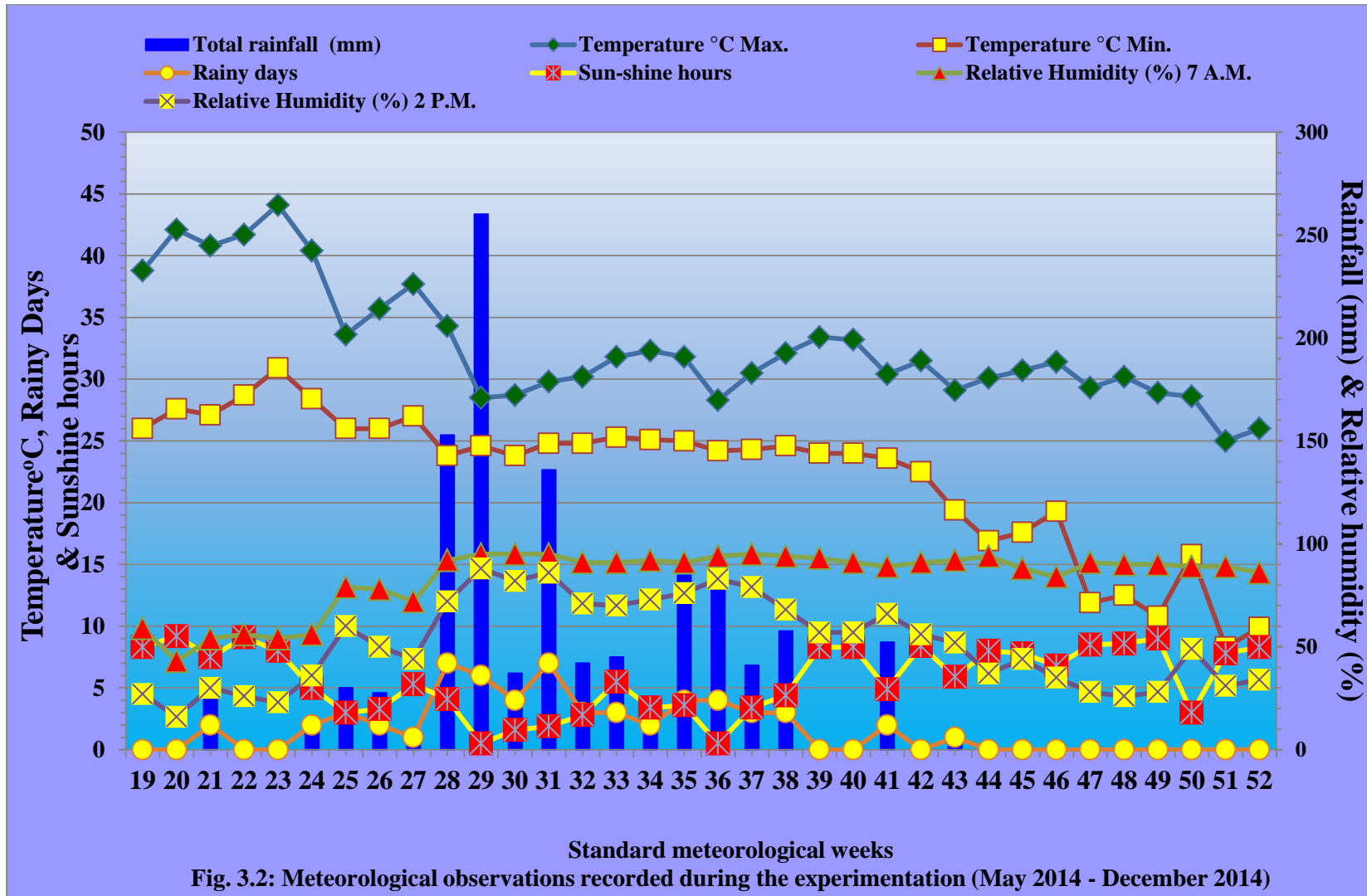


Fig. 3.1: Meteorological observations recorded during the experimentation (May 2013 - December 2013)



3.5.1 Experimental details

Crop	: Custard apple (<i>Annona squamosa</i> L.)
Location of Experiment	: <i>In-situ</i> plantation at Northern Bastar (Chhattisgarh)
Age of trees/plants	: 8 to 10 Years
Number of Replications	: Four
Number of Treatments	: 60 Custard apple genotypes
Design	: Randomized Complete Block Design
Soil type	: Silty-loam
Season	<i>Kharif</i> 2013-14 and <i>Kharif</i> 2014-15

3.6 Experimental methods

The detailed methods of the experiments are described below:

3.6.1 Experimental design

The experiment was laid out in Randomized Complete Block Design (RCBD) with 60 genotypes of custard apple replicated four times each having four branches in four side *i.e.*, North, East, West and South, which was treated as a replication. The genotypes were selected through village people and prepared passport data for research randomly in each village and blocks.




3.6.2 Cultural practices




The standard package of practices was adopted throughout the studies. The intercultural operation was done time to time at pre and post-monsoon seasons. To control the weeds of experimental site, hand weeding was done during the month of July and September.


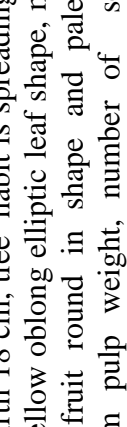

3.7 Observations recorded on morphological and yield parameters

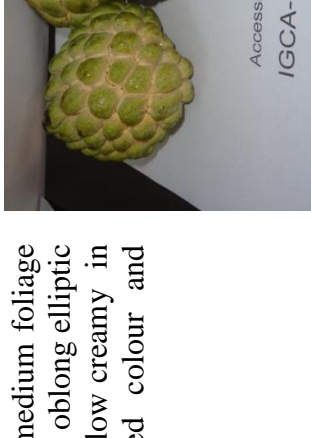
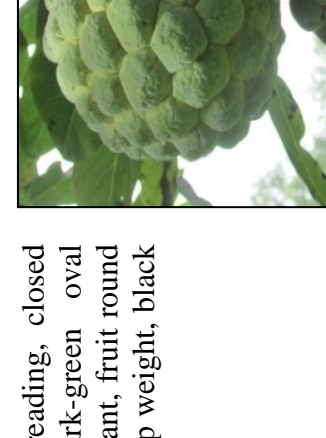
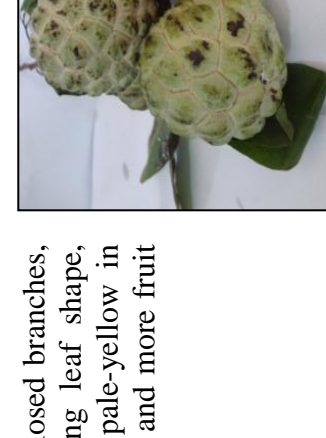
In-situ genotypes of custard apple available in different villages of Kanker district were identified on the basis of information collected from local people. Following genotypes were marked with appropriate number so that the data on different attributes for each genotype may be recorded.

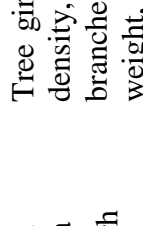
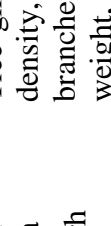
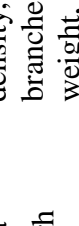
Table 3.3: Custard apple (*Annona squamosa* L.) genotypes used for experimental material

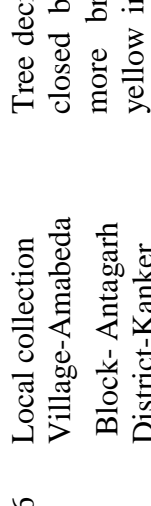
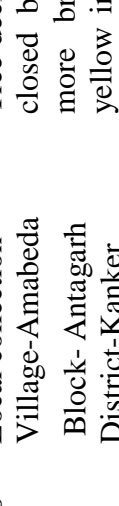
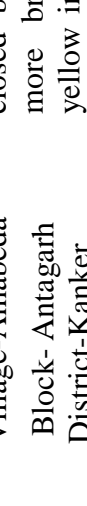
S. No.	Name of genotype	Source of genotype	Salient traits	Photographs
1.	IGCA-1	Local collection Village-Babu Saletola Block-Kanker District-Kanker (Chhattisgarh)	Tree habit is semi-spreading, branches close, medium plant height, oblong leaf shape, fruit heart shape and green in color, more branches per plant, good pulp weight, black seed colour and more fruit yield per plant.	
2.	IGCA-2	Local collection Village-Dumali Block-Kanker District-Kanker (Chhattisgarh)	Tree girth 20 cm, tree habit is spreading, branches close, medium plant height, dark-green oblong leaf shape, fruit heart shape and pale-yellow in color, more branches per plant, good pulp weight, black seed colour and more fruit yield per plant	
3.	IGCA-3	Local collection Village-Dudhawa Block-Kanker District-Kanker (Chhattisgarh)	Tree girth 18 cm, tree habit is semi-spreading, medium foliage density and plant height, more branches per plant, dark-green oblong elliptic leaf shape, fruit round in shape and pale-yellow in color, good pulp weight, black seed colour and more fruit yield per plant.	




S. No.	Name of genotype	Source of genotype	Salient traits	Photographs
4.	IGCA-4 Local collection Village-Khamdongri Block-Kanker District-Kanker (Chhattisgarh)	Tree girth 20 cm, tree habit is spreading, medium foliage density, dark green oblong leaf shape, more branches per plant, fruit heart shape and green in color , good pulp weight, black seed colour and more fruit yield per plant		
5.	IGCA-5 Local collection Village-Kulgaon Block-Kanker District-Kanker (Chhattisgarh)	Tree girth 19 cm, tree habit is semi-spreading, closed branches, dark-green oblong leaf shape, more branches per plant, fruit round in shape and pale-yellow in color, good pulp weight, black seed colour and more fruit yield per plant.		
6.	IGCA-6 Local collection Village-Pidapal Block-Kanker District-Kanker (Chhattisgarh)	Tree girth 20 cm, tree habit is spreading, closed branches, dark-green oblong leaf shape, more branches per plant, fruit heart shape and pale-yellow in color, good pulp weight, number of seed is medium and medium fruit yield per plant.		

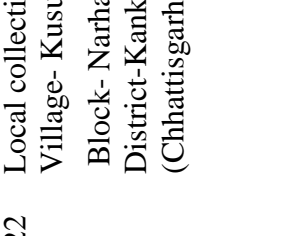
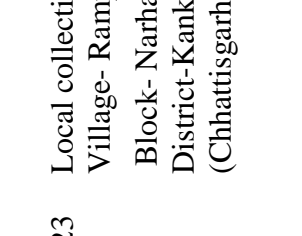
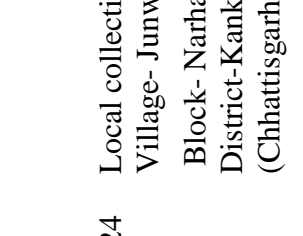
S. No.	Name of genotype	Source of genotype	Salient traits	Photographs
7.	IGCA-7	Local collection Village-Kurutola Block- Charama District-Kanker, (Chhattisgarh)	Tree girth 18 cm, tree habit is spreading, closed branches, pale-yellow oblong elliptic leaf shape, more branches per plant, fruit round in shape and pale-yellow in color, medium pulp weight, number of seed is more and medium fruit yield per plant.	
8.	IGCA-8	Local collection Village-Kherkheda Block- Charama District-Kanker (Chhattisgarh)	Tree girth 20 cm, tree habit is spreading, medium foliage density, dark green oblong leaf shape, more branches per plant, fruit pale-yellow in colour and heart shape, medium pulp weight, black seed colour and medium fruit yield per plant.	
9.	IGCA-9	Local collection Village-Palewa Block- Charama District-Kanker (Chhattisgarh)	Tree girth 18 cm, tree habit is semi-spreading, medium foliage density, dark green oblong elliptic leaf shape, more branches per plant, fruit pale-yellow in colour and heart shape and pale-yellow in color, medium pulp weight, black seed colour and medium fruit yield per plant.	




S. No.	Name of genotype	Source of genotype	Salient traits	Photographs
10.	IGCAA-10	Local collection Village-Jhipatola Block- Charama District-Kanker (Chhattisgarh)	Tree girth 20 cm, tree habit is spreading, medium foliage density, less branches per plant, dark-green oblong elliptic leaf shape, fruit heart shape and pale-yellow creamy in colour, medium pulp weight, black seed colour and medium fruit yield per plant.	
11.	IGCA-11	Local collection Village-Parsoda Block- Charama District-Kanker (Chhattisgarh)	Tree girth 19 cm, tree habit is semi-spreading, closed branches, medium foliage density, dark-green oval lanceolate leaf shape, more branches per plant, fruit round in shape and pale-yellow in color, good pulp weight, black seed colour and more fruit yield per plant.	
12.	IGCA-12	Local collection Village-Lakhanpuri Block- Charama District-Kanker (Chhattisgarh)	Tree girth 18 cm, tree habit is drooping, closed branches, medium foliage density, dark-green oblong leaf shape, more branches, fruit round in shape and pale-yellow in color, good pulp weight, black seed colour and more fruit yield per plant.	




S. No.	Name of genotype	Source of genotype	Salient traits	Photographs
13.	IGCA-13	Local collection Village-Erabeda Block- Antagarh District-Kanker (Chhattisgarh)	Tree girth 17 cm, tree habit is spreading, medium foliage density, dark-green oblong elliptic leaf shape, more branches, fruit round in shape pale yellow, good pulp weight, black seed colour and medium fruit yield per plant.	
14.	IGCA-14	Local collection Village-Kolar Block- Antagarh District-Kanker (Chhattisgarh)	Tree girth 16 cm, tree habit is semi-spreading, medium foliage density, dark-green oblong leaf shape, more branches, fruit heart shape pale yellow, good pulp weight, black seed colour and medium fruit yield per plant.	
15.	IGCA-15	Local collection Village-Tahkal Block- Antagarh District-Kanker (Chhattisgarh)	Tree girth 19 cm, tree habit is drooping, closed branches, dark green oblong leaf shape, more branches per plant, fruit heart shape and pale-yellow in colour, good pulp weight, black seed colour and medium fruit yield per plant.	

S. No.	Name of genotype	Source of genotype	Salient traits	Photographs
16.	IGCA-16	Local collection Village-Amabeda Block- Antagarh District-Kanker (Chhattisgarh)	Tree deciduous, trunk girth 19 cm, tree habit is drooping, closed branches, dark-green oblong elliptic leaf shape, more branches per plant, fruit round in shape and pale-yellow in color, medium pulp weight, black seed colour and medium fruit yield per plant	
17.	IGCA-17	Local collection Village-Talgaon Block- Antagarh District-Kanker (Chhattisgarh)	Tree girth 18 cm, tree habit is semi-spreading, closed branches, dark-green oblong leaf shape, more branches per plant, fruit round in shape and pale-yellow in color, medium pulp weight, black to brown seed colour and medium fruit yield per plant.	
18.	IGCA-18	Local collection Village-Barrebeda Block- Antagarh District-Kanker (Chhattisgarh)	Tree girth thick, tree habit is semi-spreading, more foliage, dark-green oblong elliptic leaf shape, more branches per plant, fruit round in shape pale-yellow, medium pulp weight, black to brown seed colour and more fruit yield per plant.	


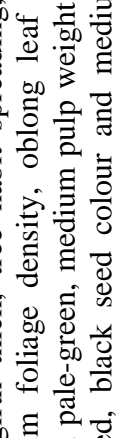
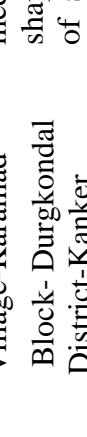
S. No.	Name of genotype	Source of genotype	Salient traits	Photographs
19.	IGCA-19	Local collection Village- Sarangpal Block- Narharpur District-Kanker (Chhattisgarh)	Tree girth thick, tree habit is spreading dark-green lanceolate leaf shape, more branches per plant, fruit heart shape and pale-yellow in color, more pulp weight, black to brown seed colour and more fruit yield per plant.	 <p>Photograph showing three green, bumpy fruits of genotype IGCA-19 on a red background. A white label with 'IGCA-19' is placed on the top fruit.</p>
20.	IGCA-20	Local collection Village- Markatola Block- Narharpur District-Kanker (Chhattisgarh)	Tree girth thick, tree habit is semi-spreading, dark-green oblong elliptic leaf shape, more branches per plant, fruit heart shape and light-green, pale-green, more pulp weight, black to brown seed colour less number of seed and more fruit yield per plant.	 <p>Photograph showing three green, bumpy fruits of genotype IGCA-20 on a red background. A white label with 'IGCA-20' is placed on the bottom fruit.</p>
21.	IGCA-21	Local collection Village- Kisanpuri Block- Narharpur District-Kanker (Chhattisgarh)	Tree girth thick, tree habit is spreading, dark-green oblong leaf shape, foliage density medium, more branches per plant, fruit heart shape and pale-yellow in color, pale-green, more pulp weight, black to brown seed colour less number of seed and more fruit yield per plant.	 <p>Photograph showing a single dark green, bumpy fruit of genotype IGCA-21 hanging from a branch with green leaves. A white label with 'IGCA-21' is placed on the fruit.</p>


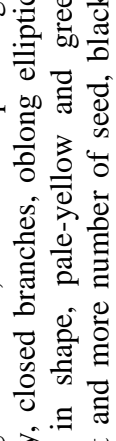

S. No.	Name of genotype	Source of genotype	Salient traits	Photographs
22.	IGCA-22	Local collection Village- Kusumpani Block- Narharpur District-Kanker (Chhattisgarh)	Tree girth thick, tree habit is semi-spreading, closed branches, medium foliage density, dark-green oblong leaf shape, more branches per plant, fruit round in shape and green, medium pulp weight, black seed colour and medium fruit yield per plant.	 A photograph showing a cluster of green, bumpy fruits hanging from a branch. A small white label with the text 'IGCA-22' is attached to the branch.
23.	IGCA-23	Local collection Village- Rampur Block- Narharpur District-Kanker (Chhattisgarh)	Tree girth thick, tree habit is spreading, closed branches, medium foliage density, dark-green oblong leaf shape, more branches per plant, fruit round in shape and pale-yellow in color, medium pulp weight, black seed colour and medium fruit yield per plant.	 A photograph showing two clusters of pale yellow-green, bumpy fruits hanging from a branch. A small white label with the text 'IGCA-23' is attached to the branch.
24.	IGCA-24	Local collection Village- Junwani Block- Narharpur District-Kanker (Chhattisgarh)	Tree girth thick, tree habit is semi- spreading, medium foliage density, dark-green oblong elliptic leaf shape, fruit round in shape, pale-yellow, medium pulp weight less number of seed, black seed colour and medium fruit yield per plant.	 A photograph showing two clusters of pale yellow-green, bumpy fruits hanging from a branch. A small white label with the text 'Accession No. IGCA-13-24' is attached to the branch.



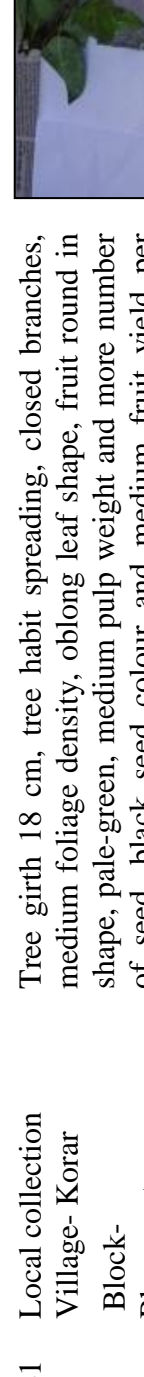
S. No.	Name of genotype	Source of genotype	Salient traits	Photographs
25.	IGCA-25	Local collection Village-Pardal Block- Durgkondal District-Kanker (Chhattisgarh)	Tree girth thick, tree habit is semi- spreading, medium foliage density, dark-green oblong elliptic leaf shape, fruit heart shape and green in color, light-green, medium pulp weight and less number of seed, black seed colour and medium fruit yield per plant.	
26.	IGCA-26	Local collection Village-Hotkondal Block- Durgkondal District-Kanker (Chhattisgarh)	Tree girth thick, tree habit is spreading, closed branches, medium foliage density, dark-green oblong leaf shape, fruit round in shape, pale-yellow, medium pulp weight and less number of seed, black seed colour and medium fruit yield per plant.	
27.	IGCA-27	Local collection Village-Hotkondal Block- Durgkondal District-Kanker (Chhattisgarh)	Tree girth thick, tree habit is semi-spreading, closed branches, dark-green oblong leaf shape, fruit round in shape, pale-green, medium pulp weight and number of seed, black seed colour and medium fruit yield per plant.	

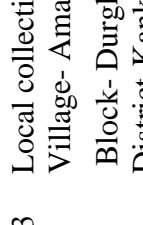

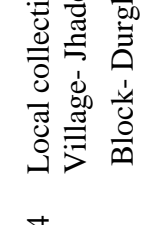
S. No.	Name of genotype	Source of genotype	Salient traits	Photographs
28.	IGCA-28	Local collection Village-Rastuli Block- Durgkondal District-Kanker (Chhattisgarh)	Tree girth thick, tree habit is spreading, closed branches, dark-green oblong elliptic leaf shape, fruit heart shape, green, medium pulp weight and number of seed, black seed colour and medium fruit yield per plant.	
29.	IGCA-29	Local collection Village-Saganipur Block- Durgkondal District-Kanker (Chhattisgarh).	Tree girth thick, tree habit is semi-spreading, medium foliage density, closed branches, dark-green oblong leaf shape, fruit heart shape, pale-green, medium pulp weight and more number of seed, black seed colour and medium fruit yield per plant.	
30.	IGCA-30	Local collection Village-Heparkasa Block- Durgkondal District-Kanker (Chhattisgarh)	Tree girth thick, tree habit spreading, closed branches, medium foliage density, dark-green oval lanceolate leaf shape, fruit heart shape, pale-green, medium pulp weight and more number of seed, black seed colour and medium fruit yield per plant.	

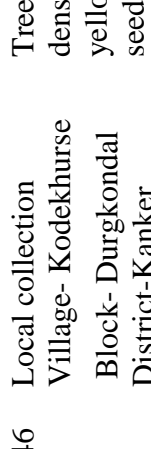
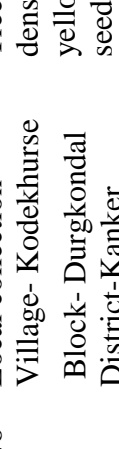
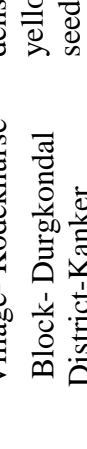
S. No.	Name of genotype	Source of genotype	Salient traits	Photographs
31.	IGCA-31	Local collection Village-Tamani Block- Durgkondal District-Kanker (Chhattisgarh)	Tree girth thick, tree habit spreading, closed branches, medium foliage density, dark-green oval lanceolate leaf shape, fruit heart shape, pale-green, medium pulp weight and number of seed is more, black seed colour and medium fruit yield per plant.	
32.	IGCA-32	Local collection Village-Kanarpur Block- Durgkondal District-Kanker (Chhattisgarh)	Tree girth thick, tree habit spreading, closed branches, medium foliage density, dark-green oval lanceolate leaf shape, fruit round shape, pale-green, medium pulp weight and number of seed, black seed colour and medium fruit yield per plant	
33.	IGCA-33	Local collection, Village-Kukuri Block- Durgkondal District-Kanker (Chhattisgarh)	Tree girth thick, tree habit semi-spreading, medium foliage density, dark-green oblong leaf shape, fruit heart shape, pale-green, medium pulp weight and number of seed, black seed colour and medium fruit yield per plant.	




S. No.	Name of genotype	Source of genotype	Salient traits	Photographs
34.	IGCA-34	Local collection Village-Karamad Block- Durgkondal District-Kanker (Chhattisgarh)	Tree girth thick, tree habit spreading, closed branches, medium foliage density, oblong leaf shape, fruit heart shape, pale-green, medium pulp weight and more number of seed, black seed colour and medium fruit yield per plant.	
35.	IGCA-35	Local collection Village-Karamad Block- Durgkondal District-Kanker (Chhattisgarh)	Tree girth 18 cm, tree habit semi-spreading, closed branches, oblong leaf shape, fruit round in shape, pale-green, medium pulp weight and more number of seed, black seed colour and medium fruit yield per plant.	
36.	IGCA-36	Local collection Village-Bagdah Block- Durgkondal District-Kanker (Chhattisgarh)	Tree girth 19 cm, tree habit erect, closed branches, oblong elliptic leaf shape, fruit round in shape, pale-yellow and green, medium pulp weight and more number of seed, black seed colour and medium fruit yield per plant.	




S. No.	Name of genotype	Source of genotype	Salient traits	Photographs
37.	IGCA-37	Local collection, Village- Sambalpur Block- Bhanupratappur District-Kanker (Chhattisgarh)	Tree girth 18 cm, tree habit spreading, medium foliage density, closed branches, oblong elliptic leaf shape, fruit round in shape, pale-yellow and green, medium pulp weight and more number of seed, black seed colour and medium fruit yield per plant.	
38.	IGCA-38	Local collection, Village- Bhanbeda Block- Bhanupratappur District-Kanker (Chhattisgarh)	Tree girth 19 cm, tree habit spreading, medium foliage density, closed branches, oval leaf shape, fruit heart shape, pale-yellow, medium pulp weight and more number of seed, black seed colour and medium fruit yield per plant.	
39.	IGCA-39	Local collection, Village- Mulla Block- Bhanupratappur District-Kanker (Chhattisgarh)	Tree girth 18 cm, tree habit spreading, medium foliage density, closed branches, oval leaf shape, fruit round in shape, pale-yellow, medium pulp weight and more number of seed, black seed colour and medium fruit yield per plant.	


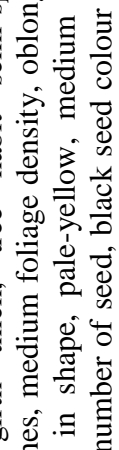
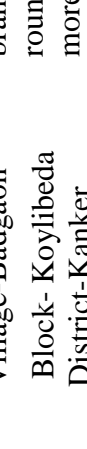
S. No.	Name of genotype	Source of genotype	Salient traits	Photographs
40.	IGCA-40	Local collection Village- Chilhati Block- Bhanupratappur District-Kanker (Chhattisgarh)	Tree girth 19 cm, tree habit spreading, medium foliage density, closed branches, oval leaf shape, fruit heart shape, pale-yellow, medium pulp weight and more number of seed, black seed colour and medium fruit yield per plant.	
41.	IGCA-41	Local collection Village- Korar Block- Bhanupratappur District-Kanker (Chhattisgarh)	Tree girth 18 cm, tree habit spreading, closed branches, medium foliage density, oblong leaf shape, fruit round in shape, pale-green, medium pulp weight and more number of seed, black seed colour and medium fruit yield per plant.	
42.	IGCA-42	Local collection Village- Karremad Block- Bhanupratappur District-Kanker (Chhattisgarh)	Tree girth 19 cm, tree habit spreading, medium foliage density, closed branches, oblong leaf shape, fruit heart shape, pale-green, medium pulp weight and more number of seed, black seed colour and medium fruit yield per plant.	




S. No.	Name of genotype	Source of genotype	Salient traits	Photographs
43.	IGCA-43	Local collection Village- Amatwahi Block- Durgkondal District-Kanker (Chhattisgarh)	Tree girth 19 cm, tree habit spreading, medium foliage density, oblong leaf shape, fruit round in shape, pale-green, less pulp weight and more number of seed, black seed colour and medium fruit yield per plant.	
44.	IGCA-44	Local collection Village- Jhadekhurse Block- Durgkondal District-Kanker (Chhattisgarh)	Tree girth 19 cm, tree habit semi-spreading, medium foliage density, oblong leaf shape, fruit heart shape, pale-green, medium pulp weight and more number of seed, black seed colour and medium fruit yield per plant.	
45.	IGCA-45	Local collection, Village- Hatkondal Block- Durgkondal District-Kanker (Chhattisgarh)	Tree girth 18 cm, tree habit semi-spreading, closed branches, medium foliage density, oblong leaf shape, fruit round in shape, pale-yellow, medium pulp weight and more number of seed, black seed colour and medium fruit yield per plant.	

S. No.	Name of genotype	Source of genotype	Salient traits	Photographs
46.	IGCA-46	Local collection Village- Kodekhurse Block- Durgkondal District-Kanker (Chhattisgarh)	Tree girth 18 cm, tree habit spreading, medium foliage density, oblong leaf shape, fruit round in shape, pale-yellow, less pulp weight and more number of seed, black seed colour and medium fruit yield per plant.	
47.	IGCA-47	Local collection Village- Raurwadi Block- Durgkondal District-Kanker (Chhattisgarh)	Tree girth 19 cm, tree habit semi-spreading, medium foliage density, oblong leaf shape, fruit heart shape, pale-yellow, medium pulp weight and more number of seed, black seed colour and medium fruit yield per plant.	
48.	IGCA-48	Local collection Village- Kemal Block- Durgkondal District-Kanker (Chhattisgarh)	Tree girth thick, tree habit spreading, medium foliage density, oval leaf shape, fruit heart shape, pale-yellow, medium pulp weight and more number of seed, black seed colour and medium fruit yield per plant.	

S. No.	Name of genotype	Source of genotype	Salient traits	Photographs
49.	IGCA-49	Local collection, Village-Bandey Block- Koylibeda District-Kanker (Chhattisgarh)	Tree girth thick, tree habit semi-spreading, closed branches, medium foliage density, oval leaf shape, fruit heart shape, pale-green-yellow, medium pulp weight and more number of seed, black seed colour and medium fruit yield per plant.	 <p>A photograph showing a cluster of green, bumpy fruits (likely a type of mango) against an orange background. A white label with the text 'IGCA-49' is attached to the cluster.</p>
50.	IGCA-50	Local collection Village-Sitram Block- Koylibeda District-Kanker (Chhattisgarh)	Tree girth thick, tree habit semi-spreading, closed branches, medium foliage density, oval leaf shape, fruit round in shape, pale-green-yellow, medium pulp weight and more number of seed, black seed colour and less fruit yield per plant.	 <p>A photograph showing a cluster of green, bumpy fruits against a light blue background. A white label with the text 'Accession No. IGCA-13-50' is visible.</p>
51.	IGCA-51	Local collection Village-Katarubodi Block- Koylibeda District-Kanker (Chhattisgarh)	Tree girth thick, tree habit semi-spreading, closed branches, medium foliage density, oval leaf shape, fruit round in shape, pale-green, less pulp weight and more number of seed, black seed colour and less fruit yield per plant.	 <p>A photograph showing a cluster of green, bumpy fruits against a light blue background. A white label with the text 'Accession No. IGCA-13-51' is visible.</p>

S. No.	Name of genotype	Source of genotype	Salient traits	Photographs
52.	IGCA-52	Local collection Village-Karmed Block- Koylibeda District-Kanker (Chhattisgarh)	Tree girth thick, tree habit spreading, medium foliage density, oval leaf shape, fruit round in shape, pale-green, less pulp weight and more number of seed, black seed colour and less fruit yield per plant	
53.	IGCA-53	Local collection Village-Chiramtarae Block- Koylibeda District-Kanker (Chhattisgarh)	Tree girth thick, tree habit semi-drooping, closed branches, medium foliage density, closed branches, oblong leaf shape, fruit oval in shape, pale- yellow, medium pulp weight and more number of seed, black seed colour and medium fruit yield per plant.	
54.	IGCA-54	Local collection, Village-Udanpur Block- Koylibeda District-Kanker (Chhattisgarh)	Tree girth thick, tree habit semi-spreading, medium foliage density, oblong leaf shape, fruit oval in shape, pale-green, medium pulp weight and more number of seed, black seed colour and medium fruit yield per plant.	

S. No.	Name of genotype	Source of genotype	Salient traits	Photographs
55.	IGCA-55	Local collection, Village-Badgaon Block- Koylibeda District-Kanker (Chhattisgarh)	Tree girth thick, tree habit semi-spreading, closed branches, medium foliage density, oblong leaf shape, fruit round in shape, pale-yellow, medium pulp weight and more number of seed, black seed colour and medium fruit yield per plant.	
56.	IGCA-56	Local collection, Village-Sikhsord Block- Koylibeda District-Kanker (Chhattisgarh)	Tree girth thick, tree habit spreading, closed branches, medium foliage density, oblong leaf shape, fruit round in shape, pale-yellow, less pulp weight and more number of seed, black seed colour and less fruit yield per plant.	
57.	IGCA-57	Local collection, Village-Parodi Block- Koylibeda District-Kanker (Chhattisgarh)	Tree girth thick, tree habit semi-spreading, medium foliage density, oval leaf shape, fruit round in shape, pale- yellow, less pulp weight and more number of seed, black seed colour and less fruit yield per plant.	

S. No.	Name of genotype	Source of genotype	Salient traits	Photographs
58.	IGCA-58	Local collection Village-Simangi Block- Koylibeda District-Kanker (Chhattisgarh)	Tree girth thick, tree habit spreading, medium foliage density, oval leaf shape, fruit round in shape, pale-yellow, black seed colour, less pulp weight and more number of seed, and less fruit yield per plant.	
59.	IGCA-59	Local collection Village-Gumabeda Block- Koylibeda District-Kanker (Chhattisgarh)	Tree girth thick, tree habit semi-drooping, medium foliage density, oval leaf shape, fruit round in shape, pale-yellow, black seed colour, less pulp weight and more number of seed, and less fruit yield per plant.	
60.	IGCA-60	Local collection, Village-Chargaon Block- Koylibeda District-Kanker (Chhattisgarh)	Tree girth thick, tree habit semi-spreading, closed branches, medium foliage density, oval leaf shape, fruit heart shape, pale-yellow, black seed colour, medium pulp weight and more number of seed, and medium fruit yield per plant.	

Observations on morphological, yield parameters, descriptive as well as parametric, were recorded and genotypes categorized, wherever applicable as per the standard descriptors of custard apple (Mahajan *et al.*, 2002) for two seasons.

Table.3.4: *In-situ* custard apple genotypes and their Location

S. No.	Genotypes	Latitude	Longitude	Mean Sea Level (metre)	Location	
					Village	Block
1.	IGCA-1	N 20°19.297	E 081° 32.502	385	Babu Saletola	Kanker
2.	IGCA-2	N 20°19.292	E 081° 32.486	383	Dumali	Kanker
3.	IGCA-3	N 20°20.203	E 081° 32.065	384	Dudhawa	Kanker
4.	IGCA-4	N 20°20.199	E 081° 32.078	388	Khamdongri	Kanker
5.	IGCA-5	N 20°20.197	E 081° 32.057	382	Kulgaon	Kanker
6.	IGCA-6	N 20°20.210	E 081° 33.061	386	Pidapal	Kanker
7.	IGCA-7	N 20°12.297	E 081° 33.057	383	Kurutola	Charama
8.	IGCA-8	N 20°12.256	E 081° 31.789	389	Kherkheda	Charama
9.	IGCA-9	N 20°13.257	E 081° 33.855	383	Palewa	Charama
10.	IGCA-10	N 20°20.271	E 081° 33.912	383	Jhipatola	Charama
11.	IGCA-11	N 20°11.350	E 081° 31.936	414	Parsoda	Charama
12.	IGCA-12	N 20°11.345	E 081° 31.922	414	Lakhanpuri	Charama
13.	IGCA-13	N 20°15.245	E 081° 33.101	433	Erabeda	Antagarh
14.	IGCA-14	N 20°15.249	E 081° 33.103	423	Kolar	Antagarh
15.	IGCA-15	N 20°15.241	E 081° 33.089	420	Tahkal	Antagarh
16.	IGCA-16	N 20°15.244	E 081° 33.099	421	Amabeda	Antagarh
17.	IGCA-17	N 20°15.243	E 081° 33.102	422	Talgaon	Antagarh
18.	IGCA-18	N 20°15.240	E 081° 33.087	426	Barrebeda	Antagarh
19.	IGCA-19	N 20°11.548	E 081° 31.933	431	Sarangpal	Narharpur
20.	IGCA-20	N 20°11.550	E 081° 31.936	430	Markatola	Narharpur
21.	IGCA-21	N 20°11.558	E 081° 31.925	433	Kisanpuri	Narharpur
22.	IGCA-22	N 20°11.545	E 081° 31.923	438	Kusumpani	Narharpur
23.	IGCA-23	N 20°11.549	E 081° 31.919	435	Rampur	Narharpur
24.	IGCA-24	N 20°11.550	E 081° 31.910	437	Junwani	Narharpur
25.	IGCA-25	N 20°19.310	E 081° 32.489	383	Pardal	Durgkondal
26.	IGCA-26	N 20°19.278	E 081° 32.492	382	Hotkondal	Durgkondal
27.	IGCA-27	N 20°19.279	E 081° 32.486	380	Hotkondal	Durgkondal
28.	IGCA-28	N 20°19.298	E 081° 32.475	387	Rastuli	Durgkondal
29.	IGCA-29	N 20°19.285	E 081° 32.465	388	Saganipur	Durgkondal
30.	IGCA-30	N 20°19.297	E 081° 32.502	385	Heparkasa	Durgkondal
31.	IGCA-31	N 20°11.721	E 081° 22.558	556	Tamani	Durgkondal
32.	IGCA-32	N 20°11.774	E 081° 22.532	559	Kanarpur	Durgkondal
33.	IGCA-33	N 20°12.732	E 081° 22.598	550	Kukuri	Durgkondal
34.	IGCA-34	N 20°11.566	E 081° 33.124	553	Karamad	Durgkondal

S. No.	Genotypes	Latitude	Longitude	Mean Sea Level (metre)	Location	
					Village	Block
35.	IGCA-35	N 20°11.545	E 081° 33.133	554	Karamad	Durgkondal
36.	IGCA-36	N 20°13.136	E 081° 20.590	555	Bagdah	Durgkondal
37.	IGCA-37	N 20°18.216	E 081° 26.470	327	Sambalpur	Bhanupratappur
38.	IGCA-38	N 20°19.250	E 081° 33.501	323	Bhanbeda	Bhanupratappur
39.	IGCA-39	N 20°18.297	E 081° 31.477	393	Mula	Bhanupratappur
40.	IGCA-40	N 20°19.288	E 081° 33.356	390	Chilhathi	Bhanupratappur
41.	IGCA-41	N 20°18.290	E 081° 32.432	398	Korar	Bhanupratappur
42.	IGCA-42	N 20°18.295	E 081° 32.436	396	Karremad	Bhanupratappur
43.	IGCA-43	N 20°16.235	E 081° 31.425	402	Amatwahi	Durgkondal
44.	IGCA-44	N 20°17.242	E 081° 31.422	432	Jhadekhurse	Durgkondal
45.	IGCA-45	N 20°17.245	E 081° 31.420	431	Hatkondal	Durgkondal
46.	IGCA-46	N 20°17.248	E 081° 31.431	435	Kodekhurse	Durgkondal
47.	IGCA-47	N 20°17.249	E 081° 31.432	433	Rauarwadi	Durgkondal
48.	IGCA-48	N 20°17.240	E 081° 31.438	423	Kemal	Durgkondal
49.	IGCA-49	N 20°18.232	E 081° 31.420	325	Bandey	Koylibeda
50.	IGCA-50	N 20°18.210	E 081° 31.428	322	Sitram	Koylibeda
51.	IGCA-51	N 20°18.216	E 081° 31.425	329	Kutru Bodi	Koylibeda
52.	IGCA-52	N 20°18.214	E 081° 31.427	323	Kardmed	Koylibeda
53.	IGCA-53	N 20°18.216	E 081° 31.429	330	Chiramtarai	Koylibeda
54.	IGCA-54	N 20°18.218	E 081° 31.432	323	Udanpur	Koylibeda
55.	IGCA-55	N 20°18.336	E 081° 30.465	345	Badgaon	Koylibeda
56.	IGCA-56	N 20°19.345	E 081° 30.470	346	Shikhsord	Koylibeda
57.	IGCA-57	N 20°18.355	E 081° 31.474	356	Parodi	Koylibeda
58.	IGCA-58	N 20°19.389	E 081° 30.466	362	Simangi	Koylibeda
59.	IGCA-59	N 20°18.299	E 081° 31.467	358	Gumabeda	Koylibeda
60.	IGCA-60	N 20°18.302	E 081° 31.471	354	Chargaon	Koylibeda

1. Tree habit

As per the descriptors of custard apple, considering the overall nature of tree growth, custard apple genotypes were categorized into “upright and compact” (trunk erect with more number of erect branches), “upright and open” (trunk erect and usually with sparse more of open branches) and “spreading” (branches close to ground spreading horizontally) tree habit.

2. Branching pattern

Based on the growth habit of branches, the genotypes were grouped into “extensive” (one branch arises below apex of twig with each flush of growth) and

“intensive” (several branches arise below apex of twig with each flush of growth) pattern based on the descriptors of custard apple.

3. Plant height (m)

The height of the tree was measured vertically from the ground to the tip of the tree and recorded as plant height in metres with the help of instrument Hypso-Meter. The plant height of genotypes was classified based on the descriptor as “dwarf” (< 5.5 m), “semi-tall” (5.5-8.5 m) and “tall” (> 8.5 m).

4. Canopy height (m)

Canopy height was measured from the lowest portion of the canopy to the top portion of the canopy using extendable measuring pole and was expressed in metres.

5. Trunk girth (cm)

The circumference of the tree trunk (main stem at collar region of the plant) was measured at 30 cm above from the base and recorded as tree girth in centimetres.

6. Canopy spread (m)

The diametric length of the ground space occupied by the tree was measured in two directions and the canopy spread was recorded in metres as “North-South Spread” and “East- West Spread” for all genotypes. The canopy spread were classified based on the descriptor as less (< 3.0 m), intermediate (3.0-6.0 m) and high (>6.0m).

7. Colour of new flush

Visual colour of young leaves was recorded as dark-green to green.

8. Leaf colour

Visual colour of mature leaves was recorded as green, dark-green and light green as per the custard apple (Mahajan *et al.*, 2002) Descriptors in all the genotypes.

9. Length of leaf (cm)

The length of leaf size was recorded by using scale. Average number of 10 leaves in different direction of the plant was used for the observation and length of leaf

(cm) was recorded. Non destructive method sampling was done for this purpose. The leaf length of genotypes was classified based on the descriptor as small.

10. Number of alternate leaf per branch

Number of alternate leaves per branch was counted manually in each replication and genotypes during the flushing and then total number of leaves were calculated.

11. Leaf shape

Fully expanded mature leaves were observed and the characteristic shape of the leaf was recorded as oblong, obovate (club shaped), or oval as per the Custard apple Descriptors in all the genotypes.

12. Leaf apex shape

Tip of the matured leaves was observed for recording the leaf apex shape as 'pointed', 'rounded' or 'indented' (slight notch).

13. Number of laterals per m²

One square metres wooden frame was hand-held on tree canopy and all the shoots, flowering as well as non-flowering ones, falling within the wooden frame were counted. Such counts were taken in all the four directions and mean of them was expressed as the number of laterals/m² in each genotype.

14. Number of flowering laterals per m²

This was derived from the above exercise described at S. No. 12, which in turn was used for computing per cent flowering intensity per m² (% of flowering laterals over total number of laterals). The flowering intensity per m² of genotypes was classified based on the descriptor as low (< 40 %), medium (40-70 %) and high (> 70 %).

15. Season of flowering

Time of flowering was recorded by noting down the date of emergence of first 10-15 flowers per branches. Based on this, the genotypes were identified as "Early"

(15th June – 25th June), “Mid-season” (25th June – 20th July) and “late” (20th July – 5th August) types.

16. Length of Inflorescence (cm)

The length of flower was measured vertically from base to the tip of flower and recorded in centimeters. Five flower in each direction were measured per branches and mean flower length was worked out.

17. Flowering duration

Sixty genotypes were selected to study flowering duration and other flowering characters and branches were treated as replication in each genotypes. Five branches in each direction were tagged at random before flowering. The branches were tagged in all the genotypes, as and when emerged, depending on the time of flowering in each genotype. The tagged branches were selected for recording the date from the day of first flower initiation to the day of last flowering in each branch. The genotypes were classified based on the descriptors as Short – (<90 days), Medium- (60 to 90 days) and Long- (>90 days).

18. Number of flowers per branch

Number of flowers per branch was counted manually in each replication and genotypes during the flowering and then total number of flowers was calculated.

19. Petal colour

Such descriptive character as colour of petal (dark-green, light-green, creamy-white), were observed and recorded as per the custard apple Descriptors (Mahajan *et al.*, 2002) in all the genotypes.

20. Number of fruits per tree

During the peak time of the season, numbers of fruits set and developed to maturity were counted in each of branches and in each direction. Mean number of fruits per tree was worked out in each genotype.

21. Fruit shape

Such descriptive character as fruit shape (oblong, round, heart shape), were observed and recorded as per the custard apple Descriptors (Mahajan *et al.*, 2002), in all the genotypes.

22. Fruit colour

Such descriptive character as colour of matured fruits (Pale-yellow, creamy-white, light-green, pink and dark-green), were observed and recorded as per the custard apple Descriptors (Mahajan *et al.*, 2002) in all the genotypes.

23. Fruit width (cm)

Individual mature fruits were measured for width with the help of Vernier Calipers. Four side width of fruits was recorded and mean width computed and expressed as fruit width in centimetre.

24. Fruit length (cm)

An individual mature fruit was taken for measuring the length with the help of scale. Four side length of fruits was recorded and mean length computed and expressed as fruit length in centimetre.

25. Fruit weight (g)

Individual weight of three fruits, collected from the mature fruits, was recorded and mean weight computed was expressed as fruit weight in grams. Genotypes were classified into those having fruits of low (< 50g), medium (200-300 g) and high (> 400 g) weight.

26. Fruit set (%)

Percentage of fruit set per tree was worked out in each genotype. First recorded the total number of bisexual flowers in a branch and thereafter counted the total number of fruits set then divided the total number of fruit set by the number of bisexual flowers and multiplied by hundred.

27. Length of pedicel (cm)

Length from the point of attachment to fruit stalk of three individual fruits, which were used for recording length of pedicel, and it was measured with measuring scale. The mean length was computed and expressed in centimetres.

28. Pedicel thickness (mm)

The thickness of individual pedicel was measured with Vernier Caliper and the mean was computed and expressed as pedicel thickness in millimetres.

29. Pericarp length (cm)

The length of pericarp of individual fruits was measured vertically with the help of scale and the mean was computed and expressed as pericarp length in centimetres.

30. Pericarp weight (g)

Individual weight of pericarp, collected from the ripened fruits, was recorded and means weight was computed and expressed as pericarp weight in grams.

31. Pulp weight (g)

Individual weight of pulp, collected from the ripened fruits, was recorded and mean weight computed was expressed as pulp weight in grams. Genotypes were classified into those having fruits of “low”(< 50g), “medium” (50-100 g) and “high” (> 200 g) pulp weight.

32. Seed length (mm)

Individual seed length was measured vertically with the help of scale and the mean was computed and expressed as seed length in centimetres.

33. Seed width (mm)

Individual seed of fruits was taken for measuring the seed width with the help of Vernier Calipers. Four side widths of seed were recorded and mean width was computed and expressed as fruit width in centimetre.

34. Number of seeds per fruit

Seeds were collected from ripened fruit and counted. Mean number of seeds per fruit was worked out and recorded as number of seeds in each genotype.

35. Seed weight (g)

The seed weight of individual seed, collected from the extracted seed, was recorded and mean weight computed was expressed as seed weight in grams. Genotypes were classified into those having fruits of “low” (< 2-3g), “medium” (3-5 g) and “high” (> 5 g) seed weight.

36. Fruit cracking (%)

Percentage of fruit cracking was recorded after dividing the number of cracked fruits by the total number of fruits on the tree during ripening in each genotype and presented as per cent fruit cracking in a tree.

37. Fruit yield per plant (kg)

Total weight of fruits collected from each tree during the entire season was recorded and mean weight was expressed as fruit yield per tree in kilograms.

38. Number of fruits per tree

Fruits were collected from the tree and counted. Mean number of fruits per tree was worked out and recorded as number of fruits in each genotype.

39. Pulp colour

Such descriptive character as colour of fruits pulp (creamy-white, light -white, white), were observed and recorded as per the custard apple Descriptors (Mahajan *et al.*, 2002) in all the genotypes.

40. Pulp texture

Such descriptive character as texture of fruit pulp (granular, smooth, and cloudy) were observed and recorded as per the custard apple Descriptors (Mahajan *et al.*, 2002) in all the genotypes.

41. Seed colour

Such descriptive character as colour of seed (brown, black, dark-black) were observed and recorded as per the custard apple Descriptors (Mahajan *et al.*, 2002) in all the genotypes.

42. Keeping quality (Shelf life)

Ripened fruits were stored at room temperature and recorded the number of spoiled fruits and number of days. Mean number of keeping days of fruits was worked out in each genotype.

43. Pulp recovery per cent

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

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

44. Pulp:seed ratio

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

45. Peel per cent

Peel per cent was calculated by dividing the weight of peel by total weight of fruit multiplied by 100.

3.8 Observations recorded on chemical composition of fruits

1. Total Soluble Solids(°Brix)

Total soluble solids (TSS) of custard apple pulp of all the genotypes was recorded by using a Hand Refractometer at 20°C, which is based on the principle of total refraction and expressed in ° Brix.

2. 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 in all the genotypes, (Ranganna, 1986).

$$\% \text{ Total acidity} = \frac{\text{Titrate} \times \text{Normality of alkali} \times \text{Volume made up} \times \text{Equivalent Weight of acid} \times 100}{\text{Volume of sample taken for estimation} \times \text{Weight or volume of Sample taken} \times 1000}$$

3. Total sugar (%)

Sugar was determined by the method of Lane and Eynon as described by Ranganna (1986). The Standard invert sugar solution was prepared by dissolving 9.5 g sucrose and 5 ml concentrate HCL then volume made upto 100 ml. This solution was allowed to stand for further three days at 20-25°C for inversion to take place and used for several months during analysis.

For total sugars, 50 ml of filtered sample was taken in a 250 ml conical flask to which 50 ml water and 5g of citric acid was added, boiled gently for 10 minutes to complete the inversion of sucrose, transferred to 250 ml volumetric flask and neutralized with 1N NaOH. The volume was made up-to the mark and determined the total sugars as invert sugars. Titration was done for all the genotypes.

$$\text{Total sugar as invert sugar (\%)} = \frac{\text{mg of invert sugar} \times \text{Dilution} \times 100}{\text{Titrate} \times \text{Wt or volume of the sample} \times 100}$$

$$\% \text{ Sucrose} = (\% \text{ Total invert sugar} - \% \text{ Reducing sugar originally present}) \times 0.95$$

$$\% \text{ Total sugar} = (\% \text{ Reducing sugar} + \% \text{ Sucrose}).$$

4. Reducing sugar (%)

Reducing sugar was determined by the method of Lane and Eynon as described by Ranganna (1986). This method is based on the principle that invert sugar reduces the copper in Fehling's solution to red, insoluble cuprous oxide. The sugar content in a food sample is estimated by determining the volume of the unknown sugar solution to completely reduce a measured volume of Fehling's solution.

Apparatus: Volumetric flask 100 ml, Conical flask 250 ml, Burette 50 ml, Pipette and Water bath/heater.

Reagents

- (1) Fehling's solution (A)
- (2) Fehling's solution (B)
- (3) Methylene blue indicator: methylene blue 1% aqueous.
- (4) 45 % Neutral lead acetate solution
- (5) 22 % Potassium oxalate solution
- (6) Standard invert sugar solution AR sucrose 9.5 g and concentrate HCl 5 ml and volume up to 100 ml.

Fehling's solution A: Copper sulphate 69.28 g and volume made upto one litre and Fehling's solution (B): Potassium sodium tartrate 346 g and sodium hydroxide (NaOH) 100 g and volume made upto one litre

25 ml of the standard invert solution was taken with pipette into 250 ml volumetric flask and 50 ml of water was added. Few drops of phenolphthalein indicator were added and neutralized with 20 % NaOH until the solution turns pink. This was acidify with 1 N HCl by adding it drop wise. Volume was made upto mark with water (1 ml= 2.5 mg of invert sugar).

25 g of filtered pulp juice was weighed and it was transferred into 250 ml volumetric flask. 100 ml of distilled water was added and this was neutralized with 1 N NaOH, then 2 ml of lead acetate solution was added. It was shaken and stand for 10 minutes. Then 2 ml of potassium oxalate solution was added. Volume made up with water, and filtered.

10 ml of the mixed Fehling's solution A and B was pipetted into a 250 ml flask. 50 ml of water was added. Burette was filled with the clarified sugar solution. Sugar solution from burette was added to the Fehling's solution which was sufficient to reduce it. It was mixed and heated. Three drops of methylene blue solution was added and titration was completed by adding the sugar solution drop wise until the indicator is completely decolorized. The volume of solution required was recorded. The end

point appears with brick-red colour. The reducing sugar was expressed in per cent and calculated by the following formula:

$$\text{Reducing sugar (\%)} = \frac{\text{mg of invert sugar X Dilution X 100}}{\text{Titrate X Weight or volume of the sample X 1000}}$$

To 25g of the sample in a volumetric flask, 100ml of water was added and neutralized with 1N NaOH. Two ml of 66% lead acetate solution was added and kept for 10 minutes. Excess lead acetate was precipitated by necessary amount of 20% potassium oxalate, made upto the volume with water, filtered and taken in burette. Ten ml of mixed Fehling's solution was taken in 250ml conical flask. Little quantity of the sample was run into flask and heated to boil moderately for 2 minutes. Three drops of methylene blue solution was added and completed the titration until the indicator was completely decolourized. Brick-red colour of the solution indicates the end point. Titration was done for in all the genotypes.

5. Non-reducing sugar (%)

The non-reducing sugar was determined by subtracting the value of reducing sugar from total sugar percentage in all the genotypes of custard apple.

$$\% \text{ Non-reducing sugar} = \% \text{ Total invert sugar} - \% \text{ Reducing sugar originally present}$$

6. Organoleptic evaluation

The pulp extract from fully ripe fruits was subjected to sensory evaluation by the panel of five judges in hedonic rating test as described by Ranganna (1986). The pulp was evaluated for colour, aroma, appearance, taste and overall acceptability.

The overall acceptability is based on the mean scores obtained from all the characters studied under the organoleptic test. The products which score seven or more for overall acceptability are considered as acceptable. The mean scores obtained for pulp of different genotypes was calculated. The acceptability of the pulp is based on the point's gains in hedonic rating scale. The final rating is based upon scores of overall acceptability.

HEDONIC RATING TEST FOR JUDGES

Name:

Date:

Product:

Taste the sample and check how much you like or dislike. Use the appropriate scale to show your attitude by checking at the point that best describes your feeling about the sample. Please give a reason for this attitude. Remember you are the only who can tell what you like. An honest expression of your personal feeling will help in the evaluation.

Grading	Points	Colour	Appearance	Aroma	Taste	Overall acceptability
Like extremely	9					
Like very much	8					
Like moderately	7					
Like slightly	6					
Neither like nor dislike	5					
Dislike slightly	4					
Dislike moderately	3					
Dislike very much	2					
Dislike extremely	1					

3.9. Statistical analysis

Before proceeding with the combined analysis, it is necessary to test whether the error mean squares of the individual experiments are homogeneous. The homogeneity of error mean squares can be tested by Hartley's test. Hartley's F -Maximum test is given by $F\text{-max.} = \text{Larger error MS} / \text{Smaller error MS}$.

With $(t-1)$ and f degrees of freedom where t and f are the number of treatments and the error degrees of freedom in the experiment with higher mean square. As a working rule the error mean squares can be taken as homogeneous if $F\text{-max.}$ is less than 3.

3.9.1. Analysis of variance

The data obtained from the individual plants were statistically analyzed as per the procedure given by Gomez and Gomez (1984).

Table 3.5: The Skeleton of Analysis of Variance for Randomized Complete Block Design

Source of variation	Degree of freedom	Mean Sum of Squares	Expected Sum of squares	Mean
Replications	3	MSS_r		
Treatments	59	MSS_t	$\sigma_e^2 + r\sigma_g^2$	
Error	177	MSS_e		σ_e^2

The mean data were subjected to variance analysis and test of significance as per the method of Fisher (1936).

r = Number of replication, t = Number of treatment

a. Critical difference

CD = S Ed x t value at 5 % at error degree of freedom

$$SEd = \frac{\sqrt{2EMS}}{r}$$

Where,

SEd = Standard error of difference between two treatment means

EMS = Error mean sum of square

r = Number of replications

b. Standard error of mean

$$SEm = \frac{\sqrt{EMS}}{r}$$

c. Coefficient of variation (CV) (%)

Coefficient of variation is standard deviation expressed as percentage of mean

$$CV (\%) = \frac{SD}{\bar{X}} \times 100$$

Where,

SD = standard deviation

\bar{X} = Mean of character

3.9.2. Variability parameters

Mean

The mean was recorded by summing up all the observation and then dividing by the total number of observations.

$$\bar{X} = \frac{\sum x}{N}$$

Where,

$\sum x$ = Sum of all observations

n = Total number of observations

Range

Range is the difference between the highest and the lowest value of a series of observations and thus provides the information about the extent of variability present in the genotypes.

3.9.3. Variability for PCV and GCV

Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were calculated by the method as suggested by Burton (1952).

Phenotypic coefficient of variation (PCV)

$$\sigma_p^2 = \sigma_g^2 + \sigma_e^2$$

$$PCV = \left(\frac{\sigma_p}{\bar{x}} \right) \times 100 \quad \text{Where } \sigma_p = \sqrt{\sigma_p^2}$$

Genotypic Coefficient of Variation (GCV)

$$GCV = \left(\frac{\sigma_g}{\bar{x}} \right) \times 100 \quad \text{Where } \sigma_g = \sqrt{\sigma_g^2}$$

Where,

σ_p^2 = Phenotypic variance

σ_p = Phenotypic standard deviation

σ_g^2 = Genotypic variance

σ_g = Genotypic standard deviation

σ_e^2 = Environment variance

\bar{x} = General Mean

The estimates of PCV and GCV were classified as less, moderate and high according to Robinson (1966).

Range	Category
<50%	Low
50-70%	Moderate
>70%	High

3.9.4 Heritability (broad sense)

It is the ratio of genotypic variance to the phenotypic variance (total variance). Heritability for the present study was calculated in a broad sense by adopting the formula as suggested by Hanson *et al.* (1956) and Robinson *et al.* (1966).

$$h^2(\text{bs})\% = \frac{\sigma_g^2}{\sigma_p^2} \times 100$$

Where,

$h^2(\text{bs})$ = heritability in broad sense,

σ_g^2 = Genotypic variance,

σ_p^2 = Phenotypic variance

The broad sense heritability estimates were classified as less, moderate and high as following:

Range	Category
0-50 per cent	Low
51 – 69 per cent	Moderate
> 70 per cent	High

3.9.5. Genetic advance

Improvement in the mean genotypic value of selected plants over the parental population is known as genetic advance. Expected genetic advance (GA) was calculated by the method suggested by Johnson *et al.* (1955).

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

Where,

GA	=	Genetic advance
K	=	Constant (Standardized selection differential) having the value of 2.06 at 5 per cent level of selection intensity.
h^2	=	Heritability of the character
σ_p	=	Phenotypic standard deviation

3.9.6. Genetic advance as percentage of mean

It was calculated by the following formula

$$GA \text{ as percentage of mean} = \frac{\text{Genetic advance}}{\text{General mean}} \times 100$$

Range	Category
> 20 per cent	High
10 – 20 per cent	Moderate
< 10 per cent	Less

3.9.7. Estimates of correlation coefficient

Correlation coefficient (r) is the measurement of relationship between two variables. It was estimated by using the formula given by Miller *et al.* (1958).

$$r_{(xy)} = \frac{\text{Cov}(xy)}{\sqrt{\text{Var}(x) \cdot \text{Var}(y)}}$$

Where,

$r_{(xy)}$	=	Correlation coefficient between variable x and y
$\text{Var}(x)$	=	Variance of x variable
$\text{Var}(y)$	=	Variance of y variable
$\text{Cov}(xy)$	=	Covariance between variable x and y

Genotypic, phenotypic and environmental correlation coefficients were computed by substituting corresponding variance and covariance in the above mentioned formula.

3.9.8. Significance of correlations

't' test was applied to test the significance of the correlation coefficients. 't' values were calculated by using the following formula.

$$t = \frac{|r|}{\sqrt{1-r^2}} \times \sqrt{n-2}$$

Comparing 't' values at (n-2) degrees of freedom tested the significance of correlation coefficient (r). If calculated value of 't' is greater than the tabular value of 't' at (n-2) degree of freedom at given probability level, the coefficient of correlation is considered as significant.

3.9.9. Path coefficient analysis

The genotypic correlation coefficients (r) were further partitioned into direct and indirect effects with the help of path coefficient analysis as suggested by Wright (1921).

Path coefficients were obtained by the following simultaneous equations which express basic relationship between correlation and path coefficients.

$$1. \quad r_{ln} = P_{ln} + r_{ln} P_{ln} + \dots + r_{l(n-1)} P_{(n-1)n}$$

$$2. r_{2n} = P_{2n} + r_{21} P_{1n} + \dots + r_{1(n-1)} P_{(n-1)n}$$

$$(n-1) r_{n(n-1)n} = p_{(n-1)n} + r_{(n-1)n} P_{1n} + \dots + r_{(n-1)(n-2)} P_{(n-1)n}$$

The residual effect is estimated as it permits precise explanation about the pattern of interaction of other possible components of yield. The unexpected variation of residual factor is obtained from the equation.

$$I = p_{n+}^2 + P_{ln}^2 + p_{2n}^2 + \dots + P_{(n-1)}^2 + P_{ln} r_{12} P_{2n} + 2P_{ln} r_{13} P_{1n} + \dots + P_{(n-1)n} r_{(n-2)} P_{1n}$$

Where, 1, 2, 3, ..., (n-1) the component character and n is the character upon which direct and indirect effects are studied.

3.9.10. Genetic divergence study

The D^2 statistic originally developed by Mahalanobis (1928) and further elaborated by Rao (1952) was applied for assessment of genetic divergence between the populations. The D^2 values between any two populations were estimated from the sample on the basis of characters p by following formula

$$D^2_p = \sum_{i=1}^p \sum_{j=1}^p (\Delta_{ij}) \Delta_i \Delta_j$$

Where,

(Δ_{ij}) = is the reciprocal of (ij) the pooled common dispersion matrix (*i.e.* error matrix)

Δ_i = is the difference in the mean value of i^{th} character

Δ_j = is the difference in the mean value of j^{th} character

The computation is very much simplified when the characters under study are independent and are expressed in terms of their respective standard errors. In this case, computation of D^2 values reduces to simple summation of the differences in mean values of various characters of two populations *i.e.* $\sum d_i^2$. It is, therefore, preferred first to transform the correlated variables to uncorrelated means by pivotal condensation method (Rao, 1952), which supplies the values required for transformation of the raw

data. For each combination, the mean deviation *i.e.* $Y_{1i} - Y_{2i}$ is computed and the D^2 value is computed as sum of the squares of these deviations.

$$D^2 = \sum(Y_{1i} - Y_{2i})^2$$

Where, $i = 1, 2, \dots, p$ number of characters

Y_{1i} = Transformed uncorrelated mean of i^{th} character for genotype 1

Y_{2i} = Transformed uncorrelated mean of i^{th} character for genotype 2

The significance of D^2 values is tested against the table value of χ^2 at p degree of freedom, where, p is the total number of characters included in the study and if calculated value is higher than the table value, it is considered as significant and vice-versa. Later the grouping of the genotypes into distinct clusters is done after arranging the genotypes in order of their relative distances (D^2 values) from each other following the method suggested by Rao (1952) for cluster formation.

3.9.11. Average Intra and Inter-Cluster Distances

The formula to measure average intra-cluster distance is $\sum D^2_i / n$, where, $\sum D^2_i$ is the sum of distances between all possible combinations (n) of the genotypes included in a cluster.

Average inter cluster distance between the genotypes in cluster i and cluster $j = \sum D^2_{ij} / (n_i \times n_j)$.

Where,

$\sum D^2_{ij}$ is the sum of distance between the genotypes in cluster i and cluster j

n_i = number of genotypes in cluster i

n_j = number of genotypes in cluster j .

With the help of D^2 values between and within clusters, a diagram showing the relationship between different genotypes can be drawn, which is not exactly to the scale.

3.9.12. Contribution of individual characters towards total divergence

In all the combinations of genotypes, $[n(n-1)/2]$, each character is ranked on the basis of values $(Y_{1i} - Y_{2i})$. Rank 1 is given to the highest mean difference and rank p to the lowest mean difference, where p is the total number of characters. Using these

ranks, the following table is prepared to work out the per cent contribution of each character to the total divergence.

Character	X₁	X₂.....	X_p	Total
Number of times appearing first in ranking	A	B.....	P	n(n-1)/2
Per cent contribution				100

$$\text{Per cent contribution by } X_i = \frac{\text{No. of times appearing first ranking by } X_i}{n(n-1)/2} \times 100$$

Where,

$X_i \dots X_p$ are individual characters

N = is the number of genotypes

In this study, the genotypes were grouped into a number of clusters using computer software programme “Statistical Packages for Agricultural Research (SPAR 1)”.

3.10 Visual observation of selected 6 genotypes



IGCA-21



IGCA-22



IGCA-12



IGCA-20



IGCA-4



IGCA-11



IGCA-1



IGCA-2



IGCA-3

CHAPTER-IV

RESULTS AND DISCUSSION

The results obtained in the present investigation entitled “**Studies on genetic variability and characterization of custard apple (*Annona squamosa* L.) genotypes in Northern Bastar of Chhattisgarh**” have been described under the following heads.

4.1 Analysis of variance

4.2 Genetic variability

4.3 Heritability and genetic advance

4.4 Correlation coefficient analysis

4.5 Path coefficient analysis

4.6 Genetic divergence

4.1 Analysis of variance for quantitative traits

The Analysis of variance (ANOVA) worked out for quantitative and qualitative traits with respect to fruit yield and its components in custard apple indicated that the mean sum of squares due to genotypes were highly significant for all the characters. This is an indication of existence of sufficient variability for the traits (Table 4.1 and 4.2).

4.2 Genetic variability

Genetic parameters of variation for fruit yield and its components in custard apple are presented in Table 4.3 and 4.4.

4.2.1 Range and mean performance for quantitative traits of fruit yield and its components during the year 2013-14 and 2014-15.

The character wise observations recorded on quantitative traits during the year 2013-14, 2014-15 and pooled data have been given in Appendix VII.

The range and mean performance for pooled data are presented in Table 4.3.

1. Number of alternate leaf

The character number of alternate leaf varied between 214.75 (IGCA-58) to 358.75 (IGCA-22) with a mean value of 318.48 alternate leaf.

2. Length of Leaf (cm)

Range performance of character length of leaf varied between 5.50 cm (IGCA-59) to 7.61 cm (IGCA-10) with a mean value of 6.50 cm length of leaf.

3. Number of Flowers per branch

The character 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.

4. Days to 50 % maturity

Days to 50 % maturity varied between 113.87 (IGCA-22) to 128.37 (IGCA-15) with a mean value of 122.82 days to 50% maturity.

5. Total number of fruits

The character total number of fruits ranged from 12.75 (IGCA-60) to 33.37 (IGCA-21) with a mean value of 18.49 fruits per branch.

6. Fruit width (cm)

The character fruit width varied between 2.27 cm (IGCA-57) to 4.71 cm (IGCA-21) with a mean value of 3.34 cm per fruit.

7. Length of fruit (cm)

The length of fruit varied between 5.43 cm (IGCA-59) to 12.53 cm (IGCA-19) with a mean value of 9.48 cm length of fruit.

Table 4.1: Analysis of variance for quantitative traits of fruit yield and its components in custard apple during the year 2013-14 and 2014-15

Source of Variation	d.f.	Mean Sum of Squares									
		1	2	3	4	5	6	7	8	9	10
		No. of Alternate Leaf	Length of Leaf (cm)	No. of Flowers Per Branch	Days to 50 % Maturity	Total No. of Fruits	Fruit Width (cm)	Fruit Length (cm)	Fruit Weight (g)	Length of Pedicel (cm)	Pedicel Thickness
Replication	3	2018.48	0.12	2.52	23.09	3.07	0.08	0.42	414.03	0.03	1.99
Treatment	59	3776.93**	2.56**	43.61**	58.65**	70.70**	1.90**	10.63**	43591.57**	1.93**	95.78**
Error	177	1575.91	0.50	3.26	20.66	1.94	0.04	0.36	196.71	0.02	0.90
Total	239										

Source of Variation	d.f.	Mean Sum of Squares									
		11	12	13	14	15	16	17	18	19	20
		Length of Pericarp (cm)	Weight of Pericarp (g)	Seed Length (mm)	Seed Width (mm)	No. of Seeds/Fruit	No. of Seed Weight(g)	Pulp Weight (g)	Areole Weight(g)	No. of Fruits/Tree	Fruit Yield/Plant (kg)
Replication	3	0.01	0.08	3.03	0.64	7.15	8.86	48.86	52.88	622.56	37.30
Treatment	59	1.40**	4.22**	19.71**	2.21**	22.05**	38.79**	14297.72**	6526.76**	1996.92**	1388.69**
Error	177	0.01	0.04	1.62	0.29	2.89	4.25	41.58	21.03	236.82	39.31
Total	239										

**Significant at 5% probability level,

Table 4.2: Analysis of variance for qualitative traits of fruit yield and its components in custard apple during the year 2013-14 and 2014-15

Source of Variation	d.f.	Mean Sum of Squares									
		1	2	3	4	5	6	7	8	9	10
Total		Total Sugar (%)	Total Sugar (%)	Reducing Sugar (%)	Non-reducing Sugar (%)	Acidity (%)	Keeping Days (Shelf life)	Pulp Ratio	Pulp -Seed Ratio	Peel Percentage	Fruit Yield Per Plant
Replication	3	4.80	1.73	0.92	0.01	0.01	0.35	49.33	0.16	15.80	37.31
Treatment	59	19.73**	31.42**	21.95**	2.81**	0.01**	3.31**	42.62**	26.26**	24.54**	1388.69**
Error	177	2.74	0.88	0.77	0.02	0.01	0.21	29.14	0.06	15.94	39.31
Total	239										

**Significant at 5% probability level

8. Fruit weight (g)

The yield parameter fruit weight ranged from 152.64 g (IGCA-60) to 570.12 g (IGCA-21) with a mean value of 231.34 g weight of fruit.

9. Length of pedicel (cm)

The character length of pedicel varied between 1.13 cm (IGCA-57) to 3.57 cm (IGCA-21) with a mean value of 2.31cm.

10. Pedicel thickness (mm)

The character pedicel thickness varied between 11.25 mm (IGCA-59) to 25.63 mm (IGCA-21) with a mean value of 16.15 mm.

11. Length of pericarp (cm)

The character length of pericarp varied between 1.31 cm (IGCA-24) to 3.31 cm (IGCA-21) with a mean value of 1.99 cm.

12. Weight of pericarp (g)

The yield component weight of pericarp varied between 2.27 g (IGCA-8) to 5.84 g (IGCA-21) with a mean value of 3.43 g.

13. Seed length (mm)

The character length of seed ranged from 15.37 mm (IGCA-10) to 25.25 mm (IGCA-57) with a mean value of 20.62 mm.

14. Seed width (mm)

The character width of seed varied between 5.25 mm (IGCA-3) to 8.63 mm (IGCA-57) with a mean value of 7.69 mm.

15. Number of seeds per fruit

The character number of seeds per fruit varied between 25.37 (IGCA-21) to 34.87 (IGCA-36) with a mean value of 31.81 seeds.

16. Weight of seed (g)

The character weight of seeds per fruit ranged from 25.25 g (IGCA-22) to 62.77 g (IGCA-26) with a mean value of 34.10 g.

17. Weight of pulp (g)

The yield parameter weight of pulp per fruit varied between 69.97 g (IGCA-60) to 300.64 g (IGCA-21) with a mean value of 114.36 g.

18. Weight of areole (g)

The character weight of areole per fruit varied between 46.21 g (IGCA-60) to 205.11 g (IGCA-21) with a mean value of 78.77 g.

19. Number of fruits per tree

The yield character number of fruits per tree ranged from 283.50 (IGCA-53) to 370.00 (IGCA-21) with a mean value of 305.46 fruits per tree.

20. Fruit yield per plant

The yield component fruits yield per plant ranged from 101.16 kg (IGCA-39) to 152.21 kg (IGCA-21) and mean value was calculated as 113.41 kg.

4.2.2 Range and mean performance for qualitative traits of fruit yield and its components in custard apple during the year 2013-14 and 2014-15

The observations recorded on qualitative traits during the year 2013-14, 2014-15 and pooled data have been given in Appendix VIII.

The range and mean performance for pooled data are presented in Table 4.4

1. Total soluble solids (°Brix)

The character Total Soluble Solids ranged from 19.26 °Brix (IGCA-48) to 28.08 °Brix (IGCA-21) with a mean value of 22.37 °Brix.

2. Total sugar (%)

The qualitative character Total Sugar ranged from 14.27 (IGCA-57) to 23.77 per cent (IGCA-2) with a mean value recorded as 18.38 per cent.

3. Reducing sugar (%)

The qualitative trait Reducing Sugar ranged from 11.36 (IGCA-58) to 19.45 per cent (IGCA-3) with a mean value calculated as 14.57 per cent.

4. Non-reducing sugar (%)

The character Non-Reducing Sugar ranged from 3.17 (IGCA-25) to 6.87 per cent (IGCA-51) with a mean value of 4.53 per cent.

5. Acidity (%)

The acidity in custard apple pulp ranged from 0.22 (IGCA-21) to 0.46 per cent (IGCA-15) with a mean value of 0.38 per cent.

6. Keeping days (Shelf life)

The Keeping Days of custard apple fruits ranged from 3.0 (IGCA-42, IGCA-43, IGCA-49, IGCA-51, IGCA-52, IGCA-53, IGCA-54, IGCA-55, IGCA-56, IGCA-57, IGCA-58, IGCA-59, IGCA-60) to 6.50 (IGCA-21) with a mean value calculated as 3.82 days.

7. Pulp ratio

The character Pulp ratio ranged from 41.69 (IGCA-57 and IGCA-58) to 55.01 (IGCA-25) with a mean value of 48.33.

8. Pulp-seed ratio

The character Pulp-Seed Ratio ranged from 2.08 (IGCA-60) to 12.65 (IGCA-21) with a mean value recorded as 3.77.

9. Peel percentage

The character Peel Percentage ranged from 26.26 (IGCA-57) to 38.70 (IGCA-36) with a mean value of 33.17.

10. Fruit yield per plant (kg)

The character fruit yield per plant ranged from 101.25 kg (IGCA-37) to 152.25 kg (IGCA-21) and mean value was calculated as 113.89 kg.

The measurement of existing variability in genetic material has been the basic requirement of a breeding programme. In the present investigation, a wide range of variability was observed for nearly all the traits *viz.*, number of alternate leaf, length of leaf, number of flowers per branch, days to 50 % maturity, seed length, seed width, number of seeds per fruit, fruit yield per plant, weight of pulp, weight of areole, number of fruits per tree and weight of seed in total gene pool, indicating the existence of sufficient variability among the genotypes for the quantitative and qualitative traits *viz.*, fruit yield per plant, pulp ratio, peel percentage, reducing sugar, total sugar, total soluble solids. Whereas, little variability has been observed for total number of fruits, fruit width, length of fruit, fruit weight, length of pedicel, pedicel thickness, length of pericarp, weight of pericarp in quantitative and qualitative traits *viz.*, pulp-seed ratio, non-reducing sugar, acidity, keeping days (shelf life). These findings are in general agreement with the findings of Cliff (1977), Islam *et al.* (1991), Jagtap and Kokate (1991), George *et al.* (1999), Carvalho *et al.* (2000), Wang *et al.* (2001), Saulo *et al.* (2006), Keny and Paulo (2010), Paulo *et al.* (2009) and Bhatnagar *et al.* (2012).

4.2.3 Genotypic and phenotypic coefficient of variation for quantitative traits of fruit yield and its components during the year 2013-14 and 2014-15

The genotypic and phenotypic coefficients of variation for quantitative traits have been computed by pooled data are presented in table 4.3 and fig. 4.1.

Genotypic and phenotypic coefficients of variation are simple measures of variability; these measures are commonly used for the assessment of variability. The relative values of these types of coefficient gives an idea about the magnitude of

Genetic Parameters

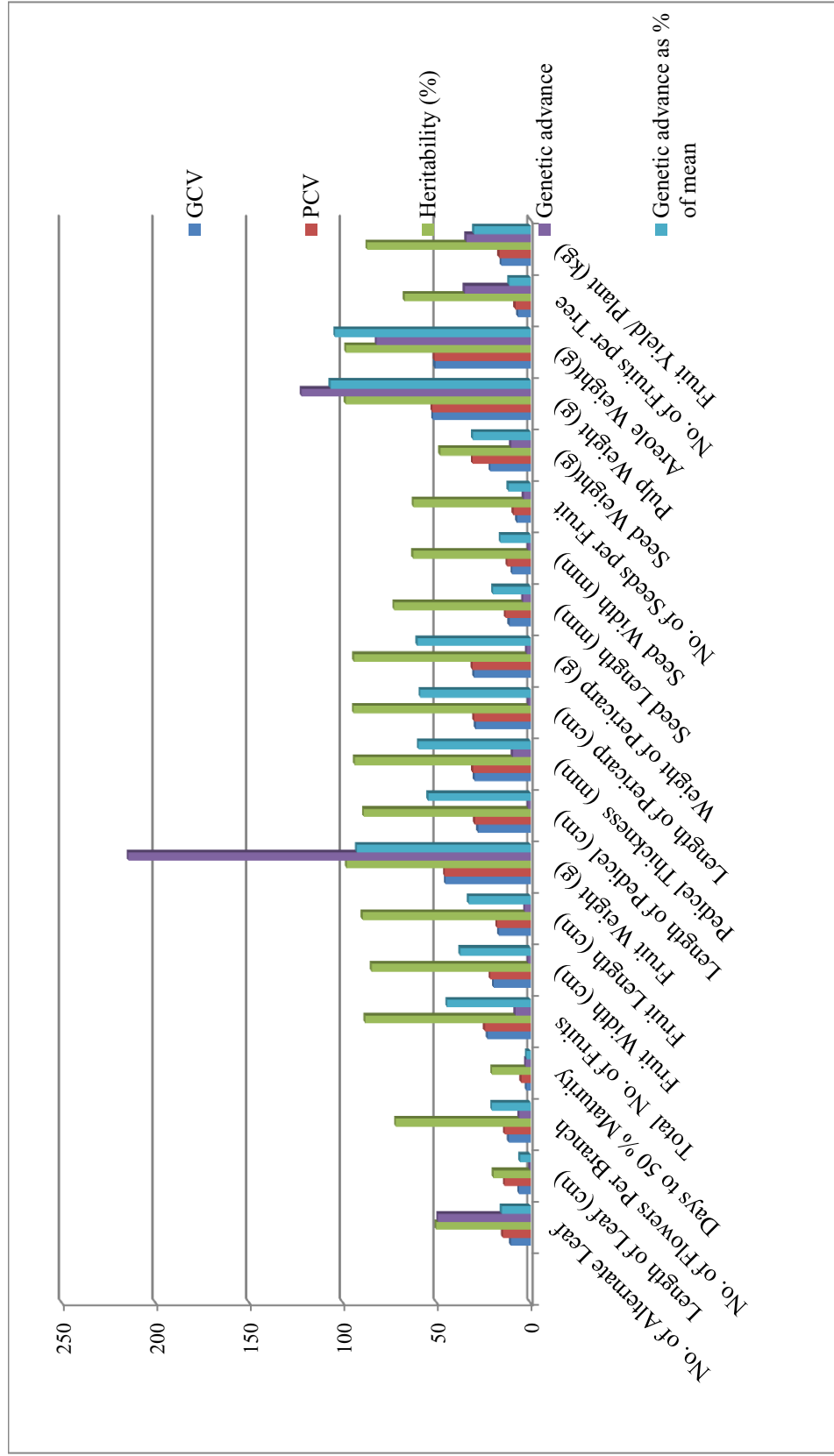


Fig. 4.1: Genetic parameters of variation for fruit yield and its components in custard apple for quantitative traits during the year 2013-14 and 2014-15 (Pooled data)

variability present in a genetic population. Thus, the components of variation such as genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were computed. The phenotypic coefficients of variation were marginally higher than the corresponding genotypic coefficients of variation indicated the influence of environment in the expression of the characters under study.

Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) are categorized as low (less than 10%), moderate (10-20%) and high (more than 20%) as suggested by Sivasubramaniam and Madhavamenon (1973).

The highest GCV (52.21%) and PCV (52.51%) was observed for pulp weight, which is followed by areole weight (51.04% and 51.39%), fruit weight (45.47% and 45.89%), weight of pericarp (30.25% and 31.15%), pedicel thickness (29.98% and 30.85%), length of pedicel (28.14% and 29.81%), total number of fruits (23.04% and 24.53), seed weight (21.57% and 31.05%) and fruit width (19.83% and 21.52%). The moderate GCV and PCV were observed for fruit length (16.96% and 17.91) which is followed by fruit yield per plant (15.75% and 16.87%), seed length (11.45% and 13.42) and number of alternate leaf (10.62% and 14.95%). Rest of the traits exhibited low GCV and PCV estimates.

The results on genotypic and phenotypic coefficient of variation clearly indicated that the phenotypic coefficients of variation in general were slightly higher than the genotypic coefficients of variation for all the characters indicating the substantial influence of environment in the expression of the characters. The character pulp weight had the highest GCV and PCV. The moderate GCV and PCV were observed for fruit weight followed by weight of pericarp.

The GCV and PCV were low for the characters *viz.*, days to 50% maturity, length of leaf, number of fruits per tree, number of seeds per fruit and seed width.

4.2.4 Genotypic and phenotypic coefficient of variation for qualitative traits of fruit yield and its components in custard apple during the year 2013-14 and 2014-15

The data on genotypic and phenotypic coefficients of variation for qualitative traits computed from pooled observations have been presented in table 4.4 and fig. 4.2.

The character pulp-seed ratio had highest GCV (67.97%) and PCV (68.30%) and keeping days (23.07% and 25.85%). The moderate GCV and PCV were observed for non-reducing sugar (18.45% and 18.62%), fruit yield per plant (16.13% and 17.04%), reducing sugar (15.80% and 16.90%), total sugar (15.03% and 15.87%) and acidity (14.19% and 15.65%). Rest of the traits exhibited low GCV and PCV estimates.

The results on genotypic and phenotypic coefficient of variation clearly indicated that the phenotypic coefficients of variation in general were slightly higher than the genotypic coefficients of variation for all the characters indicating the substantial influence of environment in the expression of the characters. The character pulp-seed ratio had the highest GCV and PCV. The moderate GCV and PCV were observed for non-reducing sugar followed by fruit yield per plant, reducing sugar and total sugar. Similar findings were also reported earlier by Cliff (1977), Islam *et al.* (1991), Jagtap and Kokate (1991), Shete *et al.* (1991), George *et al.* (1999), Carvalho *et al.* (2000), Wang *et al.* (2001), Saulo *et al.* (2006), Keny and Paulo (2010), Paulo *et al.* (2009) and Bhatnagar *et al.* (2012).

4.3 Heritability and genetic advance

Heritability governs the resemblance between parents and their progeny, whereas, the genetic advance provides the knowledge about expected gain for a particular character after selection. Heritability suggests the relative role of genetic factors in expression of phenotypes and also acts as an index of transmissibility of a particular trait to its offsprings. However, the knowledge of heritability alone does not help in formulating concrete breeding programme, genetic advance along with heritability helps to ascertain the possible genetic control for any particular trait. The

nature and extent of the inherent ability of a genotype for a character is an important parameter determining the extent of improvement of any crop species. Heritability and genetic advance are the important genetic parameters for selecting a genotype that permit greater effectiveness of selection by separating out environmental influence from total variability.

Heritability estimates along with genetic advance are normally more useful in predicting the gain under selection than that of heritability alone. However, it is not necessary that a character showing high heritability will also exhibit high genetic advance (Johnson *et al.*, 1955). An attempt has been made in the present investigation to estimate heritability in broad sense and categorized as low (<50%), moderate (50-70%) and high (>70%) as suggested by Robinson (1966).

4.3.1 Heritability for fruit yield and its components in custard apple for quantitative traits during the year 2013-14 and 2014-15

The data computed from two year pooled observation on heritability for quantitative traits have been presented in table 4.3 and fig. 4.1.

In present investigation, the highest heritability estimate was recorded for the character pulp weight (98.80%) followed by areole weight (98.60%), fruit weight (98.20), length of pericarp (94.50), weight of pericarp (94.30), pedicel thickness (93.90), fruit length (89.70), length of pedicel (89.10), total number of fruits (88.30), fruit yield per plant (87.20), fruit width (84.90), seed length (72.80) and number of flowers per branch (72.00).

The moderate heritability was observed for the character seed width (62.80), number of fruits per tree (67.30), number of seeds per fruit (62.60) and number of alternate leaf (50.40).

4.3.2 Heritability for fruit yield and its components in custard apple for qualitative traits during the year 2013-14 and 2014-15

The heritability estimate for qualitative traits computed from two years pooled data are presented in table 4.4 and fig. 4.4.

In present investigation, the highest heritability estimate was recorded for the character in qualitative traits of pulp-seed ratio (99.02%) followed by non-reducing sugar (98.80%), total sugar (90.53%), fruit yield per plant (90.02%), reducing sugar (87.46%), acidity (82.77%), keeping days (80.02%). The moderate heritability was observed for the character total soluble solid (61.17%). Rest of the traits exhibited low heritability.

In the present study, low heritability was observed for the qualitative traits of peel percentage (12.86%) and pulp ratio (10.08%). The above findings are in conformity with the earlier reports of Cliff (1977), Islam *et al.* (1991), Jagtap and Kokate (1991), George *et al.* (1999), Carvalho *et al.* (2000), Wang *et al.* (2001), Saulo *et al.* (2006), Keny and Paulo (2010), Paulo *et al.* (2009) and Bhatnagar *et al.* (2012).

4.3.3 Genetic advance for fruit yield and its components in custard apple for quantitative traits during the year 2013-14 and 2014-15

The genetic advance for quantitative traits computed from two pooled data have been presented in table 4.3 and fig. 4.1

The magnitude of genetic advance was categorized as high (> 20%), moderate (10%-20%) and low (< 10%). The highest genetic advance was observed for fruit weight (44.68) followed by number of fruits per tree (35.26), pulp weight (32.27), areole weight (28.24) and number of alternate leaf (19.48). The moderate genetic advance was observed for the character seed weight (10.53), whereas, rest of the traits showed low genetic advance.

4.3.4 Genetic advance for fruit yield and its components in custard apple for qualitative traits during the year 2013-14 and 2014-15

The genetic advance for qualitative traits computed from pooled data is presented in table 4.4 and fig. 4.4.

The magnitude of genetic advance was categorized as high ($> 20\%$), moderate ($10\%-20\%$) and low ($< 10\%$). The highest genetic advance was observed for fruit yield per plant (35.81). Whereas, rest of the traits showed low genetic advance.

4.3.5 Genetic advance as percentage of mean for fruit yield and its components in custard apple for quantitative traits during the year 2013-14 and 2014-15

The data of genetic advance as percentage of mean for quantitative from pooled observation of two years are presented in table 4.3 and fig. 4.1.

Among 20 characters studied, the highest genetic advance as percentage of mean was observed for total number of fruits (44.59) followed by fruit width (37.64), areole weight (35.85), fruit length (33.08), seed weight (30.88), fruit yield per plant (30.29), pulp weight (28.21), number of flowers per branches (20.60), seed length (20.12), pedicel thickness (19.86), seed width (16.14), number of alternate leaf (15.54), fruit weight (19.31), length of pedicel (14.71), number of seeds per fruit (11.92), number of fruits per tree (11.54), weight of pericarp (10.51), length of pericarp (10.51), length of leaf (5.69) and days to 50% maturity (2.16).

In the present investigation, high heritability coupled with high genetic advance as percentage of mean was found for pulp weight, followed by areole weight, fruit weight, weight of pericarp, pedicel thickness, length of pericarp and length of pedicel, which indicated the predominance of additive gene action in the expression of these characters which could be utilized through selection for improvement in these characters. Rest of the traits showed high to moderate heritability estimates coupled with moderate to low genetic advance as percentage of mean indicated the role of non-additive genetic variance in their expression.

4.3.6 Genetic advance as percentage of mean for fruit yield and its components in custard apple for qualitative traits during the year 2013-14 and 2014-15

The genetic advance as percentage of mean for qualitative traits computed from pooled data of two years observations are given in table 4.4 and fig. 4.4.

Among 10 characters studied, the highest genetic advance as percentage of mean was observed for pulp:seed ratio (139.35), keeping days (42.40), non-reducing sugar (37.64), fruit yield per plant (31.44), reducing sugar (30.41), total sugar (29.31), acidity (26.49), total soluble solids (14.80), peel percentage (3.14) and pulp ratio (2.52).

In the present investigation, high heritability coupled with high genetic advance as percentage of mean was found for fruit yield per plant, total sugar, pulp-seed ratio, reducing sugar and total soluble solids, which indicated the predominance of additive gene action in the expression of these characters which could be utilized through selection for improvement in these characters. Rest of the traits showed high to moderate heritability estimates coupled with moderate to low genetic advance as percentage of mean indicated the role of non-additive genetic variance in their expression. Similar results have also been reported by Cliff (1977), Islam *et al.* (1991), Jagtap and Kokate (1991), George *et al.* (1999), Carvalho *et al.* (2000), Wang *et al.* (2001), Saulo *et al.* (2006), Keny and Paulo (2010), Paulo *et al.* (2009) and Bhatnagaret *al.* (2012).

Genetic Parameters

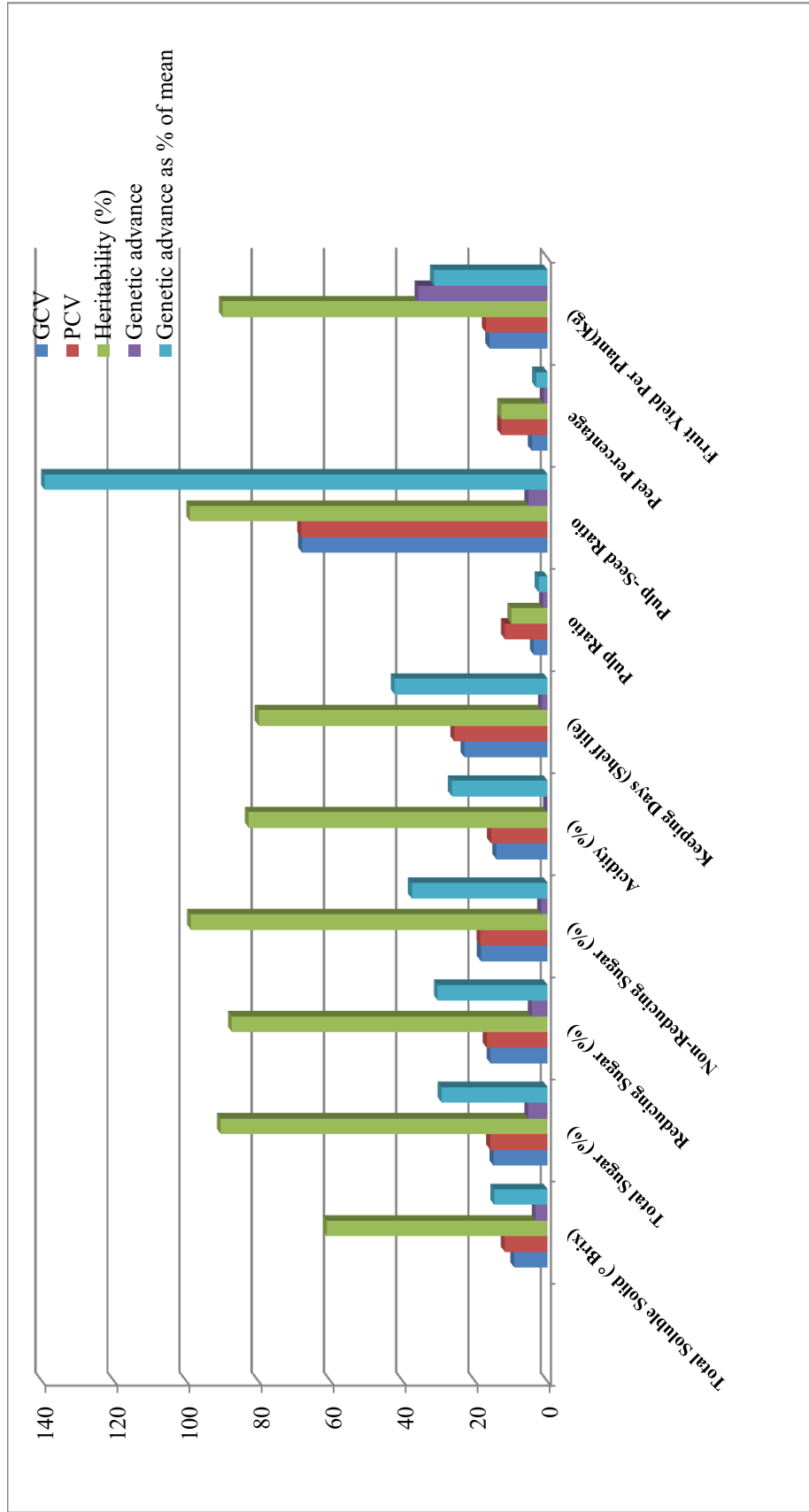


Fig. 4.2: Genetic parameters of variation for fruit yield and its components in custard apple for qualitative traits during the year 2013-14 and 2014-15 (Pooled data)

Table 4.3: Genetic parameters of variation for fruit yield and its components in custard apple for quantitative traits during the year 2013-14 and 2014-15 (Pooled data)

S.No.	Characters	Grand mean (\bar{X})		PCV	GCV	Heritability (%)	Genetic advance	Genetic advance as % of mean
		Min.	Max.					
1.	No. of Alternate Leaf	318.48	214.75	358.75	10.62	14.95	19.48	15.54
2.	Length of Leaf (cm)	6.50	5.50	7.61	6.20	13.91	0.37	5.69
3.	No. of Flowers Per Branch	29.64	25.87	43.50	11.78	13.88	6.12	20.60
4.	Days to 50 % Maturity	122.82	113.87	128.37	2.31	5.09	2.65	2.16
5.	Total No. of Fruits	18.49	12.75	33.37	23.04	24.53	8.23	44.59
6.	Fruit Width (cm)	3.34	2.27	4.71	19.83	21.52	1.26	37.64
7.	Fruit Length (cm)	9.48	5.43	12.53	16.96	17.91	3.14	33.08
8.	Fruit Weight (g)	231.34	152.63	570.12	45.47	45.89	44.68	19.31
9.	Length of Pedicel (cm)	2.31	1.13	3.57	28.14	29.81	1.26	14.71
10.	Pedicel Thickness (mm)	16.15	11.25	25.63	29.98	30.85	9.66	19.86
11.	Length of Pericarp (cm)	1.99	1.31	3.31	29.39	30.23	1.17	18.87
12.	Weight of Pericarp (g)	3.43	2.27	5.84	30.25	31.15	2.07	10.51
13.	Seed Length (mm)	20.62	15.37	25.25	11.45	13.42	4.15	20.12
14.	Seed Width (mm)	7.69	5.25	8.63	9.88	12.47	1.24	16.14
15.	No. of Seeds per Fruit	31.81	25.37	34.87	7.32	9.25	3.79	11.92
16.	Seed Weight(g)	34.10	25.25	62.77	21.57	31.05	10.53	30.88
17.	Pulp Weight (g)	114.36	69.97	300.64	52.21	52.51	32.27	28.21
18.	Areole Weight(g)	78.77	46.21	205.11	51.04	51.39	28.24	35.85
19.	No. of Fruits per Tree	305.46	283.50	370.00	6.83	8.32	35.26	11.54
20.	Fruit Yield/ Plant (kg)	113.41	101.16	152.21	15.75	16.87	34.36	30.29

Table 4.4: Genetic parameters of variation for fruit yield and its components in custard apple for qualitative traits during the 2013-14 and 2014-15(Pooled analysis)

S. No.	Characters	Grand mean (\bar{X})	Range		GCV	PCV	Heritability (%)	Genetic advance	Genetic advance as % of mean
			Min.	Max.					
1.	Total Soluble Solid (° Brix)	22.37	19.26	28.08	9.21	11.82	61.17	3.31	14.80
2.	Total Sugar (%)	18.38	14.27	23.77	15.03	15.87	90.53	5.39	29.31
3.	Reducing Sugar(%)	14.57	11.36	19.45	15.80	16.90	87.46	4.43	30.41
4.	Non-Reducing Sugar(%)	4.53	3.17	6.88	18.45	18.62	98.80	1.71	37.64
5.	Acidity(%)	0.38	0.22	0.46	14.19	15.65	82.77	0.10	26.49
6.	Keeping Days (Shelf life)	3.82	3.00	6.50	23.07	25.85	80.02	1.62	42.40
7.	Pulp Ratio	48.33	41.69	55.01	3.80	11.80	10.08	1.22	2.52
8.	Pulp-Seed Ratio	3.77	2.08	12.65	67.97	68.30	99.02	5.25	139.35
9.	Peel Percentage	33.17	26.26	38.70	4.42	12.82	12.86	1.04	3.14
10.	Fruit Yield Per Plant(Kg)	113.89	101.25	152.25	16.13	17.04	90.02	35.81	31.44

4.4 Correlation coefficient analysis

Correlation coefficient is a statistical measure which is used to find out the degree and direction of relationship between two or more variables. Correlation coefficient analysis measures the mutual relationship between various characters and determines the component characters on which selection can be based for genetic improvement. Knowledge about inter-relationship between yield and yield-contributing characters facilitates the choice of efficient breeding method to be adopted. To estimate the association between two characters, correlation coefficient at phenotypic, genotypic and environmental levels were worked out in all possible combinations among yield components.

Correlation analysis clearly revealed that the phenotypic and genotypic correlations in general are similar in direction but the magnitude of genotypic correlation was higher than the phenotypic correlations. The low phenotypic correlation could be attributed to masking influence and modifying effect of the environment on the association of characters. Pandey and Gritton (1975) pointed out no suitable test of significance of genetic correlation is available. Therefore, their primary utility is in strengthening interpretations based on phenotypic correlation and in better predicting correlated responses to selection. Hence, important findings based on phenotypic correlation are discussed here. In the present investigation, correlation coefficients at genotypic, phenotypic and environmental level have been worked out among fruit yield and its components and the data are presented in Table 4.5, 4.6, 4.8 and 4.9

4.4.1 Phenotypic and Genotypic correlation coefficients for fruit yield and its components in custard apple for quantitative traits during the year 2013-14 and 2014-15

Data on phenotypic and genotypic correlation coefficients for quantitative traits are presented in Table 4.5 and 4.6.

The character number of alternate leaf showed highly significant positive correlation with characters number of flowers per branches, total number of fruits, fruit width, fruit length, fruit weight, length of pedicel, pedicel thickness, length of pericarp, weight of pericarp, pulp weight, areole weight, number of fruits per tree and fruit yield per plant at both the phenotypic and genotypic level. It shows highly significant negative correlation with days to 50 % maturity and seed length at both the phenotypic and genotypic level, while with seed weight at genotypic level only.

Length of leaf exhibited highly significant positive correlation with number of flowers per branches, fruit weight, length of pericarp, weight of pericarp, pulp weight, areole weight, number of fruits per tree and fruit yield per plant at both the phenotypic and genotypic level while with total number of fruits, length of pedicel and pedicel thickness at genotypic level only. Length of leaf showed highly significant negative correlation with seed weight at both phenotypic and genotypic level, while with seed width and number of seeds per fruit at genotypic level only.

Number of flowers per branches exhibited highly significant positive correlation with total number of fruits, fruit length, fruit weight, length of pedicel, pedicel thickness, length of pericarp, weight of pericarp, pulp weight, areole weight, number of fruits per tree and fruit yield per plant at both the phenotypic and genotypic level, while with fruit width at phenotypic level only. Number of flowers per branch showed highly significant negative correlation with days to 50 % maturity, seed length, seedwidth, number of seeds per fruit and seed weight at both the genotypic and phenotypic level.

Highly significant positive correlation of days to 50 % maturity was observed with seed length, seed width, number of seeds per fruit and seed weight at both the phenotypic and genotypic level. While, this character showed highly significant negative correlation with total number of fruits, fruit width, fruit length, fruit weight, length of pedicel, pedicel thickness, length of pericarp, weight of pericarp, pulp weight,

areole weight, number of fruits per tree and fruit yield per plant at both the genotypic and phenotypic level.

Total number of fruits exhibited highly significant positive correlation with fruit width, fruit length, fruit weight, length of pedicel, pedicel thickness, length of pericarp, weight of pericarp, pulp weight, areole weight, number of fruits per tree and fruit yield per plant at both the levels. While, on the other hands, such character recorded highly significant negative correlation with seed length, seed width, number of seeds per fruit and seed weight at both the genotypic and phenotypic level.

The character fruit width showed highly significant positive correlation with fruit length, fruit weight, length of pedicel, pedicel thickness, length of pericarp, weight of pericarp, pulp weight, areole weight, number of fruits per tree and fruit yield per plant at both the phenotypic and genotypic level. Fruit width found highly significant negative correlation with seed length, seed width, number of seeds per fruit and seed weight at both the levels.

The character fruit length had shown highly significant positive correlation with fruit weight, length of pedicel, pedicel thickness, length of pericarp, weight of pericarp, pulp weight, areole weight, number of fruits per tree and fruit yield per plant at both phenotypic and genotypic level. Whereas, fruit length showed highly significant negative correlation with seed length, seed width, number of seeds per fruit and seed weight at both levels.

The character fruit weight exhibited highly significant positive correlation with length of pedicel, pedicel thickness, length of pericarp, weight of pericarp, pulp weight, areole weight, number of fruits per tree and fruit yield per plant at both the phenotypic and genotypic level, while highly significant negative correlation was found with seed length, seed width, number of seeds per fruit and seed weight at both the levels.

Highly significant positive correlation of length of pedicel was observed with pedicel thickness, length of pericarp, weight of pericarp, pulp weight, areole weight,

number of fruits per tree and fruit yield per plant at both the phenotypic and genotypic level, while highly significant negative correlation with seed length, seed width, number of seeds per fruit and seed weight at both the genotypic and phenotypic level.

The character pedicel thickness had shown highly significant positive correlation with length of pericarp, weight of pericarp, pulp weight, areole weight, number of fruits per tree and fruit yield per plant at both phenotypic and genotypic level, while highly significant negative correlation with seed length, seed width, number of seeds per fruit and seed weight at both the genotypic and phenotypic level.

Highly significant positive correlation of length of pericarp was observed with weight of pericarp, pulp weight, areole weight, number of fruits per tree and fruit yield per plant at both phenotypic and genotypic level, while highly significant negative correlation was observed with seed length, seed width, number of seeds per fruit and seed weight was found at both genotypic and phenotypic level.

Weight of pericarp exhibited highly significant positive correlation with pulp weight, areole weight, number of fruits per tree and fruit yield per plant at both the phenotypic and genotypic level, while highly significant negative correlation was observed with seed length, seed width, number of seeds per fruit and seed weight at both genotypic and phenotypic level.

Seed length recorded highly significant positive correlation with seed width, seeds per fruit and seed weight at both the phenotypic and genotypic level, while, highly significant negative correlation was observed with pulp weight, areole weight, number of fruits per tree and fruit yield per plant at both the genotypic and phenotypic level.

Seed width recorded highly significant positive correlation with number of seeds per fruit and seed weight at both the phenotypic and genotypic level, while, highly significant negative correlation was exhibited with pulp weight, areole weight, number of fruits per tree and fruit yield per plant at both the levels.

The character number of seeds per fruit found highly significant positive correlation with seed weight at both the genotypic and phenotypic level, while highly significant negative correlation was recorded with pulp weight, areole weight, number of fruits per tree and fruit yield per plant at both the genotypic and phenotypic level.

The character seed weight found highly significant negative correlation with pulp weight, areole weight, number of fruits per tree and fruit yield per plant at both genotypic and phenotypic level.

The character pulp weight had shown highly significant positive correlation with areole weight, number of fruits per tree and fruit yield per plant at both the genotypic and phenotypic level.

Areole weight had also shown highly significant positive correlation with number of fruits per tree and fruit yield per plant at both the genotypic and phenotypic level and character number of fruits per tree also found highly significant positive correlation with fruit yield per plant at both the genotypic and phenotypic level.

4.4.2 Genotypic and Phenotypic correlation coefficients for fruit yield and its components in custard apple for qualitative traits during the year 2013-14 and 2014-15

The data on qualitative traits for genotypic and phenotypic correlation coefficient have been given in Table 4.8 and 4.9.

The character total soluble solids exhibited highly significant positive correlation with total sugar, reducing sugar, keeping days, pulp ratio, pulp-seed ratio, peel % and fruit yield per plant with both the genotypic and phenotypic level, while highly significant negative correlation was found with acidity at both the phenotypic and genotypic level.

Total sugar is showed highly significant positive correlation with reducing sugar, keeping days, pulp ratio, pulp-seed ratio, peel % and fruit yield per plant with

both the phenotypic and genotypic level, while highly significant negative correlation with acidity was observed at both the phenotypic and genotypic level.

Reducing sugar recorded highly significant positive correlation with keeping days, pulp ratio, pulp-seed ratio, peel % and fruit yield per plant at both the phenotypic and genotypic level, while highly significant negative correlation was seen with non-reducing sugar and acidity at both the phenotypic and genotypic level.

Non-reducing sugar recorded highly significant negative correlation with keeping days, pulp ratio, pulp-seed ratio and peel % at both the phenotypic and genotypic level and the character acidity registered highly significant negative correlation with keeping days, pulp ratio, pulp-seed ratio, peel % and fruit yield per plant at both the phenotypic and genotypic level.

Highly significant positive correlation of keeping days with pulp ratio, pulp-seed ratio, peel % and fruit yield per plant was exhibited at both the phenotypic and genotypic level and the character pulp ratio had also shown highly significant positive correlation with pulp-seed ratio, peel % and fruit yield per plant at both the phenotypic and genotypic level.

The character pulp-seed ratio found highly significant positive correlation with peel % and fruit yield per plant at both the phenotypic and genotypic level and the character peel percentage was found highly significant positive correlation with fruit yield per plant at both the phenotypic and genotypic level.

An overall observation of correlation coefficient analysis revealed that direct selection for quantitative traits *i.e.*, length of pedicel, number of seeds per fruits, number of fruits per tree, areole weight, pulp weight, fruit yield per plant and qualitative traits *viz.*, reducing sugar, pulp-seed ratio, peel percentage and pulp ratio may lead to the development of high-yielding custard apple genotypes. The experimental findings on correlation coefficient analysis are in general agreement with the earlier reporter of Deshmukh *et al.* (2001), Joshi *et al.* (2001), Lima *et al.* (2004),

Mariguele and Silva (2010), Paulo *et al.* (2009), Mariguele and Silva (2012) and Keny *et al.* (2010).

4.5 Path coefficient analysis

Path coefficient analysis measures the direct and indirect contribution of various independent characters on a dependent character. Path coefficient analysis given by Dewey and Lu (1959) has been used to estimate the magnitude and direction of direct and indirect effects of various yield-contributing characters. Correlation coefficients along with path coefficients together provide more reliable information which can be effectively predicted in crop improvement programme. If the correlation between yield and a character is due to direct effect of a character, it reveals true relationship between them and direct selection for this trait will be rewarding for yield improvement. However, if the correlation coefficient is mainly due to indirect effects of the character through another component trait, indirect selection through such trait will be effective for yield improvement. Genotypic correlation coefficients of various yield attributing characters for fruit yield per plant were further partitioned into direct and indirect effects. The data on quantitative and qualitative traits for genotypic path have been given in Table 4.7 and 4.10.

4.5.1 Path coefficients showing direct and indirect effects of different quantitative traits on fruit yield and its components during the year 2013-14 and 2014-15

The genotypic path coefficient of fruit yield with important quantitative traits was partitioned into direct and indirect effects taking fruit yield per plant as dependent variable. The direct and indirect effects of different quantitative traits on fruit yield per plant are presented in table 4.7

Path coefficient analysis of different quantitative traits contributing towards fruit yield per plant revealed that fruit weight had highest positive direct effect (3.449) relationship with fruit yield per plant followed by pulp weight (1.455), number of fruits per tree (0.616), days to 50% maturity (0.396), total number of fruits (0.233), length of pedicel (0.153), number of seeds per fruit (0.137), number of alternate leaf (0.115),

seed weight (0.076), fruit length (0.049), pedicel thickness (0.032) and fruit width (0.024).

Number of alternate leaf showed low positive direct effect on fruit yield per plant. It is due to negligible positive indirect effect on fruit yield per plant *via* total number of fruits, pedicel thickness, number of flowers per branches, fruit width, weight of pericarp, length of pedicel, fruit length, areole weight, pulp weight, fruit weight, number of fruits per tree, length of pericarp, length of leaf and negligible negative indirect effect *via* seed length, seed weight, days to 50% maturity, number of seeds per fruit and seed width.

The character, length of leaf had shown low negative direct effect on fruit yield per plant due to negligible positive indirect effect on fruit yield per plant *via* days to 50% maturity, seed weight, seed length and negligible negative indirect effect *via* fruit weight, areole weight, pulp weight, number of fruits per tree, length of pericarp, total number of fruits, fruit length, number of flowers per branch and weight of pericarp.

The character, number of flowers per branches expressed low negative direct effect on fruit yield per plant due to negligible positive indirect effect on fruit yield per plant *via* days to 50% maturity, seeds per fruit, seed width, seed length, seed weight and negligible negative indirect effect *via* total number of fruits, number of fruits per tree, fruit weight, pulp weight, areole weight, weight of pericarp, pedicel thickness, fruit width, length of pericarp, fruit length and length of pedicel.

Days to 50% maturity showed high positive direct effect on fruit yield per plant due to high negative indirect effect *via* number of seeds per fruit, seed width and moderate positive indirect effect *via* seed length and low positive indirect effect *via* seed weight. Such results also due to the high negative indirect effect *via* number of flowers per branches, total number of fruits, number of fruits per tree, areole weight, pulp weight, fruit weight, weight of pericarp, pedicel thickness, fruit width, length of pericarp, fruit length, length of pedicel and low negative indirect effect *via* number of alternate leaf and length of leaf.

Total number of fruits had shown moderately positive direct effect on fruit yield per plant due to moderate positive indirect effect *via* number of flowers per branches and low positive indirect effect *via* number of fruits per tree, areole weight, weight of pericarp, pulp weight, fruit weight, pedicel thickness, fruit width, length of pericarp, length of pedicel, fruit length, number of alternate leaf, length of leaf. Such results also due to the moderate negative indirect effect *via* days to 50% maturity and low negative indirect effect *via* number of seeds per fruit, seed width, seed length and seed weight.

The character, fruit width had shown negligible positive direct effect on fruit yield per plant due to negligible positive indirect effect *via* fruit length, pedicel thickness, length of pedicel, weight of pericarp, total number of fruits, pulp weight, areole weight, number of fruits per tree, number of flowers per branches, fruit weight, length of pericarp and negligible negative indirect effect *via* days to 50% maturity, seed length and number of seeds per fruit.

Fruit length showed negligible positive direct effect on fruit yield per plant due to negligible positive indirect effect *via* fruit width, weight of pericarp, pedicel thickness, pulp weight, areole weight, number of fruits per tree, fruit weight, length of pedicel, total number of fruits, number of flowers per branches, length of pericarp and negligible negative indirect effect *via* days to 50% maturity, seed length, number of seeds per fruit and seed width.

The character, fruit weight had shown very high positive direct effect on fruit yield per plant due to very high positive indirect effect *via* pulp weight, areole weight, number of fruits per tree, weight of pericarp, length of pericarp, number of flowers per branches, total number of fruits, fruit length, fruit width, pedicel thickness, length of pedicel, length of leaf, number of alternate leaf and very high negative indirect effect *via* days to 50% maturity, number of seeds per fruit, seed width, seed length and seed weight.

Length of pedicel showed low positive direct effect on fruit yield per plant due to low positive indirect effect *via* fruit width, fruit length, total number of fruits, pedicel thickness, length of pericarp, number of flowers per branches, areole weight, weight of pericarp, pulp weight, fruit weight and low negative indirect effect *via* days to 50% maturity, seed length and number of seeds per fruit.

Pedicel thickness showed negligible positive direct effect on fruit yield per plant due to negligible positive indirect effect *via* fruit width, total number of fruits, number of flowers per branches, weight of pericarp, fruit length, areole weight, number of fruits per tree, fruit weight, length of pedicel, pulp weight and negligible negative indirect effect *via* days to 50% maturity, seed length and number of seeds per fruit.

Length of pericarp expressed negligible negative direct effect on fruit yield per plant due to negligible positive indirect effect *via* days to 50% maturity, seed width, seeds per fruit and negligible negative indirect effect *via* fruit weight, pulp weight, areole weight, fruits per tree, weight of pericarp, flowers per branches, total number of fruits, length of pedicel, fruit width, fruit length.

Weight of pericarp expressed negligible negative direct effect on fruit yield per plant due to negligible positive indirect effect *via* days to 50% maturity, number of seeds per fruit, seed width and negligible negative indirect effect *via* areole weight, number of fruits per tree, pulp weight, fruit weight, number of flowers per branches, length of pericarp, total number of fruits, fruit length and fruit width.

Seed length showed negligible negative direct effect on fruit yield per plant due to negligible positive indirect effect *via* fruit width, fruit length, length of pericarp, number of alternate leaf, weight of pericarp, total number of fruits, areole weight, pedicel thickness, pulp weight, number of flowers per branches, fruit weight, length of pericarp, number of fruits per tree and negligible negative indirect effect *via* days to 50% maturity, seed width and number of seeds per fruit.

The character, seed width showed negligible negative direct effect on fruit yield per plant due to negligible positive indirect effect *via* pulp weight, areole weight, total number of fruits, fruit weight, length of pericarp, weight of pericarp, fruits per tree, number of flowers per branches, fruit length and negligible negative indirect effect *via* days to 50% maturity and number of seeds per fruit.

The character, number of seeds per fruit had shown low positive direct effect on fruit yield per plant due to low positive indirect effect *via* days to 50% maturity, seed length, seed width and low negative indirect effect *via* fruit weight, pulp weight, areole weight, number of fruits per tree, weight of pericarp, length of pericarp, number of flowers per branches and total number of fruits.

Seed weight showed negligible positive direct effect on fruit yield per plant due to negligible positive indirect effect *via* days to 50% maturity, number of seeds per fruit and negligible negative indirect effect *via* number of fruits per tree, fruit weight, areole weight, pulp weight, number of alternate leaf, pedicel thickness, length of pericarp and total number of fruits.

The character, pulp weight exhibited very high positive direct effect on fruit yield per plant due to very high positive indirect effect *via* fruit weight, areole weight, number of fruits per tree, length of pericarp, weight of pericarp, number of flowers per branches, total number of fruits, fruit width, fruit length, pedicel thickness and very high negative indirect effect *via* days to 50% maturity, number of seeds per fruit and seed width.

The character, areole weight showed very high negative direct effect on fruit yield per plant due to very high positive indirect effect *via* days to 50% maturity, number of seeds per fruit, seed width, seed length, seed weight and very high negative indirect effect *via* areole weight, pulp weight, fruit weight, number of fruits per tree, weight of pericarp, length of pericarp, number of flowers per branches, total number of fruits, fruit width, fruit length, pedicel thickness, length of pedicel, length of leaf and number of alternate leaf.

The character, number of fruits per tree had shown high positive direct effect on fruit yield per plant due to high positive indirect effect *via* pulp weight, fruit weight, areole weight, weight of pericarp, number of flowers per branches, total number of fruits, length of pericarp, pedicel thickness, fruit width, fruit length, length of pedicel, length of leaf and high negative indirect effect *via* days to 50% maturity, number of seeds per fruit, seed weight, seed length and seed width.

4.5.2 Path coefficients showing direct and indirect effects of different qualitative traits on fruit yield and its components during the year 2013-14 and 2014-15

The direct and indirect effects of different qualitative traits on fruit yield per plant are presented in table 4.10. Path coefficient analysis of different qualitative traits contributing towards fruit yield per plant revealed that reducing sugar had highest positive direct effect (0.742) relationship with fruit yield per plant followed by pulp-seed ratio (0.556), peel percentage (0.082) and non-reducing sugar (0.067).

The quality character, total soluble solid showed low negative direct effect on fruit yield per plant due to low positive indirect effect *via* acidity, non-reducing sugar and low negative indirect effect *via* pulp ratio, peel percentage, reducing sugar, pulp-seed ratio, total sugar and keeping days.

Total sugar had shown high negative direct effect on fruit yield per plant due to high positive indirect effect *via* acidity and low positive indirect effect *via* non-reducing sugar. Such results also due to the high negative indirect effect *via* pulp ratio peel percentage, reducing sugar, pulp-seed ratio, keeping days and total soluble solid.

Reducing sugar showed high positive direct effect on fruit yield per plant due to high positive indirect effect *via* peel percentage, pulp ratio, total sugar, pulp-seed ratio, total soluble solid, keeping days and high negative indirect effect *via* acidity and low negative indirect effect *via* non-reducing sugar.

Non-reducing sugar had shown negligible positive direct effect on fruit yield per plant due to negligible positive indirect effect *via* acidity and negligible negative indirect effect *via* pulp ratio, peel percentage, keeping days and reducing sugar.

Acidity showed moderately negative direct effect on fruit yield per plant due to moderate positive indirect effect *via* pulp ratio, peel percentage, total soluble solid and low positive indirect effect *via* reducing sugar, total sugar, pulp-seed ratio, keeping days.

Keeping days had shown negligible negative direct effect on fruit yield per plant due to negligible positive indirect effect *via* acidity and negligible negative indirect effect *via* pulp ratio, peel percentage, total sugar, reducing sugar, pulp-seed ratio and total soluble solids.

Pulp ratio had shown negligible negative direct effect on fruit yield per plant due to negligible positive indirect effect *via* acidity, non-reducing sugar and negligible negative indirect effect *via* total soluble solid, reducing sugar, total sugar, pulp-seed ratio and keeping days.

Pulp-seed ratio showed high positive direct effect on fruit yield per plant due to high positive indirect effect *via* pulp ratio, peel percentage, reducing sugar, total soluble solid, total sugar, keeping days and high negative indirect effect *via* acidity.

Peel percentage showed negligible positive direct effect on fruit yield per plant due to low positive indirect effect *via* total sugar, reducing sugar and negligible positive indirect effect *via* keeping days, pulp ratio. The result acidity and non-reducing sugar have negligible negative indirect effect.

Hence, direct selection for these traits could be practiced for developing high-yielding custard apple genotypes. The present findings are in general agreement with the report of Deshmukh *et al.* (2001), Joshi *et al.* (2003), Lima *et al.* (2004), Mariguele and Silva (2010a), Paulo *et al.* (2009), Mariguele and Silva (2010b) and Keny *et al.* (2010)

Table 4.5: Genotypic (G) correlation coefficients for quantitative traits of fruit yield and its components in custard apple during the year 2013-14 and 2014-15

S.No	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1.	-0.175*	0.602**	-0.278**	0.641**	0.577**	0.532**	0.455**	0.591**	0.648**	0.399**	0.577**	-0.734**	-0.361	-0.343**	-0.673**	0.494**	0.531**	0.476	0.472**
2.	1.000	0.390**	-0.078	0.244**	-0.014	0.194*	0.503**	0.095**	0.115**	0.346**	0.296**	-0.184*	-0.260**	-0.320**	-0.533**	0.481**	0.470**	0.492**	0.447**
3.	1.000	1.000	-0.843**	0.827**	0.008	0.602**	0.697**	0.567**	0.620**	0.597**	0.737**	-0.575**	-0.609**	-0.656**	-0.816**	0.705**	0.715**	0.822**	0.679**
4.	1.000	1.000	1.000	-0.764**	-0.624**	-0.794**	-0.681**	-0.713**	-0.728**	-0.691**	-0.799**	0.512**	0.678**	0.720**	0.706**	-0.686**	-0.684**	-0.759**	-0.656**
5.	1.000	1.000	1.000	1.000	0.635**	0.573**	0.714**	0.587**	0.701**	0.647**	0.729**	-0.601**	-0.668**	-0.617**	-0.830**	0.727**	0.736**	0.815**	0.701**
6.	1.000	1.000	1.000	1.000	1.000	0.834**	0.649**	0.726**	0.802**	0.596**	0.737**	-0.726**	-0.518**	-0.497**	-0.712**	0.675**	0.683**	0.721**	0.652**
7.	1.000	1.000	1.000	1.000	1.000	1.000	0.693**	0.714**	0.724**	0.623**	0.789**	-0.752**	-0.573**	-0.608**	-0.700**	0.701**	0.714**	0.729**	0.686**
8.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.608**	0.675**	0.859**	0.860**	-0.630**	-0.729**	-0.858**	-0.997**	0.997**	0.999**	0.928**	0.941**
9.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.697**	0.652**	0.585**	-0.752**	-0.542**	-0.505**	-0.642**	0.630**	0.644**	0.656**	0.637**
10.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.613**	0.715**	-0.606**	-0.480**	-0.572**	-0.711**	0.691**	0.703**	0.740**	0.624**
11.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.781**	-0.619**	-0.636**	-0.779**	-0.835**	0.859**	0.863**	0.873**	0.798**
12.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-0.665**	-0.702**	-0.801**	-0.891**	0.868**	0.875**	0.921**	0.803**
13.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.621**	0.551**	0.712**	-0.659**	-0.668**	-0.647**	-0.674**
14.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.640**	0.709**	-0.733**	-0.726**	-0.691**	-0.714**
15.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.794**	-0.841**	-0.827**	-0.871**	-0.805**
16.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-0.993**	-0.996**	-0.998**	-0.969**
17.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999**	0.981**	0.946**
18.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
19.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
20.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

1.No. of Alternate Leaf
2.Length of Leaf (cm)
3.No. of Flowers Per Branches
4.Days to 50 % Maturity
5.Total No. of Fruits
6.Fruit Width (cm)
7.Fruit Length (cm)
8.Fruit Weight (g)
9.Length of Pedicel (cm)
10.Pedicel Thickness (mm)
11.Length of Pericarp (cm)
12. Weight of Pericarp (g)
13.Seed Length (mm)
14.Seed Width (mm)
15.Seeds per Fruit
16.Seed Weight(g)
17.Pulp Weight (g)
18.Areole Weight(g)
19.No. of Fruits Per Tree
20.Fruit Yield Per Plant (kg)

Table 4.6: Phenotypic (P) correlation coefficients for quantitative traits of fruit yield and its components in custard apple during the year 2013-14 and 2014-15

S. No.	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1.	0.011	0.227**	-0.189**	0.271***	0.340**	0.243**	0.239**	0.319**	0.336**	0.238**	0.288**	-0.412**	-0.127*	-0.038	-0.158*	0.241**	0.276**	0.264**	0.226**
2.	1.0000	0.173**	-0.035	0.152*	0.004	0.158*	0.356**	0.054	0.080	0.233**	0.218**	-0.109	-0.112	-0.154*	-0.281**	0.339**	0.331**	0.309**	0.261**
3.	1.0000	1.0000	-0.396**	0.717**	0.470**	0.458**	0.603**	0.483**	0.524**	0.513**	0.626**	-0.405**	-0.433**	-0.402**	-0.551**	0.610**	0.620**	0.556**	0.569**
4.	1.000	1.000	1.000	-0.414**	-0.369**	-0.424**	-0.384**	-0.392**	-0.416**	-0.310**	-0.442**	0.276**	0.276**	0.333**	0.314**	-0.373**	-0.379**	-0.306**	-0.354**
5.	1.000	1.000	1.000	1.000	0.575**	0.517**	0.667**	0.545**	0.660**	0.611**	0.683**	-0.483**	-0.500**	-0.467**	-0.677**	0.684**	0.698**	0.612**	0.644**
6.	1.000	1.000	1.000	1.000	1.000	0.747**	0.614**	0.686**	0.758**	0.564**	0.686**	-0.581**	-0.393**	-0.347**	-0.540**	0.647**	0.651**	0.543**	0.595**
7.	1.000	1.000	1.000	1.000	1.000	1.000	0.645**	0.656**	0.664**	0.578**	0.729**	-0.598**	-0.418**	-0.470**	-0.578**	0.656**	0.664**	0.539**	0.626**
8.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.589**	0.660**	0.842**	0.836**	-0.541**	-0.563**	-0.649**	-0.794**	0.986**	0.981**	0.819**	0.883**
9.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.674**	0.635**	0.563**	-0.625**	-0.417**	-0.398**	-0.529**	0.614**	0.629**	0.522**	0.602**
10.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.593**	0.691**	-0.508**	-0.371**	-0.437**	-0.562**	0.677**	0.686**	0.581**	0.575**
11.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.754**	-0.548**	-0.497**	-0.613**	-0.670**	0.846**	0.850**	0.702**	0.748**
12.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-0.546**	-0.553**	-0.639**	-0.726**	0.846**	0.851**	0.712**	0.743**
13.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-0.559**	-0.578**	-0.479**	-0.527**
14.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-0.568**	-0.577**	-0.466**	-0.533**
15.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-0.657**	-0.653**	-0.518**	-0.584**
16.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-0.818**	-0.810**	-0.656**	-0.756**
17.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.989**	0.823**	0.892**
18.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.827**	0.890**
19.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.755**
20.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

1.No. of Alternate Leaf
2.Length of Leaf (cm)
3.No. of Flowers Per Branches
4.Days to 50 % Maturity
5.Total No. of Fruits
6.Fruit Width (cm)
7.Fruit Length (cm)
8.Fruit Weight (g)
9.Length of Pedicel (cm)
10.Pedicel Thickness (mm)
11.Length of Pericarp (cm)
12.Weight of Pericarp (g)
13.Seed Length (mm)
14.Seed Width (mm)
15.Seeds per Fruit
16.Seed Weight (g)
17.Pulp Weight (g)
18.Arcole Weight (g)
19.No. of Fruits Per Tree
20.Fruit Yield Per Plant (kg)

Table 4.7: Genotypic path coefficients for quantitative traits of fruit yield and its components in custard apple during the year 2013-14 and 2014-15

Characters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Correlation with Fruit yield/ plant (r)
1.	-0.176	0.031	-0.106	0.049	-0.113	-0.101	-0.094	-0.080	-0.104	-0.114	-0.070	-0.102	0.129	0.063	0.060	0.118	-0.087	-0.093	-0.084	0.472**
2.	0.003	-0.016	-0.005	0.001	-0.004	0.000	-0.003	-0.008	-0.002	-0.002	-0.006	-0.005	0.003	0.004	0.005	0.009	-0.008	-0.008	-0.008	0.447**
3.	0.137	0.068	0.227	-0.191	0.188	0.127	0.136	0.158	0.129	0.141	0.135	0.167	-0.130	-0.138	-0.149	-0.185	0.160	0.162	0.186	0.679**
4.	-0.018	-0.005	-0.055	0.066	-0.050	-0.041	-0.052	-0.045	-0.047	-0.048	-0.045	-0.052	0.034	0.045	0.047	0.046	-0.045	-0.045	-0.050	-0.656**
5.	0.183	0.070	0.236	-0.218	0.286	0.181	0.164	0.204	0.168	0.200	0.185	0.208	-0.172	-0.191	-0.176	-0.237	0.208	0.210	0.233	0.701**
6.	0.056	-0.001	0.054	-0.060	0.061	0.097	0.081	0.063	0.070	0.078	0.058	0.071	-0.070	-0.050	-0.048	-0.069	0.065	0.066	0.070	0.652**
7.	-0.053	-0.019	-0.060	0.079	-0.057	-0.083	-0.099	-0.069	-0.071	-0.072	-0.062	-0.078	0.074	0.057	0.060	0.069	-0.069	-0.071	-0.072	0.686**
8.	0.117	0.129	0.178	-0.174	0.183	0.166	0.177	0.256	0.155	0.173	0.220	0.220	-0.161	-0.187	-0.220	-0.255	0.256	0.256	0.263	0.941**
9.	0.051	0.008	0.049	-0.061	0.051	0.063	0.062	0.052	0.086	0.060	0.056	0.050	-0.065	-0.047	-0.044	-0.055	0.054	0.056	0.057	0.637**
10.	-0.136	-0.024	-0.130	0.153	-0.147	-0.168	-0.152	-0.142	-0.146	-0.210	-0.129	-0.150	0.127	0.101	0.120	0.149	-0.145	-0.148	-0.155	0.624**
11.	-0.099	-0.086	-0.148	0.172	-0.161	-0.148	-0.155	-0.213	-0.162	-0.152	-0.248	-0.194	0.154	0.158	0.194	0.207	-0.213	-0.214	-0.217	0.798**
12.	0.023	0.012	0.030	-0.032	0.029	0.030	0.032	0.034	0.023	0.029	0.031	0.040	-0.027	-0.028	-0.032	-0.036	0.035	0.035	0.037	0.803**
13.	0.174	0.044	0.136	-0.121	0.142	0.172	0.178	0.149	0.178	0.143	0.147	0.158	-0.237	-0.147	-0.131	-0.169	0.156	0.158	0.153	-0.674**
14.	-0.080	-0.058	-0.135	0.151	-0.149	-0.115	-0.128	-0.162	-0.121	-0.107	-0.141	-0.156	0.138	0.223	0.142	0.158	-0.163	-0.162	-0.154	-0.714**
15.	-0.003	-0.003	-0.006	0.007	-0.006	-0.005	-0.006	-0.008	-0.005	-0.005	-0.007	-0.007	0.005	0.006	0.009	0.007	-0.008	-0.008	-0.008	-0.805**
16.	-0.571	-0.453	-0.693	0.599	-0.705	-0.605	-0.595	-0.847	-0.545	-0.603	-0.709	-0.756	0.605	0.602	0.674	0.849	-0.849	-0.851	-0.933	-0.969**
17.	0.141	0.138	0.202	-0.197	0.208	0.193	0.201	0.287	0.181	0.198	0.246	0.249	-0.189	-0.210	-0.241	-0.287	0.286	0.287	0.295	0.946**
18.	0.905	0.801	1.218	-1.164	1.253	1.163	1.215	1.702	1.097	1.196	1.469	1.489	-1.138	-1.237	-1.408	-1.707	1.704	1.703	1.754	0.943**
19.	-0.180	-0.186	-0.312	0.288	-0.309	-0.274	-0.276	-0.390	-0.249	-0.281	-0.331	-0.349	0.245	0.262	0.330	0.417	-0.391	-0.391	-0.379	0.989**

Genotypic Path Coefficient Residual effect = 0.3380; Direct effect on main diagonal (bold figures)

1.No. of Alternate Leaf	5.Total No. of Fruits	9.Length of Pedicel (cm)	13.Seed Length (mm)	17.Pulp Weight (g)
2.Length of Leaf (cm)	6.Fruit Width (cm)	10.Pedicel Thickness (mm)	14.Seed Width (mm)	18.Areole Weight (g)
3.No. of Flowers Per Branches	7.Fruit Length (cm)	11.Length of Pericarp (cm)	15.No. of Seeds per Fruit	19.No. of Fruits Per Tree
4.Days to 50 % Maturity	8.Fruit Weight (g)	12.Weight of Pericarp (g)	16.Seed Weight (g)	

Table 4.8: Genotypic (G) correlation coefficients for qualitative traits of fruit yield and its components in custard apple during the year 2013-14 and 2014-15

S. No.	Characters	2	3	4	5	6	7	8	9	10
1.	Total Soluble Solids	0.821**	0.867**	-0.153*	-0.859**	0.759**	0.997	0.865**	0.998**	0.836**
2.	Total Sugar	1.000	0.970**	-0.139*	-0.819**	0.829**	0.991	0.863**	0.995**	0.866**
3.	Reducing Sugar		1.000	-0.225**	-0.824**	0.857**	0.996	0.928**	0.959**	0.919**
4.	Non-reducing Sugar			1.000	0.037	-0.274**	-0.605	-0.154*	-0.593**	-0.130*
5.	Acidity				1.000	-0.812**	-0.991	-0.816**	-0.910**	-0.834**
6.	Keeping Days (Shelf Life)					1.000	0.994	0.831**	0.998**	0.818**
7.	Pulp Ratio						1.000	0.998**	0.989**	0.998**
8.	Pulp-Seed Ratio							1.000	0.978**	0.941**
9.	Peel Percentage								1.000	0.944**
10.	Fruit Yield Per Plant									1.000

1.	Total Soluble Solids (° Brix)	2.	Total Sugar (%)	3.	Reducing Sugar (%)	4.	Non-Reducing Sugar (%)	5.	Acidity (%)
6.	Keeping Days (Shelf Life)	7.	Pulp Ratio	8.	Pulp-Seed Ratio	9.	Peel Percentage	10.	Fruit Yield Per Plant (kg)

Table 4.9: Phenotypic (P) correlation coefficients for qualitative traits of fruit yield and its components in custard apple during the year 2013-14 and 2014-15

S. No.	Characters	2	3	4	5	6	7	8	9	10
1.	Total Soluble Solids	0.633**	0.684**	-0.120	-0.615**	0.548**	0.291**	0.659**	0.3174**	0.638**
2.	Total Sugar	1.000	0.919**	-0.128*	-0.697**	0.715**	0.356**	0.810**	0.393**	0.775**
3.	Reducing Sugar		1.000	-0.212**	-0.697**	0.699**	0.361**	0.854**	0.372**	0.797**
4.	Non-reducing Sugar			1.000	0.030	-0.239**	-0.194**	-0.151*	-0.212**	-0.126
5.	Acidity				1.000	-0.672**	-0.342**	-0.732**	-0.329**	-0.728**
6.	Keeping Days (Shelf Life)					1.000	0.362**	0.738**	0.341**	0.718**
7.	Pulp Ratio						1.000	0.457**	0.668**	0.394**
8.	Pulp-Seed Ratio							1.000	0.342**	0.889**
9.	Peel Percentage								1.000	0.325**
10.	Fruit Yield Per Plant									1.000

1. Total Soluble Solids (° Brix) 2. Total Sugar (%) 3. Reducing Sugar (%) 4. Non-Reducing Sugar (%) 5. Acidity (%)
6. Keeping Days (Shelf Life) 7. Pulp Ratio 8. Pulp-Seed Ratio 9. Peel Percentage 10. Fruit Yield Per Plant (kg)

Table 4.10: Genotypic path coefficients for qualitative traits of fruit yield and its components in custard apple during the year 2013-14 and 2014-15

S.No	Characters	1	2	3	4	5	6	7	8	9	Correlation with Fruit yield/ plant (r)
1.	Total Soluble Solids	-0.116	-0.096	-0.101	0.018	0.101	-0.088	-0.181	-0.101	-0.125	0.836**
2.	Total Sugar	-0.379	-0.462	-0.448	0.065	0.378	-0.383	-0.643	-0.399	-0.626	0.866**
3.	Reducing Sugar	0.643	0.719	0.742	-0.167	-0.612	0.636	0.869	0.688	0.967	0.919**
4.	Non-reducing Sugar	-0.010	-0.009	-0.015	0.067	0.003	-0.019	-0.041	-0.010	-0.039	-0.130*
5.	Acidity	0.208	0.198	0.199	-0.008	-0.242	0.196	0.279	0.197	0.220	-0.834**
6.	Keeping Days	-0.026	-0.029	-0.029	0.009	0.028	-0.035	-0.042	-0.029	-0.038	0.818**
7.	Pulp Ratio	-0.052	-0.046	-0.051	0.020	0.039	-0.041	-0.033	-0.042	-0.039	0.998**
8.	Pulp-Seed Ratio	0.481	0.479	0.515	-0.085	-0.453	0.461	0.691	0.556	0.543	0.941**
9.	Peel Percentage	0.089	0.111	0.107	-0.048	-0.075	0.099	0.097	0.080	0.082	0.944**

Genotypic path Coefficients Residual effect = 0.4361; Direct effects on main diagonal (**bold figures**)

1. Total Soluble Solids (° Brix) 2. Total Sugar (%) 3. Reducing Sugar (%) 4. Non-Reducing Sugar (%) 5. Acidity (%)
6. Keeping Days (Shelf Life) 7. Pulp Ratio 8. Pulp-Seed Ratio 9. Peel Percentage

4.6 Genetic divergence for fruit yield and its components in custard apple

In plant breeding, genetic diversity plays an important role because hybrids between lines of diverse origin, generally display a greater heterosis than those between closely related parents. Genetic diversity arises due to geographical separation or due to genetic barriers to crossability.

The choice of genetically diverse parents for hybridization is an important feature of crop improvement programme for getting desirable segregates. The multivariate analysis based on Mahalanobis D^2 , Tocher Method Euclidean cluster analysis is used for divergence analysis. Multivariate analysis by means of Mahalanobis D^2 statistic is a powerful tool in quantifying the degree of divergence between biological populations at genotypic level to assess the relative contribution of different components to the total divergence. The D^2 analysis classifies the genotypes into relatively homogeneous groups in such a way that within cluster diversity is minimized and between clusters diversity is maximized. The respective genotypes from diverse clusters can be utilized in breeding programme.

4.6.1 Genetic divergence for fruit yield and its components in custard apple for quantitative traits in 2013-14 and 2014-15

The present investigation was carried out to study the nature and magnitude of genetic divergence for twenty quantitative and ten qualitative traits of 60 genotypes of custard apple during 2013-14 and 2014-15 at College of Agriculture and Research Station, Northern Bastar, District-Kanker. The mean value of five observations was used for genetic divergence analysis among 60 genotypes by D^2 statistics developed by P.C. Mahalanobis (1928). The genotypes were grouped into different clusters by applying Euclidean clustering method. Intra and inter cluster distances and mean performance of the clusters for the characters were also computed. This technique has been considered as the most effective method to obtain the diverse parent for improving the quantitative as well as qualitative traits of crop. The present investigation aimed to estimate the magnitude of genetic divergence present in the 60 genotypes and to identify the suitable accessions for future breeding programme.

4.6.1.1 Cluster constellation

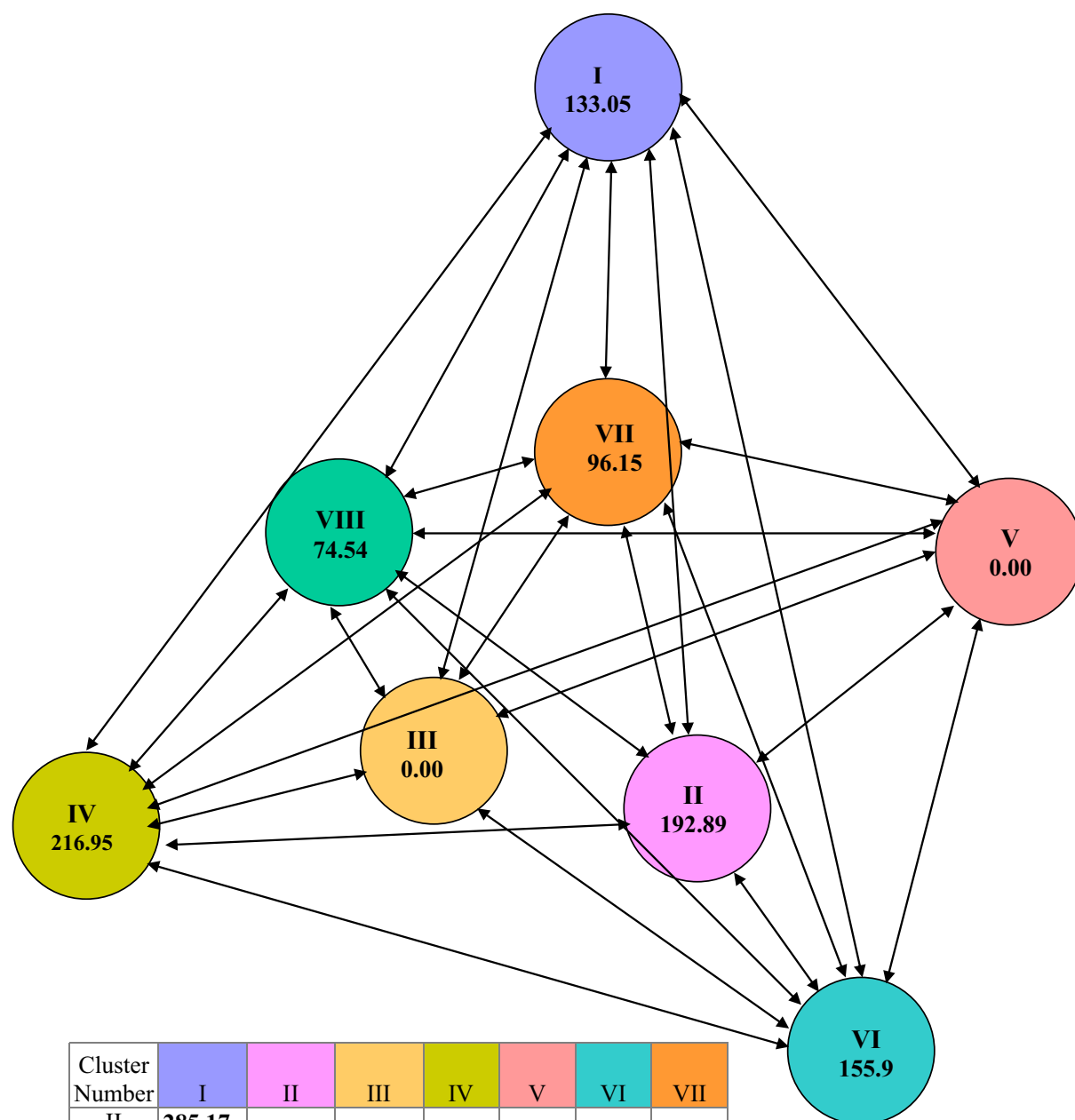
Cluster analysis for fruit yield and quality traits were estimated separately. For quantitative characters, all genotypes were grouped into 8 clusters using non-hierarchical Euclidean cluster analysis (Table 4.11). For fruit yield parameters, maximum number of genotypes were grouped into cluster III and VI (12 genotypes in each) followed by cluster V (10) and cluster VII (9). The minimum number of genotypes were found in cluster I (3) followed by cluster VIII (4). Grouping pattern of genotype indicated that genotypes within each cluster were similar type plants than the genotypes in other cluster. Clustering pattern of genotypes recognized that there is no influence of ecological location on divergence because parental populations were collected from different ecological area.

4.6.1.2 Mean performance of cluster wise

Intra and Inter-Cluster distances among 8 clusters for fruit yield and its components in custard apple are depicted in table 4.12 and fig. 4.3. The highest intra-cluster distance was recorded for cluster IV (216.95) followed by cluster II (192.89) and the smallest intra cluster distance was recorded in cluster III (0.00) and cluster V (0.00) for fruit yield and contributing traits. These results revealed that genotypes included in largest intra- cluster distances were relatively more diverse than those of smallest intra- cluster distance, it means further screening will be required to select superior genotypes because of similar type less diverse genotypes.

The highest inter-cluster distance was recorded between cluster VIII and cluster III (4610.12) followed by cluster VII and III (4459.87), whereas lowest inter-cluster distance was recorded between cluster VIII and cluster VII (132.34) followed by cluster VI and cluster VII (218.57) for fruit yield and attributing traits. The highest inter- cluster distance revealed the presence of genetic wide diversity in between groups leads to selection of such lines for hybridization and production of elite type progenies. The least inter-cluster distance revealed close relationship between the genotypes and hence, may not be emphasized upon to be used in hybridization programme. Narrow genetic base does not give rise to produce vigorous progeny.

Fig. 4.3: Cluster diagram showing inter-cluster & intra-cluster distances between eight clusters for quantitative traits



Inter Cluster Distances

- Value inside circle shows Intra Cluster Distances

4.6.1.3 Per cent contribution to variation

Cluster wise means performance of genotypes for quantitative traits of fruit yield and its components in custard apple is presented in Table 4.13. The information revealed that cluster I did not show highest cluster mean for any trait, but it showed lowest cluster mean for length of pedicel, pedicel thickness, length of pericarp, weight of pericarp and areole weight. Cluster III showed highest mean performance for length of pedicel and number of seeds per fruit. Cluster IV showed the maximum cluster mean for number of alternate leaf, length of leaf, number of flowers per branches and total number of fruits, whereas it showed lowest cluster mean for days to 50% maturity. Cluster V did not show maximum cluster mean for any trait but it showed lowest mean for length of leaf and fruit yield per plant. Cluster VI showed highest mean value for days to 50% maturity, seed length and seed width. Cluster VII showed highest mean value for seed width and seed weight, whereas it showed lowest mean value for number of alternate leaf, flowers per branches, total number of fruits, fruit width, fruit length, fruit weight, pulp weight and number of fruits per tree. Cluster VIII showed highest mean value for number of flowers per branches, fruit width, fruit length, fruit weight, pedicel thickness, length of pericarp, weight of pericarp, pulp weight, areole weight, number of fruits per tree and fruit yield per plant whereas it showed lowest mean value for seed length, seed width, number of seeds per fruit and seed weight. Genotypes of cluster VIII showed highest mean value for fruit yield and component traits, whereas lowest mean for seed yield and other seed related traits, so, it can be concluded that genotypes of cluster VIII will give good opportunity to researcher to be used as parents for developing good variety/hybrids of maximum yield, whereas genotypes of cluster IV could be used for increasing total number of of fruits and leaf characteristics.

Per cent contribution to variation is presented in table 4.13 and fig. 4.4. areole weight showed the highest contribution for divergence (27.63) followed by length of pedicel (18.02), length of pericarp (14.86), pedicel thickness (12.43), fruit width (7.40), weight of pericarp (4.63), fruit length (4.58), total number of fruits (3.33), seed

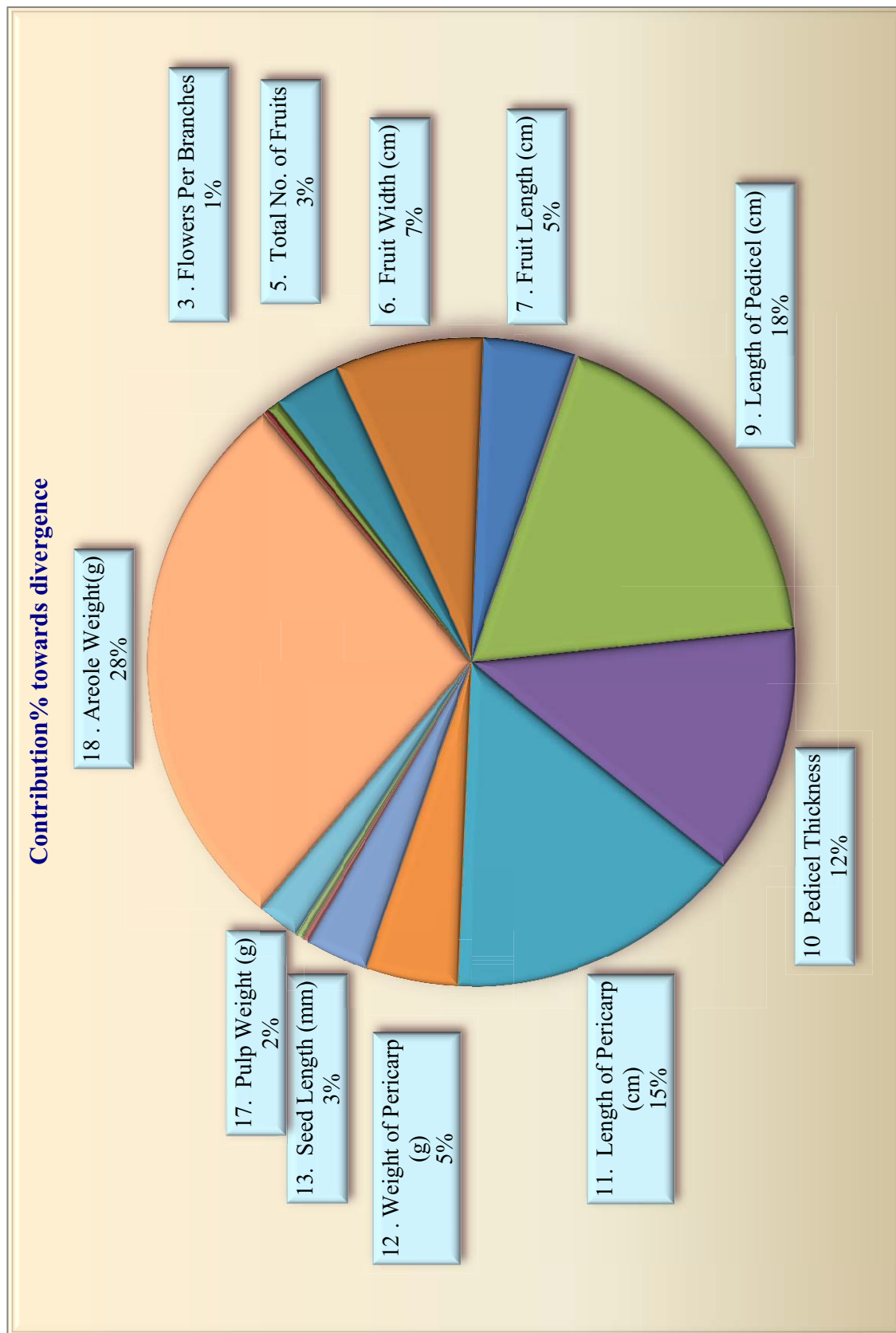


Fig.4.4: Contribution % towards divergence of genotypes for quantitative traits of fruit yield and its components in custard apple during the year 2013-14 and 2014-15

length (3.11) and pulp weight (2.15) whereas, rest of the characters showed very less percentage contribution to variation.

4.6.1.4 Cluster wise promising genotypes

Cluster wise promising genotypes for quantitative traits of fruit yield and its components in custard apple are presented in Table 4.14. Results showed that in cluster I, genotype IGCA-21 is promising for most of the traits, therefore, it can be selected as parent for further research programme to improve fruit yield and attributing traits. Genotypes IGCA-21, IGCA-3, IGCA-11, IGCA-1, IGCA-4, IGCA-2, IGCA-10, IGCA-22 are most promising for fruit yield per plant from cluster I, II, III, IV, V, VI, VII and cluster VIII, respectively.

4.6.2 Genetic divergence for qualitative traits of fruit yield and its components in custard apple during the year 2013-14 and 2014-15

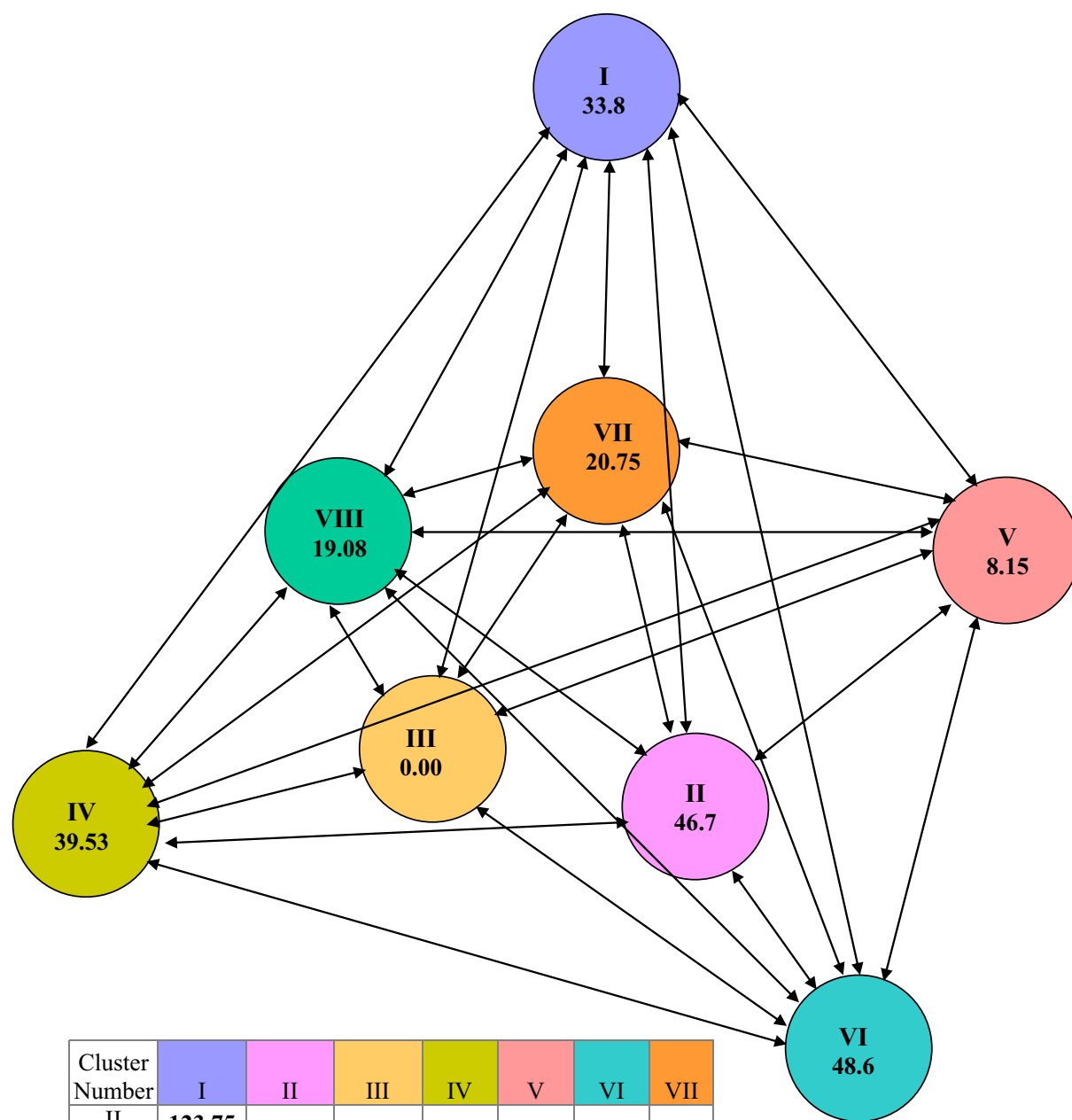
4.6.2.1 Cluster constellation

Cluster analysis for qualitative traits showed that all genotypes were grouped into 8 clusters using non-hierarchical Euclidean cluster analysis (Table 4.15 and Fig. 4.5). For qualitative parameter, maximum number of genotypes were grouped into cluster VIII (14) followed by cluster III (12). The minimum number of genotypes was found in cluster V (3) followed by cluster I (4). Grouping pattern of genotype indicated that genotypes within each cluster were similar type plants than the genotypes in other cluster. Clustering pattern of genotypes recognized that there is no influence of ecological location on divergence because parental populations were collected from different ecological area.

4.6.2.2 Intra and Inter-Cluster distances for qualitative traits

Intra and Inter-Cluster distances among 8 clusters for qualitative traits in custard apple are presented in Table 4.16. The highest intra-cluster distance was recorded for cluster VI (48.65) followed by cluster II (46.79) and the smallest intra cluster distance was recorded in cluster III (0.00) followed by cluster V (8.15) for qualitative traits. These results revealed that genotypes included in largest intra-

Fig. 4.5: Cluster diagram showing inter-cluster & intra-cluster distances between eight clusters for qualitative traits



Cluster Number	I	II	III	IV	V	VI	VII
II	123.75						
III	721.50	794.89					
IV	1327.86	1199.96	3742.72				
V	1602.26	1445.68	4166.05	52.47			
VI	1683.85	1369.65	4091.02	142.09	109.19		
VII	1359.08	1394.31	3902.15	111.11	126.14	379.16	
VIII	1399.72	1553.06	3976.95	260.65	300.53	656.61	62.20

• Inter Cluster Distances

- Value inside circle shows Intra Cluster Distances

cluster distances were relatively more diverse than those of smallest intra- cluster distance, it means further screening will be required to select superior genotypes because of similar type less diverse genotypes.

The highest inter-cluster distance was recorded between cluster V and cluster III (4166.05) followed by cluster VI and III (4091.02), whereas, lowest inter- cluster distance was recorded between cluster IV and cluster V (52.47) followed by cluster VII and cluster VIII (62.20) for qualitative traits. The highest inter- cluster distance revealed the presence of genetic wide diversity in between groups leads to selection of such lines for hybridization and production of elite type progenies. The least inter-cluster distance revealed close relationship between the genotypes and hence, may not be emphasized upon to be used in hybridization programme. Narrow genetic base does not give rise to produce vigorous progeny.

4.6.2.3 Per cent contribution to variation or mean performance of genotypes for qualitative traits

Cluster wise mean performance of genotypes for qualitative traits in custard apple is presented here in table 4.17 and fig. 4.6. The information revealed that cluster I didn't show highest cluster mean for any trait, but it showed lowest cluster mean for total soluble solid, total sugar, reducing sugar, pulp ratio and pulp-seed ratio. Cluster II showed highest mean value for acidity, whereas, it showed lowest mean value for non-reducing sugar. Cluster III showed highest mean performance for pulp ratio and peel percentage. Cluster IV showed the maximum cluster mean for non-reducing sugar, whereas, it showed lowest cluster mean for keeping days and fruit yield per plant. Cluster V showed maximum cluster mean for peel percentage. Cluster VI and cluster VII did not show highest and lowest mean value for any of the trait. Cluster VIII showed highest mean value for total soluble solid, total sugar, reducing sugar, keeping days, pulp-seed ratio, peel percentage, fruit yield per plant, whereas, it showed lowest mean value for acidity. Genotypes of cluster VIII showed highest mean value for most of the qualitative traits, so, it can be concluded that genotypes of cluster VIII will give good opportunity to researcher to be used as parents for developing good variety or

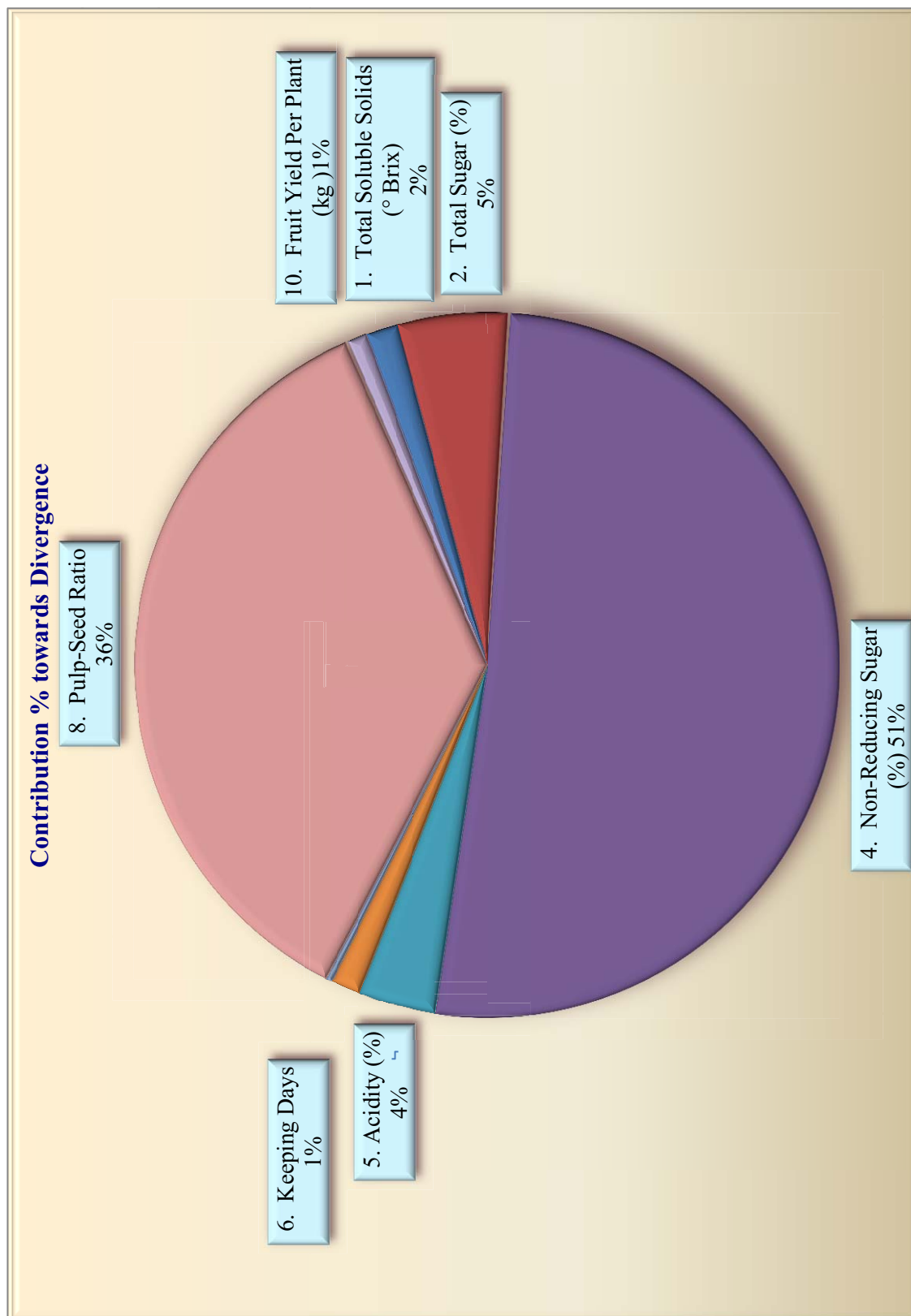


Fig. 4.6: Contribution % towards divergence of genotypes for qualitative traits of fruit yield and its components in custard apple during the year 2013-14 and 2014-15

hybrids of superior fruit quality, whereas, genotypes of cluster III could be used for increasing pulp ratio and peel percentage.

Percent contribution to variation is presented in table 4.17. Data on percent contribution to genetic divergence showed a high percentage of variation for non-reducing sugar (51.30), pulp-seed ratio (35.88), total sugar (5.03), acidity (3.56), total soluble solids (1.47), keeping days (shelf life) (1.36) and fruit yield per plant (0.90) whereas, rest of the characters had very less percentage contribution to variation.

4.6.2.4 Cluster wise promising genotypes (qualitative traits)

Cluster wise promising genotypes for qualitative traits in custard apple are presented in Table 4.18. Results showed that in cluster I, genotype IGCA-21 is promising for most of the qualitative traits, therefore, it can be selected as parent for further research programme to improve fruit quality traits. Genotypes IGCA-21, IGCA-11, IGCA-4, IGCA-2, IGCA-3, IGCA-12, IGCA-13 and IGCA-10 are most promising for pulp-seed ratio and peel percentage from cluster I, II, III, IV, V, VI, VII and cluster VIII respectively.

Varieties from geographically diverse localities are generally included in hybridization programme presuming genetic diversity. The problem of selection may further be simplified if one could identify the characters responsible for discrimination between parents. The reports available on this aspect in custard apple are rather scanty. Therefore, the present investigation was aimed at ascertaining the nature and magnitude of genetic diversity among a set of custard apple genotypes.

Genetic divergence analysis by using cluster statistics is a powerful tool in quantifying the degree of divergence between biological populations and to assess the relative contribution of different components to the total divergence. The genetic architecture of a population is controlled by the breeding behavior of the individuals. Changes in breeding systems have accelerated the genetic divergence in natural population. Custard apple is a predominantly cross-pollinated (protogyny) crop and no information is available suggesting a change in its breeding behavior under varied

environmental conditions. Discrimination of desirable parents for a successful hybridization programme is a difficult task for a plant breeder. Generally, geographical diversity has been considered as a measure of genetic diversity. However, this is an inferential criterion and it may not be so effective in quantifying or differentiating among populations. These results are in general agreement with the findings of Rao (1974), George *et al.* (2005), Le *et al.* (1998), Liu ShiBiao (2000), Samal *et al.* (2002), Liu and Chen (2002) and Mariguele and Silva (2010b).

Table 4.11: Distribution of different clusters for quantitative traits of fruit yield and its components in custard apple during the year 2013-14 and 2014-15

Cluster number	Number of genotypes	Genotypes
I	3	IGCA-5, IGCA-6, IGCA-18
II	5	IGCA-7 IGCA-9, IGCA-16, IGCA-17, IGCA-27
III	12	IGCA-1, IGCA-2, IGCA-3, IGCA-4, IGCA-10, IGCA-11, IGCA-12, IGCA-13, IGCA-19, IGCA-20, IGCA-21, IGCA-22
IV	5	IGCA-24, IGCA-25, IGCA-26, IGCA-32, IGCA-36
V	10	IGCA-8, IGCA-14, IGCA-15, IGCA-29, IGCA-30, IGCA-31, IGCA-33, IGCA-37, IGCA-41, IGCA-47
VI	12	IGCA-23, IGCA-28, IGCA-34, IGCA-35, IGCA-38, IGCA-40, IGCA-42, IGCA-43, IGCA-44, IGCA-45, IGCA-46, IGCA-54
VII	9	IGCA-39, IGCA-48, IGCA-49, IGCA-51, IGCA-52, IGCA-53, IGCA-55, IGCA-56, IGCA-58
VIII	4	IGCA-50, IGCA-57, IGCA-59, IGCA-60

Table 4.12: Intra and Inter-Cluster distances and D^2 values among 8 clusters for quantitative traits of fruit yield and its components in custard apple during the year 2013-14 and 2014-15

Cluster Number	I	II	III	IV	V	VI	VII	VIII
I	133.05	285.17	595.68	1458.32	1964.32	2016.32	2202.49	2296.07
II	192.89		892.81	1036.80	1781.01	1499.60	1643.84	1763.52
III	0.00	0.00		3328.60	4326.69	4115.09	4459.87	4610.12
IV	216.95				449.96	303.45	356.96	499.69
V						452.74	409.65	418.01
VI					0.00		218.57	369.04
VII						155.97	96.15	132.34
VIII								74.54

➤ Bold figures represent intra-cluster distance

Table 4.13: Cluster wise means performance of genotypes for quantitative traits of fruit yield and its components in custard apple during the year 2013-14 and 2014-15

Cluster numbers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
I	311.17	6.67	28.36	116.96	16.14	2.99	08.62	181.24	1.88**	13.59**	1.69**	2.93**	21.63	7.94	32.53	33.97	084.16	57.57**	294.24	104.48
II	338.61	7.32	32.67	111.64	22.36	4.23	11.71	427.28	3.18	22.17	3.12	5.18	17.67	6.75	27.75	27.01	226.63	153.82	345.25	149.05
III	336.39	6.44	29.82	114.86	18.43	3.89	10.48	191.28	2.91*	20.75	1.92	3.14	18.82	7.86	32.57*	33.66	092.41	065.04	299.25	109.75
IV	359.00*	7.53*	42.00*	106.00**	32.00*	3.75	11.13	385.00	2.56	23.50	2.57	5.15	18.00	6.50	28.25	24.23	204.05	138.60	350.00	146.75
V	348.75	5.67**	29.00	109.00	19.00	4.27	12.30	191.00	2.45	24.75	2.25	5.43	18.75	7.75	27.25	33.35	091.68	064.94	299.75	101.75**
VI	339.00	8.13	29.50	118.75*	19.25	4.55	10.95	410.75	1.90	24.50	1.85	4.75	22.50*	8.25*	32.00	28.05	217.69	147.87	344.75	145.25
VII	305.75**	5.97	28.75**	115.00	16.00**	3.15**	08.50**	172.00**	2.63	13.75	3.10	3.25	21.25	8.25**	33.00	35.07*	083.11**	060.00	289.75**	102.50
VIII	354.25	8.15	42.00*	108.25	31.75	4.70*	12.33*	570.00*	3.63	25.75*	3.35*	5.85*	15.50**	5.75**	25.75**	23.88**	302.10*	205.20*	376.00*	152.25*
%	0.06	0.28	0.62	0.00	3.33	7.40	4.58	0.17	18.02	12.43	14.86	4.63	3.11	0.34	0.40	0.00	2.15	27.63	0.00	0.00
Contribution																				

1.No. of Alternate Leaf 5.Total No. of Fruits 9.Length of Pedicel (cm) 13.Seed Length (mm) 17.Pulp Weight (g)
2.Length of Leaf (cm) 6.Fruit Width (cm) 10.Pedicel Thickness (mm) 14.Seed Width (mm) 18.Areole Weight(g)
3. No. of Flowers Per Branches 7.Fruit Length (cm) 11.Length of Pericarp (cm) 15. No. of Seeds per Fruit 19. No. of Fruits Per Tree
4.Days to 50 % Maturity 8.Fruit Weight (g) 12.Weight of Pericarp (g) 16.Seed Weight(g) 20.Fruit Yield Per Plant (kg)

Table 4.14: Cluster wise promising genotypes for quantitative traits of fruit yield and its components in custard apple during the year 2013-14 and 2014-15

S.No.	Cluster Number	I	II	III	IV	V	VI	VII	VIII
1.	No. of Alternate Leaf	IGCA-22	IGCA-11	IGCA-21	IGCA-23	IGCA-1	IGCA-13	IGCA-18	IGCA-19
2.	Length of Leaf (cm)	IGCA-10	IGCA-7	IGCA-12	IGCA-13	IGCA-43	IGCA-11	IGCA-19	IGCA-20
3.	No. of Flowers Per Branch	IGCA-21	IGCA-22	IGCA-4	IGCA-2	IGCA-3	IGCA-1	IGCA-12	IGCA-13
4.	Days to 50 % Maturity	IGCA-22	IGCA-21	IGCA-20	IGCA-2	IGCA-3	IGCA-1	IGCA-5	IGCA-4
5.	Total No. of Fruits	IGCA-21	IGCA-22	IGCA-20	IGCA-22	IGCA-4	IGCA-3	IGCA-2	IGCA-1
6.	Fruit Width (cm)	IGCA-21	IGCA-19	IGCA-4	IGCA-3	IGCA-2	IGCA-1	IGCA-10	IGCA-6
7.	Fruit Length (cm)	IGCA-19	IGCA-20	IGCA-21	IGCA-18	IGCA-10	IGCA-3	IGCA-2	IGCA-1
8.	Fruit Weight (g)	IGCA-21	IGCA-1	IGCA-2	IGCA-3	IGCA-4	IGCA-11	IGCA-12	IGCA-13
9.	Length of Pedicel (cm)	IGCA-21	IGCA-20	IGCA-2	IGCA-4	IGCA-3	IGCA-1	IGCA-10	IGCA-6
10.	Pedicel Thickness (mm)	IGCA-21	IGCA-4	IGCA-19	IGCA-1	IGCA-18	IGCA-20	IGCA-6	IGCA-13
11.	Length of Pericarp (cm)	IGCA-21	IGCA-11	IGCA-4	IGCA-12	IGCA-2	IGCA-3	IGCA-1	IGCA-10
12.	Weight of Pericarp (g)	IGCA-21	IGCA-4	IGCA-2	IGCA-1	IGCA-3	IGCA-20	IGCA-18	IGCA-19
13.	Seed Length (mm)	IGCA-9	IGCA-21	IGCA-22	IGCA-4	IGCA-3	IGCA-25	IGCA-26	IGCA-19
14.	Seed Width (mm)	IGCA-21	IGCA-3	IGCA-4	IGCA-2	IGCA-1	IGCA-5	IGCA-22	IGCA-19
15.	No. of Seeds/ Fruit	IGCA-21	IGCA-4	IGCA-3	IGCA-18	IGCA-10	IGCA-1	IGCA-11	IGCA-20
16.	Seed Weight(g)	IGCA-21	IGCA-22	IGCA-20	IGCA-4	IGCA-13	IGCA-12	IGCA-2	IGCA-18
17.	Pulp Weight (g)	IGCA-21	IGCA-1	IGCA-2	IGCA-3	IGCA-4	IGCA-11	IGCA-10	IGCA-12
18.	Areole Weight(g)	IGCA-21	IGCA-1	IGCA-2	IGCA-3	IGCA-4	IGCA-11	IGCA-12	IGCA-10
19.	No. of Fruits/ Tree	IGCA-21	IGCA-22	IGCA-2	IGCA-19	IGCA-20	IGCA-10	IGCA-4	IGCA-1
20.	Fruit Yield/ Plant (kg)	IGCA-21	IGCA-3	IGCA-11	IGCA-1	IGCA-4	IGCA-2	IGCA-10	IGCA-22

Table 4.15: Distribution of different clusters for qualitative traits of fruit yield and its components in custard apple during the year 2013-14 and 2014-15

Cluster number	Number of genotypes	Genotypes
I	4	IGCA-5, IGCA-6, IGCA-7, IGCA-9
II	8	IGCA-8, IGCA-14, IGCA-15, IGCA-18, IGCA-26, IGCA-28, IGCA-31, IGCA-36
III	12	IGCA-1, IGCA-2, IGCA-3, IGCA-4, IGCA-10, IGCA-11, IGCA-12, IGCA-13, IGCA-19, IGCA-20, IGCA-21, IGCA-22,
IV	5	IGCA-17, IGCA-34, IGCA-35, IGCA-38, IGCA-39
V	3	IGCA-25, IGCA-32, IGCA-33
VI	6	IGCA-42, IGCA-45, IGCA-46, IGCA-51, IGCA-52, IGCA-54
VII	8	IGCA-24, IGCA-29, IGCA-43, IGCA-44, IGCA-47, IGCA-49, IGCA-55, IGCA-56
VIII	14	IGCA-16, IGCA-23, IGCA-27, IGCA-30, IGCA-37, IGCA-40, IGCA-41, IGCA-48, IGCA-50, IGCA-53, IGCA-57, IGCA-58, IGCA-59, IGCA-60

Table 4.16: Intra and Inter-Cluster distances and D² values among 8 clusters for qualitative traits of fruit yield and its components in custard apple during the year 2013-14 and 2014-15

Cluster Number	I	II	III	IV	V	VI	VII	VIII
I								
II	33.84	123.75	721.50	1327.86	1602.26	1683.85	1359.08	1399.72
III		46.79	794.89	1199.96	1445.68	1369.65	1394.31	1553.06
IV			0.00	3742.72	4166.05	4091.02	3902.15	3976.95
V				39.53	52.47	142.09	111.11	260.65
VI					8.15	109.19	126.14	300.53
VII						48.65	379.16	656.61
VIII							20.75	62.20
								19.08

➤ Bold figures represent intra-cluster distance

Table 4.17: Cluster wise means performance of genotypes for qualitative traits of fruit yield and its components in custard apple during the year 2013-14 and 2014-15

Cluster numbers	Total Soluble Solids (° Brix)	Total Sugar (%)	Reducing Sugar (%)	Non-reducing Sugar (%)	Acidity (%)	Keeping Days	Pulp Ratio	Pulp-Seed Ratio	Peel Percentage	Fruit Yield per Plant (kg)
I	21.27**	16.61**	12.88**	4.91	0.40	3.34	46.23**	2.43**	31.37**	104.61
II	21.58	17.34	13.75	3.80**	0.42*	3.59	47.98	2.54	33.45	104.24
III	25.65	23.00	18.81	4.19	0.31	5.15	53.04*	8.37	36.00*	148.79
IV	21.69	17.30	13.60	6.04*	0.40	3.25**	46.29	2.55	31.59	103.66**
V	25.50	23.15	17.67	5.47	0.32	4.25	53.00	8.09	36.00*	145.50
VI	21.91	20.74	16.23	5.00	0.35	3.50	49.69	3.61	34.00	104.50
VII	21.56	20.15	15.20	4.95	0.34	5.00	48.00	2.69	34.00	146.75
VIII	28.07*	23.45*	19.30*	4.15	0.22**	6.50*	53.00	12.65*	36.00*	152.25*
% Contribution towards genetic divergence	1.47	5.03	0.11	51.30	3.56	1.36	0.28	35.88	0.11	0.90

* Highest values; ** Lowest values

Table 4.18: Cluster wise promising genotypes of genotypes for qualitative traits of fruit yield and its components in custard apple during the year 2013-14 and 2014-15

S. No.	Cluster Number	I	II	III	IV	V	VI	VII	VIII
1.	Total Soluble Solids (° Brix)	IGCA-21	IGCA-22	IGCA-10	IGCA-2	IGCA-13	IGCA-20	IGCA-12	IGCA-3
2.	Total Sugar (%)	IGCA-2	IGCA-21	IGCA-3	IGCA-22	IGCA-1	IGCA-20	IGCA-12	IGCA-11
3.	Reducing Sugar (%)	IGCA-20	IGCA-3	IGCA-2	IGCA-1	IGCA-21	IGCA-22	IGCA-4	IGCA-19
4.	Non-Reducing Sugar (%)	IGCA-7	IGCA-6	IGCA-16	IGCA-23	IGCA-12	IGCA-9	IGCA-5	IGCA-2
5.	Acidity (%)	IGCA-21	IGCA-22	IGCA-11	IGCA-20	IGCA-10	IGCA-1	IGCA-3	IGCA-12
6.	Keeping Days (Shelf life)	IGCA-21	IGCA-22	IGCA-4	IGCA-1	IGCA-11	IGCA-10	IGCA-9	IGCA-3
7.	Pulp Ratio	IGCA-21	IGCA-20	IGCA-22	IGCA-1	IGCA-2	IGCA-3	IGCA-4	IGCA-5
8.	Pulp -Seed Ratio	IGCA-21	IGCA-11	IGCA-4	IGCA-2	IGCA-3	IGCA-12	IGCA-13	IGCA-10
9.	Peel Percentage	IGCA-21	IGCA-11	IGCA-4	IGCA-2	IGCA-3	IGCA-12	IGCA-13	IGCA-10
10.	Fruit Yield / Plant (kg)	IGCA-21	IGCA-3	IGCA-11	IGCA-1	IGCA-4	IGCA-2	IGCA-10	IGCA-22

CHAPER-V

SUMMARY AND CONCLUSIONS

The present investigation entitled “**Studies on genetic variability and characterization of custard apple (*Annona squamosa* L.) genotypes in Northern Bastar of Chhattisgarh**” was undertaken to determine the extent of variability, heritability and genetic advance for various quantitative and qualitative characters for high fruit yield as well as fruit quality in custard apple.

The experimental material for the present study consisted local collection of 60 custard apple genotypes obtained from district-Kanker, (Chhattisgarh) India. The genotypes were raised in RBD with four replications during 2013-14 and 2014-15 for evaluation *In-situ* sixty custard apple genotypes were selected for investigation, which were found as wild seedling plants. Investigation worked at Antagarh, Bhanupratappur, Charama, Durgkondal, Kanker, Koymbeda, and Narharpur blocks of District- Kanker, (Chhattisgarh) India. At the start of this study, custard trees were 8 to 10 years of age.

Observations on different traits were recorded on single plant basis on five randomly selected competitive fruits separately from each plant as per the custard apple descriptors developed by ICAR, NBPGR (2002).

The measurement of existing variability in genetic material has been the basic requirement of a breeding programme. In the present investigation, a wide range of variability was observed for nearly all the traits *viz.*, number of alternate leaf, length of leaf, number of flowers per branches, days to 50 % maturity, seed length, seed width, number of seeds per fruit, fruit yield per plant, weight of pulp, weight of areole, number of fruits per tree and seed weight in total gene pool, indicating the existence of sufficient variability among the genotypes for the quantitative traits *viz.*, and qualitative traits fruit yield per plant, pulp ratio, peel percentage, reducing sugar, total sugar, total soluble solids.

Genotypic and phenotypic coefficient of variation for fruit yield and its components in custard apple for quantitative traits in *kharif* 2013-14 and *kharif* 2014-15 revealed that the pulp weight had highest GCV and PCV, areole weight, fruit weight, weight of pericarp, pedicel thickness, length of pedicel, total number of fruits, seed weight and fruit width, Genotypic and phenotypic coefficient of variation for fruit yield and its components in custard apple for qualitative traits in *Kharif* 2013-14 and *Kharif* 2014-15. The character pulp seed ratio had highest GCV and PCV and keeping days(Shelf life).

Heritability for fruit yield and its components in custard apple for quantitative traits in 2013-14 and 2014-15 showed that the highest heritability estimate was recorded for the character pulp weight followed by areole weight, fruit weight, length of pericarp, weight of pericarp, pedicel thickness, fruit length, length of pedicel, total number of fruits, fruit yield per plant, fruit width, seed length and number of flowers per branches.

Heritability for fruit yield and its components in custard apple for qualitative traits in 2013-14 and 2014-15 revealed that the highest heritability estimate was recorded for the character in qualitative traits pulp-seed ratio followed by non-reducing sugar, total sugar, fruit yield per plant, reducing sugar, titration acetic acid and keeping days(Shelf life).

The highest genetic advance for fruit yield and its components in custard apple for quantitative traits in 2013-14 and 2014-15 was observed for fruit weight followed by pulp weight, areole weight, number of alternate leaf and number of fruits per tree. Genetic advance for fruit yield and its components in custard apple for qualitative traits in 2013-14 and 2014-15 had highest genetic advance for fruit yield per plant.

Genetic advance as percentage of mean for fruit yield and its components in custard apple for quantitative traits in 2013-14 and 2014-15 showed high heritability coupled with high genetic advance as percentage of mean for pulp weight, areole weight, fruit weight, weight of pericarp, pedicel thickness, length of pericarp and

length of pedicel, which indicated the predominance of additive gene action in the expression of these characters which could be utilized through selection for improvement in these characters. Rest of the traits showed high to moderate heritability estimates coupled with moderate to low genetic advance as percentage of mean indicated the role of non-additive genetic variance in their expression.

High heritability coupled with high genetic advance as percentage of mean was found for qualitative traits of fruit yield per plant, total sugar, pulp-seed ratio, reducing sugar and total soluble solids, which indicated the predominance of additive gene action in the expression of these characters which could be utilized through selection for improvement in these characters. The test of the traits showed high to moderate heritability estimates coupled with moderate to low genetic advance as percentage of mean indicated the role of non-additive genetic variance in their expression.

Correlation for quantitative traits of character number of alternate leaf showed highly significant positive correlation with characters number of flowers per branches, total number of fruits, fruit width, fruit length, fruit weight, length of pedicel, pedicel thickness, length of pericarp, weight of pericarp, pulp weight, areole weight, number of fruits per tree and fruit yield per plant at both the phenotypic and genotypic level.

Correlation for qualitative traits on character total soluble solid exhibited highly significant positive correlation with total sugar, reducing sugar, keeping days, pulp ratio, pulp-seed ratio, peel % and fruit yield per plant at both the phenotypic and genotypic level

Path coefficients showing direct and indirect effects of different quantitative traits on fruit yield the genotypic correlation coefficient of fruit yield with important quantitative traits was partitioned into direct and indirect effects taking fruit yield per plant as dependent variable. The direct and indirect effects of different quantitative traits on fruit yield per plant.

Path coefficients showing direct and indirect effects of different qualitative traits on fruit yield the direct and indirect effects of different qualitative traits on fruit yield per plant. Path coefficient analysis of different qualitative traits contributing towards fruit yield per plant revealed that reducing sugar had highest positive direct effect relationship with fruit yield per plant followed by pulp-seed ratio, peel percentage and non-reducing sugar.

Genetic divergence for fruit yield and its components in custard apple for quantitative traits in *kharif* 2013-14 and *kharif* 2014-15 cluster analysis for fruit yield and quality traits were estimated separately. For quantitative characters, all genotypes were grouped into 8 clusters using non-hierarchical Euclidean cluster analysis. For fruit yield parameters, maximum number of genotypes were grouped into cluster III and VI (12 genotypes in each) followed by cluster V (10) and cluster VII (9). The minimum number of genotypes were found in cluster I (3) followed by cluster VIII (4).

Mean performance of cluster wise Intra and Inter-Cluster distances among 8 clusters for fruit yield and its components in custard apple. The highest intra-cluster distance was recorded for cluster VI followed by cluster II. The highest inter-cluster distance was recorded between cluster VIII and cluster III followed by cluster VII and III, whereas lowest inter- cluster distance was recorded between cluster VIII and cluster VII followed by cluster VI and cluster VII for fruit yield and attributing traits.

Percent contribution to variation cluster wise means performance of genotypes for fruit yield and its components in custard apple genotypes of cluster VIII showed maximum highest mean value for fruit yield and component traits, whereas lowest mean for fruit yield and other related traits, so, it can be concluded that genotypes of cluster VIII will give good opportunity to researcher to be used as parents for developing good variety/hybrids of maximum yield, whereas genotypes of cluster IV could be used for increasing total number of fruits and leaf characteristics.

Cluster wise promising genotypes for fruit yield and its components in custard apple. Result showed that in cluster I, genotype IGCA-21 is promising for most of the

traits. Therefore, it can be selected as parent for further research programme to improve fruit yield and attributing traits. Genotypes IGCA-21, IGCA-3, IGCA-11, IGCA-1, IGCA-4, IGCA-2, IGCA-10, IGCA-22 are most promising for fruit yield per plant from cluster I, II, III, IV, V, VI, VII and cluster VIII, respectively.

Genetic divergence for fruit yield and its components in custard apple for qualitative traits in 2013-14 and 2014-15 Cluster analysis for qualitative traits showed that all genotypes were grouped into 8 clusters using non-hierarchical Euclidean cluster analysis. For qualitative parameters, maximum number of genotypes were grouped into cluster VIII (14) followed by cluster III (12). Clustering pattern of genotypes recognized that there is no influence of ecological location on divergence because parental populations were collected from different ecological area.

Mean performance of cluster wise Intra and Inter-Cluster distances among 8 clusters for qualitative traits in custard apple. The highest intra-cluster distance was recorded for cluster VI followed by cluster II and the smallest intra cluster distance was recorded in cluster III followed by cluster V for qualitative traits. The results revealed that genotypes included in largest intra- cluster distances were relatively more diverse than those of smallest intra- cluster distance, it means further screening will be required to select superior genotypes because of similar type less diverse genotypes.

The highest inter-cluster distance was recorded between cluster V and cluster III followed by cluster VI and III whereas, lowest inter- cluster distance was recorded between cluster IV and cluster V. The least inter-cluster distance revealed that there is a close relationship between the genotypes and hence, may not be emphasized upon to be used in hybridization programme. Narrow genetic base does not give rise to produce vigorous progeny.

Percent contribution to variation genotypes of cluster VIII showed maximum highest mean value for most of the qualitative traits so, it can be concluded that genotypes of cluster VIII will give good opportunity to researcher to be used as parents

for developing good variety/hybrids of superior fruit quality whereas genotypes of cluster III could be used for increasing pulp ratio and peel percentage.

Percent contribution to variation non-reducing sugar, pulp seed ratio, total sugar, titration acetic acid, total soluble solid, keeping days and fruit yield per plant. Whereas, rest of the characters showed very less percentage contribution to variation.

Cluster wise promising genotypes for qualitative traits in custard apple. Result showed that in cluster I, genotype IGCA-21 is promising for most of the qualitative traits therefore, it can be selected as parent for further research programme to improve fruit quality traits. Genotypes IGCA-21, IGCA-11, IGCA-4, IGCA-2, IGCA-3, IGCA-12, IGCA-13 and IGCA-10 are most promising for pulp-seed ratio and peel percentage from cluster I, II, III, IV, V, VI, VII and cluster VIII, respectively.

Varieties from geographically diverse localities are generally included in hybridization programmes presuming genetic diversity. The problem of selection may further be simplified if one could identify the characters responsible for discrimination between parents.

Genetic divergence analysis by using cluster statistics is a powerful tool in quantifying the degree of divergence between biological populations and to assess the relative contribution of different components to the total divergence. The genetic architecture of a population is controlled by the breeding behaviour of the individuals. Changes in breeding systems have accelerated the genetic divergence in natural population. Custard apple is a predominantly protogynous crop and no information is available suggesting a change in its breeding behaviour under varied environmental conditions. Discrimination of desirable parents for a successful hybridization programme is a difficult task for a plant breeder. Generally, geographical diversity has been considered as a measure of genetic diversity. However, this is an inferential criterion and it may not be so effective in quantifying or differentiating between populations.

CONCLUSIONS

On the basis of findings generated from the present investigation, following conclusions can be drawn, which may be considered for clonal selection in custard apple crop in future breeding programmes:

The measurement of existing variability in genetic material has been the basic requirement of a breeding programme. In the present investigation, a wide range of variability was observed for nearly all the characters indicating the existence of sufficient variability among the genotypes for the quantitative traits and qualitative traits.

The character pulp weight had highest GCV and PCV, areole weight, fruit weight, weight of pericarp, pedicel thickness, length of pedicel, total number of fruits, seed weight and fruit width.

The character pulp-seed ratio had highest GCV and PCV and keeping days.

The highest heritability estimate was recorded for the character pulp weight followed by areole weight, fruit weight, length of pericarp, weight of pericarp, pedicel thickness, fruit length, length of pedicel, total number of fruits, fruit yield per plant, fruit width, seed length and number of flowers per branches.

The highest heritability estimate was recorded for the character in qualitative traits pulp-seed ratio followed by non-reducing sugar, total sugar, fruit yield per plant, reducing sugar, titration acetic acid and keeping days.

The highest genetic advance was observed for fruit weight followed by pulp weight, areole weight, number of alternate leaf and number of fruits per tree. The highest genetic advance was observed for fruit yield per plant.

High heritability coupled with high genetic advance as percentage of mean was found for pulp weight, areole weight, fruit weight, weight of pericarp, pedicel thickness, length of pericarp and length of pedicel, which indicated the predominance of additive gene action in the expression of these characters which could be utilized

through selection for improvement in these characters. Rest of the traits showed high to moderate heritability estimates coupled with moderate to low genetic advance as percentage of mean indicated the role of non-additive genetic variance in their expression.

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Cluster analysis for fruit yield and quality traits were estimated separately. For quantitative characters all genotypes were grouped into 8 clusters using non-hierarchical Euclidean cluster analysis for fruit yield parameters.

Mean performance of cluster wise Intra and Inter-Cluster distances among 8 clusters for fruit yield and its components in custard apple. The highest intra-cluster

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diverse than those of smallest intra- cluster distance, it means further screening will be required to select superior genotypes because of similar type less diverse genotypes.

The highest inter-cluster distance was recorded between cluster V and cluster III followed by cluster VI and III whereas lowest inter- cluster distance was recorded between cluster IV and cluster V. The least inter-cluster distance revealed that there is close relationship between the genotypes and hence, may not be emphasized upon to be used in hybridization programme. Narrow genetic base does not give rise to produce vigorous progeny.

Percent contribution to variation genotypes of cluster VIII showed maximum highest mean value for most of the qualitative traits, so, it can be concluded that genotypes of cluster VIII will give good opportunity to researcher to be used as parents for developing good variety/hybrids of superior fruit quality whereas, genotypes of cluster III could be used for increasing pulp ratio and peel percentage.

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information is available suggesting a change in its breeding behaviour under varied environmental conditions. Discrimination of desirable parents for a successful selection/hybridization programme is a difficult task for a plant breeder. Generally, geographical diversity has been considered as a measure of genetic diversity.

SUGGESTIONS FOR FUTURE RESEARCH WORK

On the basis of present study, following suggestions could be drawn to plan out further improvement programme in selecting desirable genotypes in custard apple.

1. In order to confirm the findings, the experiment may be repeated over the years and clonal selection be made.
2. Based on results of genetic variability, heritability and genetic advance, correlation coefficient and path analysis, it is suggested that selection for the characters such as fruit yield per plant are important to evolve high-yielding genotypes of custard apple.
3. From the study of cluster analysis, diverse genotypes belong to different clusters may be involved in the selection/hybridization programme.

REFERENCES

- Allard, R.W. 1960. Principles of Plant Breeding. *John Willey & Sons Inc.* New York, USA, p. 92-112.
- Anonymous. 2013. Indian Horticulture Database. *National Horticulture Board*, India. pp: 6-14.
- Barda, S. and Sen, S.K. 1997. Post harvest storage of custard apple (*Annona squamosa* L.) fruit variety Local Green under various chemical and wrapping treatments. *J. Interacademia*, **1**(4):322-328.
- Baskaran, K. and Muthiah, A.R. 2007. Associations between yield and yield attributes in custard apple (*Annona squamosa* L.). *J. Chemical and Pharmaceutical Res.*, **7**(2) pp: 312-318.
- Batten, D.J. 1990. Effect of temperature on ripening and post harvest life of fruit of atemoya (*Annona cherimola* Mill \times *Annona squamosa* L) cv. African Pride, *Scientia Horticulturae*, **45**(1-2): 129-136.
- Bhatnagar, P., Singh, J., Jain, M.C. and Singh, Bhim. 2012. Evaluation of landraces of custard apple (*Annona squamosa* L.). *Plant Archives*, **12**(2): 1045-1048.
- Black, C.A. 1965. Method of soil Analysis. *Americal Agronomy Inc.*, Madiso Wisconsin USA, pp: 131-137.
- Broughton, W.J. and Tan, G. 1979. Storage conditions and ripening of the custard apple *Annona squamosa* L. *Scientia Horticulturae*, **10**(1):73-82.
- Burton, G.W. and Vane, E.M. 1952. Estimating heritability in fall fescue (*Festuca circumclinaceae*) from replicated clonal material. *Agron. J.*, **45**(5): 478-481.
- *Carvalho, P.S. de, Bezerra, J.E.F., Lederman, I.E., Alves, M.A., and Melo Neto, M.L.de. 2000. Performance of custard apple (*Annona squamosa* L.) genotypes in the Moxoto River Valley. *Revista Brasileira de Fruticultura*, **22**(1): 27-30.
- Chandra, A. 2010. Participatory approaches in precision farming. In: *Souvenir of National Seminar on Precision Farming in Horticulture*, College of Horticulture and Forestry, Jhalawar, p: 650-657.
- Chattopadhyay, P.K. and Mandal, A. 1993. Studies on nutrition of custard apple (*Annona squamosa* L.). *J. Potassium Res.*, **9**(4): 375-379.
- Chen Weihui 1999. Effect of harvest time on the storage quality of custard apple fruit. *South China Fruits*, **28**(4): 27-29.
- Cliff, C. 1977. A survey of the potential for breeding in Annonaceae family. *Fruit Varieties J.* **31**(2): 45-47.

- Deshmukh, P.R., Wakle, P.K., Kapse, P.S., Londhe, G.K. and Wangikar, S.D. 2001. Correlates of adoption of custard apple technology. *J. Soils and Crops*, **11**(2): 210-211.
- Dikshit, N., Bhardra, S.G. and Badge, M.P. 2008. Diversity in custard apple germplasm collection from Maharashtra, India. *J. Plant Genet. Resour.*, **21**(1): 95-96.
- Fisher. 1936. A discriminant function for plant selection. *Ann. Eugenics*, 7: 240-250.
- Galton, P. 1888. Correlation and their measurement a chiefly from anthropometric data. *In Proceeding Royal Soc.*, 45: 135-145.
- George, A.P. and Nissen, R.J. 2002a. Effects of drought on fruit set, yield and quality of custard apple (*Annona spp.* hybrid) "African Pride" plants. *J. Hort. Sci. Biotechnology*, **77**(4): 418-427.
- George, A.P. and Nissen, R.J. 2002b. Control of tree size and vigour in custard apple (*Annona spp.* hybrid) cv. African Pride in subtropical Australia. *Australian J. Experimental Agri.*, **42**(4): 503-512.
- George, A.P., Broadley, R., Nissen, R.J., Hamill, S.D. and Topp, B. 1999. Breeding strategies for atemoya and cherimoya. *Acta Horticulturae*, **49**(7): 255-267.
- George, A.P., Broadley, R., Nissen, R.J. and Hamill, S.D. 2005. Breeding and selecting new varieties and rootstocks of custard apple (*Annona spp.* hybrids) in subtropical Australia. *Acta Horticulturae*, **69**(4): 125-128.
- Ghosh, S.N., Mathew, B. and Subrata Manna. 2001. Studies on physico-chemical characteristics of fruits of custard apples grown under rainfed semi-arid region of West Bengal. *Orissa J. Hort.*, **29**(1): 66-68.
- Girwani, A., Madhavi, A., Kumar, T.S., Reddy, G.S., Sheikh, M.K., Mokashi, A.N. and Rokhade, A.K. 2011. Evaluation of custard apple hybrids for fruit yield and quality attributing characters. *Acta Hort.*, **11**(7): 251-255.
- Gomez, K.A. and Gomez A.A. 1984. Statistical Procedure for Agricultural Research. *John Wiley and Sons publication*, 2nd edition.
- Gopalan, C. R., Shastri, B.V. and Balasubramanin, S.C. 1987. *Nutritive value of Indian Foods*. NIN, ICMR, Hyderabad, p.93.
- Hanson, W.D., Robinson, H.F. and Comstock, R.E. 1956. Biometrical studies of yield in segregating population Korean Lespandeza. *Agron. J.*, **4**(8): 268-272.
- Hashmi, S.I. and Pawar, V.N. 2012. Studies on physical and chemical characteristics of custard apple fruit pulp from different locations. *J. Dairying, Foods and Home Science*, **31**(2): 117-120.

- Islam, M.A., Hoque, M.A. and Hossain, A.K.M.A. 1991. Variability of custard apple fruits in Bangladesh. *Bangladesh J. of Agril. Res.*, **16**(1): 84-86.
- Jackson, M.L., 1967. Soil Chemical Analysis. *Prentice Hall Publication Pvt. Ltd.*, New Delhi, India. p.452.
- Jagtap, K.B. and Kokate, A.S. 1991. Promising custard apple (*Annona squamosa* L.) selections from Pengiri (Sangamner) region in Ahmednagar Dist. of Maharashtra. *Maharashtra J. Hort.*, **5**(2): 41-44.
- Johnson, H.W., Robinson, H.F. and Comstock, R.E. 1955. Estimates of genetic and environmental variations in Soybean. *Agron. J.*, **4**(7): 314-318.
- Jorge Andres Agustin, Sergio S. and Ledesma, D. 2014. Conservation and use of genetic resources of *Annonaceae* in Mexico. *Rev. Bras. Frutic*, **36**:152-157.
- Joshi, P.S., Bhalerao, P.S., Jahagirdar, S.W., Mahorkar, V.K. and Patil, B.R. 2003. Correlation studies in propagation of custard apple (*Annona squamosa* L.). *Annals of Plant Physiology*, **13**(2): 175-177.
- Kaul, A.K. 1967. Heritability a brief review. *J.P.G. School IARI.*, **5**: 253-267.
- *Keny, H.M. and Paulo S.L.e.S. 2010. Relationship between fruit traits of custard apple trees (*Annona squamosa* L.). *Revists Ceres*, **57**(4): 231-233.
- Kulkarni, S.S., Desai, U.T., Masalkar, S.D. and Desale, S.B. 1997. Effects of cultural and chemical treatments on yield and physico-chemical characteristics of custard apple. *J. Maharashtra Agri.*, **21**(3): 474-475.
- Kumar, A.K., Basandrai, D., Duraimurugan, P. and Srinivasan, T. 2005. Breeding for biotic stresses. *In: Biology and Breeding of Fruits Crops*, Oxford, *C.A.B. International*. p. 220-240.
- Kumar, R., Hoda, M.N. and Singh, D.K. 1977. Studies on the floral biology of custard apple (*Annona squamosa* Linn.). *Indian J. Hort.*, **34**(3): 252-256.
- *Lima e Silva, P.S., Barbin, D., Goncalves, R.J.de.S. Firmino, J.D. da C. and Fonseca, I.C. 2004. Leaf area estimates of custard apple tree progenies. *Revista Brasileira de Fruticultura*, **26**(3): 558-560.
- Liu, ShiBiao. 2000. The performance of African Pride custard apple cultivar. *China Fruits*, **9**(3): 29-30.
- Liu, ShiBiao and Chen JinRui. 2002. The effect of environmental factors on the growth, development and production of custard apple *China Fruits*, **7**(2): 47-49.
- Lush, J.I. 1940. Intra site correlations and regression of off-spring on dam as a method of estimating heritability of character. *In: Proceeding American Animal Pro.*, **3**(3): 292-301.

- Mahajan, R.K., Gangopadhyah, K.K., Gunjeet, K., Dobhal, V.K., Srivastava, U., Gupta, P.N. and Pareek, S.K. 2002. Minimal descriptors of agri-horticultural crops (Part-III: fruit crops), *National Bureau of Plant Genetic Resources*, New Delhi, India p. 80-85.
- Mahalanobis, P.C. 1928. Statistical study at chinese head measurement. *J. Abiotic Soc., Bengal*, **2**(5): 301-377.
- Mallikarjuna, T., Ranganna, B. and Dronachari, M. 2012. Respiration of custard apple (*Annona squamosa* L.) fruit under different maturity level at ambient and refrigerated condition. *J. Dairying, Food and Home Sci.*, **31**(1): 25-27.
- *Mariguele, K.H. and Fonseca e Silva, 2010a. Methods of longitudinal data analysis for the genetic improvement of sugar apple. *Pesquisa Agropecuaria Brasileira*, **46**(12): 1657-1664.
- *Mariguele, K.H. and Silva, Paulo S.L.e. 2010b. Relationship between fruit traits of custard apple trees (*Annona squamosa* L.). *Rev. Ceres*, **57**(4): 476-479.
- Martinez. G.M., Serrano and M.T. Prretel, 1993. Ethelene biosynthesis and physico-chemical changes during fruit ripening of cherimoya (*Annona cherimola* Mill). *J.Hort. Sci.*, **68**(4) : 477-483.
- Mather, K. 1949. Biometrical genetics. *Dobers Publications Inc. New York Ed. I.*
- Maurya, I.B., Singh, D.K. 2006. Custard apple, In *Advances in Arid Horticulture*, *IBDC, Lucknow*, p. 129-141.
- Mazumdar, B.C. 1977. Differences between seeded and seedless berries of custard apple (*Annona squamosa* L.). *Plant Science*, **9**(2): 103-107.
- Morton, J. 1987. "*Annona squamosa*". *Fruits of Warm Climates*, p. 69.
- Nagaraja, K., Kumar, S.A. Sathish, A. and Chandrappa, H. 2011. Effect of post harvest treatments and polyethylene packages on shelf life of custard apple fruits (*Annona squamosa* L.). *J. Agri. Sci.*, **45**(2): 456-459.
- Nath,V., Kumar, D. and Pandey, V. 2008. Fruit for the future. *SSPH, Delhi*, **1**(1): 285-299.
- Nilam, P., Naik, A.G. and Arbat, S.S. 2011. Response of post-harvest chemical treatments on shelf life and quality of custard apple (*Annona squamosa* L.) cv. Balanagar, *Indian J. Hort.*, **68**(4): 547-550.
- Olsen, S.R. and Watanabe, F.S. 1965. Test of ascorbic acid method for determining phosphorus in water and sodium bicarbonate extracts of soils. *Proc. Soil Sci. Soc. Am.*, **29**(22): 677-678.

- Pal, D.K. and Kumar, P.S. 1995. Changes in the physico-chemical and biochemical compositions of custard apple (*Annona squamosa* L.) fruits during growth, development and ripening. *J. Hort. Sci.*, **70**(4): 569-572.
- Paul, A. and Bajpai, G.C. 2000. Selection indices for yield in determinate custard apple (*Annona squamosa* L.). *J. Hort. Sci. Biotech.*, **78**(2) pp: 52-54.
- *Paulo, S., Lima, e.S., Rafaela, P. A., Keny, H.M., Kathia, M.B.e.S., Lidiane, K.de. L. and Julio, C.do. V.S. 2009. Estimates of genetic parameters for fruit yield and quality in custard apple progenies. *Revista. Brasileira de Fruticultura*, **29**(3): 155-159.
- Pearson, A.K. 1904. On the generalized theory of alternative inheritance with special reference to Mendel's law. *Phil. Trans. Roy. A.*, **20**(3): 53-86.
- Piper, C.S. 1967. Soil and Plant Analysis. *Asia Publishing House*, Bombay, India.
- Prasanna, K.N.V., Rao, D.V.S. and Krishnamurthy S. 2000. Effect of storage temperature on ripening and quality of custard apple (*Annona squamosa* L.) fruits. *J. Hort. Sci. Biotechnology*, **75**(5): 546-550.
- Pritchard, K.D. and Edwards, W. 2006. Supplementary pollination in the production of custard apple (*Annona* sp.) the effect of pollen source. *J. Hort. Sci. Biotechnology*, **81**(1): 78-83.
- Rabbani, P. Singh. S.C. 1988. Effect of chemical treatments on shelf life and quality of custard apple (*Annona squamosa* L.), *Indian J. Hort.*, **45**(4): 177-180.
- Ranganna, 1986 "Rapid Titration" method. *International Journal of Plant, Animal and Environmental Sciences*, p. 677.
- Rao, C.R. 1952. Advanced statistical methods in biometrical research. *John Wiley and Sons*, New York, USA.
- Rao, S.N. 1974. Annonas the legendary fruit. *Indian Horticulture*, **19**(3): 19-21.
- Reddy, M.V. and Heyne, E.G. 1968. Quantitative inheritance and heritability studies a resume. *Andhra Agric. J.*, **1**(5): 51-56.
- Robinson, H.F. 1966. Quantitative genetics in relation to breeding on centennial of Mendelism. *Indian J. Genet.*, **26**(A): 171-187.
- Sahoo, S.C., Panda, J.M. and Mohanty, D. 2000a. Studies on floral biology of custard apple (*Annona squamosa*) under Bhubaneswar condition. *Orissa J. Hort.*, **28**(1): 43-45.
- Sahoo, S.C., Panda, J.M. and Mohanty, D. 2000b. A note on pollen morphology, viability, pollination and fruit set in custard apple (*Annona squamosa* L.). *Orissa J. Hort.*, **28**(2): 109-110.

- Salunke, J.S. and Kute, N.S. 1995. Correlation and path analysis in custard apple (*Annona squamosa* L.). *J. Hort. Sci.*, **70**(4): 56-61.
- Samal, S., Lenka, P.C., Rout, G.R., Das, S.L. and Mohapatra, K.C. 2002. Genetic differentiation among cashewnut (*Anacardium occidentale* L.). *Proceeding of 15th Plantation Crops Symposium Placrosym XV*, Mysore, India. pp: 43-46.
- Saulo, A.S., Ana, C.V. L.D, Simone, O.A. and Vanessa, A. 2006. Fruit characterization of sugar apple genotypes in Presidente Dutra, Bahia. *Crop Breeding and Applied Biotechnology*, **8**(12): 295-302.
- Searle, S.R. 1961. Phenotypic, genotype and environmental correlation. *Biometrics.*, **17**(05): 474-480.
- Shete, M.B., Karale, A.R. and Kale, P.N. 1991. Seedling selection in custard apple. *J. Maharashtra Agri.*, **16**(2): 271-273.
- Silva, A.V.C., Muniz, E.N., Rangel, J.H.A., Yaguiiu, P., Souza, J.P.B. and Carnellosi, M.A.G. 2012. Quality of custard apple (*Annona squamosa* L.) in relation to packaging and storage period. *Acta Horticulturae*, 934:707-712.
- Singh, D.K. Hoda, M.N. and Kumar, R. 1977. Development and physico-chemical properties of custard apple. *Proceedings of Bihar Academy of Agricultural Sciences*, **25**(2): 66-67.
- Singh, S.P. 1995. Commercial Fruits, *Kalyani Publishers*, Ludhiana, India. p. 289.
- Singh, S.P. and Borase, S.S. 2003. Extending shelf life of tropical fruits through ripening retardants. *Adv. Hort. Forestry*, **9**: 79-100.
- Subbiah, B.V. and Asija, G.L. 1956. A rapid method for the estimation of nitrogen in soils. *Curr. Sci.*, **2**(25): 259-260.
- Walkley, A. and Black, C.A. 1934. An examination to different method for determination soil organic matter and proposal for modification of the chromic acid titration method. *Soil Sci.*, **3**(37): 29-38.
- Wang, J.C.Y. and Luo, S.R. 2001. Study on the effect of rootstocks on the growth and fruit quality of custard apple variety "African Pride". *China Fruits*. **6**(1): 23.24.
- Warner, J.N. 1952. A method for estimating heritability. *Agron. J.*, **24**(2): 427-430.
- Wright, S. 1921. Correlation of causation. *J. Agric. Res.*, **2**(20): 257-287.
- Xie ZhuShen, Xie XiDong and Li Jing Yue. 1999. The performance of AP custard apple variety and its cultural techniques in Guangzhou area. *South China Fruits*, **28**(2): 24-26.

*Original not seen

APPENDIX-I: Weekly Meteorological data, during the crop period, 2013-14

(May 07, 2013 to December 03, 2013)

Department of Agricultural Meteorology

Indira Gandhi Agricultural University, Raipur (C.G.) 492012

W.K. No.	Date	Max. Temp °C	Min. Temp °C	Rain-fall (mm)	Rainy days	Relative Humidity (%)		Sun Shine (hours)
						I	II	
19.	May 07-13	43.6	27.2	1.0	0	48	17	9.4
20.	14-20	43.3	27.9	0.0	0	44	15	8.8
21.	21-27	46.0	29.0	3.6	1	34	16	8.6
22.	28-03	41.7	28.0	2.2	0	58	24	7.5
23.	Jun 04-10	37.8	26.1	55.3	3	80	49	6.5
24.	11-17	32.4	25.0	105.2	3	87	67	2.6
25.	18-24	34.4	25.8	46.4	2	83	67	5.6
26.	25-01	30.4	24.9	41.0	3	88	73	1.4
27.	Jul 02-08	31.3	24.5	73.5	3	90	70	4.4
28.	09-15	31.2	24.3	144.4	5	93	78	3.9
29.	16-22	30.5	25.3	44.6	5	95	74	2.3
30.	23-29	28.4	24.7	88.2	4	92	83	0.7
31.	30-05	28.3	23.9	255.8	5	95	84	1.3
32.	Aug 06-12	31.1	24.7	87.4	4	93	76	3.3
33.	13-19	31.3	24.3	177.0	5	95	80	3.3
34.	20-26	27.9	23.8	60.5	4	92	84	1.5
35.	27-02	29.3	24.5	120.8	3	95	80	3.1
36.	Sep 03-09	31.1	24.8	54.8	4	93	76	4.2
37.	10-16	31.9	25.2	11.6	1	92	73	6.2
38.	17-23	29.9	24.1	92.6	4	93	77	2.5
39.	24-30	32.0	24.9	28.6	1	93	68	6.3
40.	Oct 01-07	30.1	24.1	45.2	5	95	75	4.2
41.	08-14	30.2	23.3	8.6	1	89	71	3.5
42.	15-21	30.7	21.4	0.0	0	91	56	8.6
43.	22-28	28.8	22.6	32.6	2	96	73	2.1
44.	29-04	30.5	17.3	0.0	0	92	38	8.9
45.	Nov 05-11	30.0	16.7	0.0	0	91	37	8.2
46.	12-18	27.5	13.2	0.0	0	91	36	7.6
47.	19-25	30.3	16.7	0.0	0	87	40	7.3
48.	26-02	30.0	15.6	0.0	0	83	35	8.4
49.	Dec 03-09	28.1	11.8	0.0	0	91	31	8.5
50.	10-16	27.7	9.8	0.0	0	90	27	9.0
51.	17-23	28.1	11.7	0.0	0	90	34	8.0
52.	24-31	28.3	12.7	0.0	0	93	40	6.5
	Mean/Total	31.89	22.05	1580.90	68	85.65	56.59	5.42

APPENDIX-II: Weekly Meteorological data during the crop period, 2014-15
(May 07, 2014 to December 03, 2014)

Department of Agricultural Meteorology
Indira Gandhi Agricultural University, Raipur (C.G.) 492012

W.K. No.	Date	Max. Temp °C	Min. Temp °C	Rain- fall (mm)	Rainy days	Relative Humidity (%)		Sun Shine (hours)
						I	II	
19.	May 07-13	38.8	26.0	0.0	0	59	27	8.3
20.	14-20	42.1	27.6	0.0	0	43	16	9.2
21.	21-27	40.8	27.1	32.2	2	54	30	7.5
22.	28-03	41.7	28.7	0.0	0	56	26	9.1
23.	Jun 04-10	44.1	30.9	0.0	0	54	23	8.0
24.	11-17	40.4	28.4	14.0	2	56	36	5.0
25.	18-24	33.6	26.0	30.0	3	79	60	3.0
26.	25-01	35.7	26.0	27.6	2	78	50	3.3
27.	Jul 02-08	37.7	27.0	9.0	1	72	44	5.3
28.	09-15	34.3	23.8	152.8	7	92	72	4.1
29.	16-22	28.5	24.6	260.2	6	95	88	0.5
30.	23-29	28.7	23.8	37.2	4	95	82	1.6
31.	30-05	29.8	24.8	136.0	7	95	86	1.9
32.	Aug 06-12	30.2	24.8	42.1	3	91	71	2.8
33.	13-19	31.8	25.3	45.0	3	91	70	5.5
34.	20-26	32.3	25.1	25.8	2	92	73	3.4
35.	27-02	31.8	25.0	84.8	4	91	76	3.6
36.	Sep 03-09	28.3	24.2	79.5	4	94	83	0.5
37.	10-16	30.5	24.3	41.0	3	95	79	3.4
38.	17-23	32.1	24.6	57.6	3	94	68	4.4
39.	24-30	33.4	24.0	0.0	0	93	57	8.3
40.	Oct 01-07	33.2	24.0	0.0	0	91	57	8.3
41.	08-14	30.4	23.6	52.2	2	89	66	4.9
42.	15-21	31.5	22.5	1.2	0	91	56	8.4
43.	22-28	29.1	19.4	5.4	1	92	52	5.9
44.	29-04	30.1	16.9	0.0	0	94	37	8.0
45.	Nov 05-11	30.7	17.6	0.0	0	88	44	7.8
46.	12-18	31.4	19.3	0.0	0	84	35	6.8
47.	19-25	29.3	11.9	0.0	0	91	28	8.5
48.	26-02	30.2	12.5	0.0	0	90	26	8.6
49.	Dec 03-09	28.9	10.8	0.0	0	90	28	9.0
50.	10-16	28.6	15.8	0.0	0	89	49	3.0
51.	17-23	25.0	8.3	0.0	0	89	31	7.8
52.	24-31	26.0	9.9	0.0	0	86	34	8.3
	Mean/Total	32.68	22.19	1133.60	59	83.32	51.76	5.71

APPENDIX-III: Mean performance of Custard Apple Genotypes in Northern Bastar of Chhattisgarh for quantitative traits of fruit yield and its components during the year 2013-14

S. No.	Name of Genotypes	1	2	3	4	5	6	7	8	9	10
1.	IGCA-1	351.00	6.47	32.75	116.63	22.50	4.39	11.63	454.50	3.40	24.88
2.	IGCA-2	338.75	6.28	33.63	115.75	23.38	4.49	12.18	441.00	3.50	22.63
3.	IGCA-3	332.50	6.21	33.75	115.75	23.63	4.51	12.02	438.00	3.47	22.25
4.	IGCA-4	332.25	6.14	34.88	118.63	24.75	4.56	11.60	435.38	3.49	25.00
5.	IGCA-5	353.00	6.49	30.75	117.63	20.00	3.69	11.45	247.25	2.21	23.13
6.	IGCA-6	326.13	6.40	31.38	118.38	21.38	4.24	10.95	191.88	3.49	24.00
7.	IGCA-7	337.50	7.43	28.50	123.38	17.25	3.53	9.07	195.88	3.39	20.25
8.	IGCA-8	329.75	6.26	28.75	122.00	17.38	3.38	8.50	192.13	2.40	18.50
9.	IGCA-9	332.88	6.19	30.25	122.25	19.75	3.55	10.98	187.88	3.47	14.63
10.	IGCA-10	337.63	7.61	30.63	120.25	20.63	4.29	12.30	428.88	3.39	14.13
11.	IGCA-11	358.63	7.16	31.75	122.63	21.75	3.49	9.75	432.13	2.22	17.63
12.	IGCA-12	333.88	7.38	32.38	122.00	22.25	3.53	11.05	421.38	2.25	21.25
13.	IGCA-13	339.13	7.36	31.88	120.75	21.75	4.22	10.95	410.63	1.88	23.38
14.	IGCA-14	332.50	6.76	31.13	121.75	20.75	3.39	8.23	188.38	2.21	21.63
15.	IGCA-15	326.38	5.70	29.50	128.38	17.75	3.45	7.75	188.00	1.79	19.38
16.	IGCA-16	328.50	6.47	28.88	124.63	18.63	4.03	10.30	180.13	2.58	23.25
17.	IGCA-17	346.13	6.74	29.25	125.63	19.13	3.46	10.07	181.25	3.11	21.88
18.	IGCA-18	348.50	6.40	29.38	121.25	19.38	4.05	12.30	191.13	2.42	24.50
19.	IGCA-19	346.13	7.05	33.88	116.38	23.63	4.57	12.52	398.63	3.10	25.00
20.	IGCA-20	345.88	7.03	39.88	114.75	29.75	4.24	12.35	394.88	3.56	24.38
21.	IGCA-21	354.00	7.24	43.50	114.63	33.38	4.71	12.32	570.13	3.58	25.63
22.	IGCA-22	358.75	7.11	42.38	113.88	32.63	3.83	11.13	384.88	2.55	23.13
23.	IGCA-23	353.38	5.91	30.00	120.00	19.25	3.40	7.82	184.63	1.64	14.75
24.	IGCA-24	315.63	6.26	30.00	121.50	19.88	3.45	8.20	156.88	2.15	15.25
25.	IGCA-25	339.13	6.18	28.63	124.13	17.13	3.78	8.77	154.88	2.01	15.38
26.	IGCA-26	329.75	5.97	29.75	123.25	17.25	3.56	10.16	161.63	2.22	13.75
27.	IGCA-27	330.88	6.30	29.50	123.88	16.50	4.19	10.34	162.50	1.86	15.13
28.	IGCA-28	339.63	6.30	29.13	125.00	23.50	3.21	7.55	164.75	2.15	13.00
29.	IGCA-29	305.75	6.14	29.13	123.63	17.25	3.19	8.50	171.88	2.84	13.63

1. No. of Alternate Leaf Fruit Width (cm) 2. Length of Leaf (cm) 3. No. of Flowers Per Branch 4. Days to 50 % Maturity 5. Total No. of Fruits
6. Fruit Width (cm) 7. Fruit Length (cm) 8. Fruit Weight (g) 9. Length of Pedicel (cm) 10. Pedicel Thickness
Contd...

Contd...

S.No.	Name of Genotypes	11	12	13	14	15	16	17	18	19	20
1.	IGCA-1	3.17	5.51	18.25	6.63	27.63	30.59	241.47	163.49	342.00	149.54
2.	IGCA-2	3.22	5.50	18.38	6.00	28.88	27.38	233.73	158.89	347.13	148.56
3.	IGCA-3	3.21	5.46	17.50	5.25	26.38	28.24	232.14	157.72	341.50	150.53
4.	IGCA-4	3.24	5.55	17.25	5.75	26.13	26.29	230.75	156.78	342.38	149.34
5.	IGCA-5	2.21	3.53	18.63	6.88	31.00	30.85	120.77	84.11	299.25	108.17
6.	IGCA-6	2.36	3.30	21.75	8.63	34.88	33.09	91.98	65.15	301.13	104.25
7.	IGCA-7	1.77	2.41	18.50	8.63	31.50	30.64	94.50	66.90	294.25	103.58
8.	IGCA-8	1.77	2.28	21.50	8.50	30.63	28.99	92.22	65.28	287.50	112.38
9.	IGCA-9	1.67	2.49	17.00	6.75	31.75	33.22	90.18	63.83	300.50	124.88
10.	IGCA-10	3.20	4.47	15.38	7.13	27.75	28.18	227.30	154.44	344.13	148.99
11.	IGCA-11	3.26	4.85	18.50	7.38	27.25	26.24	229.03	155.61	341.25	149.97
12.	IGCA-12	3.22	4.85	15.50	7.50	28.38	27.09	223.33	151.79	342.75	140.25
13.	IGCA-13	1.84	4.79	22.00	8.38	31.75	26.14	217.63	147.83	343.63	145.50
14.	IGCA-14	1.82	2.49	21.50	7.63	34.13	28.72	90.96	63.71	299.88	102.58
15.	IGCA-15	1.77	2.89	22.63	8.13	33.25	28.68	88.82	63.88	301.13	103.04
16.	IGCA-16	1.63	3.19	18.13	8.00	32.38	29.00	86.46	60.86	299.63	102.50
17.	IGCA-17	1.67	3.29	18.50	8.13	31.25	28.09	87.00	61.71	302.38	101.88
18.	IGCA-18	2.21	5.38	18.63	8.00	27.13	32.95	91.74	65.03	300.38	101.88
19.	IGCA-19	2.56	5.31	18.25	6.63	29.50	26.60	211.27	143.51	345.88	148.13
20.	IGCA-20	2.83	5.46	18.50	7.25	27.25	25.35	209.33	141.93	346.50	150.55
21.	IGCA-21	3.31	5.84	17.75	5.50	25.38	25.67	300.64	205.11	370.00	152.21
22.	IGCA-22	2.55	5.17	17.75	6.38	28.13	25.24	203.98	138.69	350.50	148.07
23.	IGCA-23	1.32	3.21	21.38	8.00	31.38	31.08	88.62	70.11	289.75	107.13
24.	IGCA-24	1.31	2.74	18.63	8.00	34.13	45.27	75.30	53.30	292.25	101.83
25.	IGCA-25	1.56	3.22	18.00	8.13	34.38	48.08	79.78	52.78	290.00	107.88
26.	IGCA-26	1.48	3.36	18.25	8.13	33.38	62.77	78.74	54.95	287.13	106.92
27.	IGCA-27	1.88	3.81	18.63	8.00	33.75	47.62	73.86	52.49	296.38	102.25
28.	IGCA-28	2.17	3.40	19.75	7.88	33.50	32.31	79.08	56.06	296.88	104.38
29.	IGCA-29	3.01	3.47	21.38	8.38	33.50	32.13	82.77	59.20	289.00	105.04

11. Length of Pericarp (cm) 12. Weight of Pericarp (g) 13. Seed Length (mm) 14. Seed Width (mm) 15. No. of Seeds/ Fruit
 16. Seed Weight(g) 17. Pulp Weight (g) 18. Areole Weight(g) 19. No. of Fruits/ Tree 20. Fruit Yield/ Plant (kg)
 Contd...

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S.No.	Name of Genotypes	1	2	3	4	5	6	7	8	9	10
30.	IGCA-30	342.13	5.97	27.63	125.63	16.13	3.30	9.55	191.88	2.20	12.38
31.	IGCA-31	337.63	6.88	26.63	124.25	15.38	3.34	9.80	182.38	2.44	14.63
32.	IGCA-32	345.38	5.54	26.75	128.13	15.63	3.60	10.35	180.38	2.54	14.63
33.	IGCA-33	330.00	5.89	28.75	123.25	16.75	2.74	8.63	177.63	2.30	13.75
34.	IGCA-34	341.00	6.64	27.63	125.00	16.00	2.80	7.68	185.25	2.24	12.38
35.	IGCA-35	340.63	6.97	29.50	125.88	15.63	2.63	7.45	186.88	2.24	11.63
36.	IGCA-36	308.38	6.49	28.38	125.00	15.88	3.31	9.93	155.38	2.45	12.88
37.	IGCA-37	333.00	6.55	26.75	125.38	15.13	3.19	10.00	185.13	2.21	13.00
38.	IGCA-38	351.88	6.36	30.75	125.25	19.88	2.35	7.55	185.00	2.28	12.13
39.	IGCA-39	348.00	6.72	28.50	123.50	17.63	2.45	7.53	190.13	2.09	13.25
40.	IGCA-40	353.38	6.61	29.25	126.25	17.75	2.66	10.50	192.38	2.01	13.88
41.	IGCA-41	297.00	6.20	28.13	123.75	14.38	2.89	10.20	194.63	2.10	13.00
42.	IGCA-42	324.50	6.68	28.13	124.75	17.63	2.95	8.18	194.00	2.00	11.38
43.	IGCA-43	272.25	7.34	26.75	124.63	15.88	3.09	8.52	195.38	2.10	12.63
44.	IGCA-44	337.88	7.16	27.88	125.00	16.25	2.66	9.50	201.50	1.84	12.63
45.	IGCA-45	277.88	7.10	27.38	125.25	14.88	3.44	9.43	198.88	1.65	11.88
46.	IGCA-46	313.75	6.06	27.88	124.00	17.50	3.41	9.02	166.75	1.98	11.50
47.	IGCA-47	257.38	6.25	27.88	124.13	17.25	3.36	9.45	166.38	2.24	11.75
48.	IGCA-48	282.25	6.82	27.25	126.00	16.63	2.80	8.57	168.63	2.28	11.50
49.	IGCA-49	277.88	6.05	25.88	123.88	16.00	2.69	8.63	173.13	1.35	13.00
50.	IGCA-50	310.63	6.41	26.25	124.75	15.63	2.36	7.70	171.88	1.23	12.25
51.	IGCA-51	287.63	6.84	26.13	122.63	14.38	2.63	8.48	173.38	1.86	11.88
52.	IGCA-52	262.25	7.07	26.38	123.75	15.63	2.76	8.68	188.50	1.84	12.25
53.	IGCA-53	222.13	6.20	26.75	124.25	16.75	2.94	8.75	177.63	2.09	12.25
54.	IGCA-54	260.00	6.18	27.50	125.75	14.50	2.85	8.65	164.63	1.76	13.13
55.	IGCA-55	264.25	6.18	26.00	126.25	13.50	2.64	8.75	167.63	1.27	13.00
56.	IGCA-56	271.25	6.49	27.38	125.13	14.38	2.71	7.65	184.38	1.61	12.13
57.	IGCA-57	283.38	6.05	26.75	127.13	15.00	2.28	7.93	173.63	1.13	11.88
58.	IGCA-58	214.75	5.94	29.50	124.38	13.75	2.47	8.45	171.25	1.52	11.25
59.	IGCA-59	226.25	5.50	26.63	124.38	12.88	2.35	5.43	171.88	1.71	11.25
60.	IGCA-60	330.63	6.06	26.63	123.50	12.75	2.39	7.35	152.63	1.51	12.50
	SEm ±	11.03	0.28	1.02	3.26	0.60	0.17	0.29	6.95	0.09	0.75
	CD at 5%	30.79	0.78	2.85	9.11	1.67	0.48	0.82	19.41	0.25	2.10
	CV	6.98	9.09	6.90	5.01	6.31	10.33	6.21	6.06	7.66	9.48

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S.No.	Name of Genotypes	11	12	13	14	15	16	17	18	19	20
30.	IGCA-30	1.64	2.84	18.50	8.38	31.63	32.99	92.10	63.89	291.50	104.83
31.	IGCA-31	1.82	2.81	20.13	8.38	34.13	32.43	87.54	61.15	290.00	107.00
32.	IGCA-32	1.55	3.21	19.38	7.75	32.88	31.78	86.36	59.21	293.63	106.21
33.	IGCA-33	1.48	3.14	21.25	7.50	33.13	31.93	85.26	59.40	294.88	102.92
34.	IGCA-34	1.55	2.83	21.75	6.50	33.38	32.43	88.92	61.60	285.75	104.63
35.	IGCA-35	1.82	2.84	21.63	7.38	34.38	32.37	87.85	62.28	296.63	102.63
36.	IGCA-36	1.55	3.16	21.75	8.38	33.88	30.22	77.23	56.53	297.25	103.04
37.	IGCA-37	1.66	3.22	20.63	8.13	34.00	32.20	88.02	62.85	299.88	102.17
38.	IGCA-38	1.56	3.97	21.50	7.63	31.75	32.53	89.25	63.05	297.63	104.79
39.	IGCA-39	1.82	2.71	21.38	8.38	32.50	32.33	87.06	62.43	295.88	101.17
40.	IGCA-40	1.84	3.19	22.00	7.63	32.88	33.33	88.65	65.46	298.75	104.71
41.	IGCA-41	1.54	3.25	22.75	8.38	32.13	33.58	89.44	63.64	298.88	103.88
42.	IGCA-42	1.82	3.04	21.63	7.88	32.75	32.97	88.10	62.75	298.50	103.38
43.	IGCA-43	1.81	2.70	21.63	7.63	32.88	33.09	92.81	62.35	289.50	107.79
44.	IGCA-44	1.84	3.10	20.13	7.38	32.25	36.30	90.38	63.74	291.00	104.50
45.	IGCA-45	1.63	3.14	22.00	7.88	33.75	34.41	90.26	63.65	298.00	102.96
46.	IGCA-46	1.69	2.39	22.50	7.63	32.63	36.29	84.43	52.65	299.50	102.29
47.	IGCA-47	1.56	3.38	21.88	8.13	31.63	51.65	82.71	52.56	297.75	102.96
48.	IGCA-48	2.14	2.86	22.25	7.63	32.13	38.20	82.05	52.93	287.38	103.21
49.	IGCA-49	1.56	2.75	23.38	7.88	34.13	34.48	82.25	55.88	305.75	103.00
50.	IGCA-50	1.34	2.74	23.38	7.63	33.38	33.31	84.87	56.20	296.50	104.04
51.	IGCA-51	1.86	2.86	23.38	8.00	34.00	33.47	82.07	52.35	296.63	101.67
52.	IGCA-52	1.77	2.51	22.38	8.13	33.38	32.91	87.64	61.68	289.50	104.38
53.	IGCA-53	1.65	2.58	22.38	8.00	33.25	47.74	85.77	57.21	283.50	102.63
54.	IGCA-54	1.86	2.74	22.88	7.88	32.25	51.78	81.74	51.86	301.00	105.92
55.	IGCA-55	1.59	2.76	22.75	7.63	32.75	51.46	78.09	59.78	287.75	102.63
56.	IGCA-56	1.56	2.33	25.00	8.38	32.13	50.61	79.08	50.40	291.88	103.38
57.	IGCA-57	1.50	2.39	25.25	8.63	33.13	33.39	73.92	49.09	293.50	104.88
58.	IGCA-58	1.81	2.61	25.00	8.63	32.88	33.61	73.35	49.59	293.25	103.13
59.	IGCA-59	1.79	2.29	24.88	8.38	33.25	32.44	71.31	49.11	305.50	106.13
60.	IGCA-60	1.82	2.29	24.38	8.63	33.00	32.99	69.97	46.21	295.50	105.50
	SEm ±	0.06	0.12	0.67	0.33	0.89	1.37	3.29	2.43	7.69	2.99
	CD at 5%	0.17	0.35	1.86	0.91	2.48	3.81	9.19	6.79	21.46	8.34
	CV	6.16	7.27	6.43	8.45	5.53	7.65	5.76	6.15	5.04	5.29

APPENDIX-IV: Mean performance of Custard Apple Genotypes in Northern Bastar of Chhattisgarh for qualitative traits of fruit yield and its components during the year 2013-14.

S.No.	Name of Genotypes	1	2	3	4	5	6	7	8	9	10
1.	IGCA-1	25.23	23.23	19.44	3.78	0.32	5.37	53.13	7.98	35.97	149.54
2.	IGCA-2	26.38	23.78	19.41	4.37	0.33	6.00	53.00	8.55	36.03	148.56
3.	IGCA-3	25.47	23.38	19.46	3.93	0.31	4.63	53.00	8.25	36.01	150.53
4.	IGCA-4	24.83	21.85	18.77	3.07	0.33	5.50	53.00	8.78	36.01	149.34
5.	IGCA-5	23.22	20.73	16.23	4.73	0.35	3.50	48.85	3.95	34.02	108.16
6.	IGCA-6	22.59	21.08	15.86	5.94	0.35	3.50	47.94	2.78	33.96	104.25
7.	IGCA-7	23.16	20.43	14.78	6.16	0.34	4.25	48.25	3.11	34.16	103.58
8.	IGCA-8	21.28	18.32	14.04	4.28	0.41	4.00	48.00	3.26	33.98	112.37
9.	IGCA-9	21.84	19.26	14.45	4.81	0.34	4.87	48.00	2.72	33.98	124.87
10.	IGCA-10	26.41	22.38	18.16	4.22	0.31	5.50	53.00	8.09	36.01	148.98
11.	IGCA-11	25.05	22.45	17.76	4.68	0.31	5.37	53.00	8.73	36.01	149.96
12.	IGCA-12	25.47	22.80	17.73	5.07	0.31	4.37	53.00	8.24	36.02	140.25
13.	IGCA-13	26.20	22.66	18.17	4.48	0.32	4.25	53.00	8.37	36.00	145.50
14.	IGCA-14	22.25	19.16	15.24	3.93	0.46	3.63	48.29	3.25	33.83	102.58
15.	IGCA-15	21.25	18.24	13.96	4.27	0.46	3.50	47.25	3.19	33.98	103.04
16.	IGCA-16	21.34	18.74	13.57	5.16	0.45	3.87	48.00	3.06	33.79	102.50
17.	IGCA-17	20.15	17.81	13.91	3.90	0.42	3.63	48.00	3.23	34.05	101.87
18.	IGCA-18	20.24	18.18	14.04	4.15	0.44	3.87	48.00	2.78	34.02	101.87
19.	IGCA-19	24.51	22.15	18.23	3.93	0.31	4.75	53.00	7.94	36.00	148.13
20.	IGCA-20	25.94	23.21	19.48	3.73	0.31	4.13	53.31	8.27	35.94	150.55
21.	IGCA-21	28.10	23.46	19.27	4.18	0.21	6.87	53.10	11.77	35.97	152.21
22.	IGCA-22	26.30	23.30	19.23	4.07	0.24	6.50	53.00	8.09	36.04	148.07
23.	IGCA-23	22.22	18.25	13.17	5.07	0.37	4.12	48.00	2.88	37.96	107.13
24.	IGCA-24	20.16	17.80	13.73	4.07	0.45	3.25	48.00	1.82	33.97	101.83
25.	IGCA-25	25.33	17.68	14.26	3.42	0.34	3.63	51.51	1.87	34.08	107.87
26.	IGCA-26	26.34	18.26	14.14	4.12	0.35	3.25	48.73	1.59	34.00	106.92
27.	IGCA-27	24.61	17.60	13.99	4.96	0.35	3.63	46.14	1.69	32.79	102.25
28.	IGCA-28	21.30	17.20	13.28	3.91	0.35	3.37	48.00	2.45	34.03	104.37
29.	IGCA-29	20.22	17.86	13.87	3.90	0.45	3.00	48.16	2.59	34.44	105.04

1. Total Soluble Solids(° Brix) 2. Total Sugar (%) 3. Reducing Sugar (%) 4. Non-reducing Sugar (%) 5. Acidity (%)
6. Keeping Days (Shelf life) 7. Pulp Ratio 8. Pulp-Seed Ratio 9. Peel percentage 10. Fruit Yield Per Plant
Contd...

Contd....

S. No.	Name of Genotypes	1	2	3	4	5	6	7	8	9	10
30.	IGCA-30	22.25	18.21	13.14	5.06	0.35	3.63	48.00	2.79	33.29	104.83
31.	IGCA-31	22.17	18.27	14.48	3.78	0.33	3.50	48.00	2.71	33.53	107.00
32.	IGCA-32	22.20	17.41	14.14	3.27	0.38	5.00	48.06	2.73	32.93	106.21
33.	IGCA-33	22.26	17.14	13.98	3.20	0.41	3.37	48.00	2.68	33.44	102.92
34.	IGCA-34	20.18	17.43	13.66	3.76	0.42	3.75	48.00	2.75	33.25	104.63
35.	IGCA-35	20.35	17.20	13.47	3.72	0.36	3.50	47.02	2.72	33.34	102.63
36.	IGCA-36	21.76	17.85	13.73	3.98	0.41	3.75	49.72	2.58	36.38	103.04
37.	IGCA-37	22.23	18.27	13.58	4.68	0.42	3.00	47.57	2.74	33.98	102.16
38.	IGCA-38	21.47	17.63	13.95	3.56	0.45	3.50	46.51	2.75	34.12	104.79
39.	IGCA-39	22.47	18.31	14.50	3.81	0.41	3.50	46.33	2.69	33.24	101.16
40.	IGCA-40	22.33	18.87	14.26	4.73	0.36	3.25	46.08	2.66	34.03	104.73
41.	IGCA-41	22.15	18.68	14.14	4.66	0.38	3.50	44.47	2.67	32.70	103.87
42.	IGCA-42	22.16	19.14	13.04	6.24	0.41	3.00	44.28	2.67	32.36	103.37
44.	IGCA-43	19.74	16.78	13.30	3.84	0.45	3.00	46.24	2.80	31.92	107.79
44.	IGCA-44	21.13	16.44	13.07	4.00	0.42	3.50	43.72	2.49	31.65	104.50
45.	IGCA-45	22.14	16.64	12.25	5.50	0.41	3.00	44.35	2.63	32.02	102.96
46.	IGCA-46	23.18	17.22	13.17	5.54	0.42	3.37	45.41	2.34	31.74	102.29
47.	IGCA-47	22.71	16.73	13.80	3.93	0.42	3.25	45.39	1.83	31.85	102.96
48.	IGCA-48	20.23	16.44	12.47	4.93	0.41	3.14	45.74	2.18	31.79	103.21
49.	IGCA-49	21.24	16.19	12.65	4.50	0.42	3.00	44.50	2.39	32.47	103.00
50.	IGCA-50	21.63	17.37	12.67	4.74	0.40	3.25	45.89	2.55	32.88	104.04
51.	IGCA-51	21.79	17.23	12.44	6.58	0.41	3.00	48.37	2.47	31.16	101.66
52.	IGCA-52	21.37	17.19	13.25	5.63	0.45	3.13	46.01	2.66	33.47	104.37
53.	IGCA-53	21.58	16.77	12.98	4.98	0.42	3.00	46.44	1.99	33.00	102.63
54.	IGCA-54	21.63	16.56	13.08	5.41	0.42	3.00	45.62	1.79	32.19	105.91
55.	IGCA-55	21.94	15.92	12.78	3.88	0.41	3.25	45.72	1.73	36.79	102.62
56.	IGCA-56	22.08	17.32	13.31	4.28	0.39	3.25	44.08	1.74	28.68	103.37
57.	IGCA-57	21.18	16.21	11.79	5.61	0.42	3.13	43.67	2.22	28.91	104.87
58.	IGCA-58	19.83	16.00	11.84	5.11	0.45	3.00	43.49	2.18	29.69	103.13
59.	IGCA-59	22.24	16.28	12.49	5.20	0.39	3.00	43.36	2.22	29.97	106.12
60.	IGCA-60	20.81	16.46	11.96	5.34	0.43	3.00	43.26	2.13	30.96	105.50
	SEm ±	0.69	0.48	0.51	0.30	0.01	0.23	2.58	0.12	1.77	2.98
	CD at 5%	1.93	1.33	1.41	0.85	0.03	0.63	7.21	0.34	4.95	8.34
	CV	6.03	4.99	6.88	13.57	5.61	11.92	10.85	6.50	10.38	5.29

APPENDIX-V: Mean performance of Custard Apple Genotypes in Northern Bastar of Chhattisgarh for quantitative traits of fruit yield and its components during the year 2014-15

S. No.	Name of Genotypes	1	2	3	4	5	6	7	8	9	10
1.	IGCA-1	350.00	6.05	33.50	124.00	23.75	4.40	11.63	454.25	3.42	25.00
2.	IGCA-2	352.25	5.80	34.75	123.00	24.50	4.50	12.18	440.75	3.47	22.25
3.	IGCA-3	348.50	6.05	34.50	123.75	24.50	4.50	12.02	438.00	3.45	22.00
4.	IGCA-4	331.75	6.32	35.00	126.25	25.00	4.57	11.60	435.50	3.47	24.75
5.	IGCA-5	353.25	6.40	30.50	126.25	20.00	3.70	11.45	247.50	2.17	22.75
6.	IGCA-6	326.00	6.60	31.75	127.75	21.75	4.20	10.95	191.75	3.42	24.25
7.	IGCA-7	338.00	7.70	29.50	130.25	18.50	3.53	9.07	195.75	3.33	19.75
8.	IGCA-8	318.00	7.35	29.50	129.25	17.50	3.35	8.50	192.00	2.35	18.25
9.	IGCA-9	333.25	6.05	30.75	129.00	20.25	3.53	10.98	187.75	3.45	14.50
10.	IGCA-10	338.25	7.38	31.00	124.00	21.00	4.25	12.30	428.75	3.33	13.75
11.	IGCA-11	359.00	6.28	33.25	125.00	23.50	3.60	9.75	432.00	2.17	17.50
12.	IGCA-12	334.25	6.60	34.50	127.25	24.50	3.50	11.05	421.25	2.22	20.75
13.	IGCA-13	339.25	6.60	34.25	122.75	24.25	3.90	10.95	410.50	1.85	22.25
14.	IGCA-14	332.50	6.35	32.75	126.00	22.00	3.35	8.23	187.00	2.17	20.50
15.	IGCA-15	314.00	6.03	30.75	132.75	17.50	3.43	7.75	187.75	1.73	20.25
16.	IGCA-16	328.50	6.68	28.75	130.50	18.75	3.78	10.30	180.00	2.55	22.25
17.	IGCA-17	345.75	7.13	29.50	133.25	19.50	3.45	9.85	181.00	3.05	20.75
18.	IGCA-18	348.25	7.13	29.75	133.50	19.75	3.82	12.30	191.25	2.40	24.25
19.	IGCA-19	346.00	6.18	35.50	124.00	25.50	4.55	12.52	398.50	3.03	24.75
20.	IGCA-20	345.75	6.10	41.00	123.50	31.00	4.20	12.35	395.00	3.55	24.00
21.	IGCA-21	353.75	6.32	45.00	121.00	35.00	4.72	12.32	570.25	3.53	25.50
22.	IGCA-22	358.50	6.70	42.75	121.75	33.25	3.90	11.13	384.75	2.53	22.75
23.	IGCA-23	353.00	6.47	29.75	125.00	19.00	3.35	7.82	184.50	1.83	14.75
24.	IGCA-24	315.25	6.28	30.75	126.00	20.75	3.43	8.20	156.75	2.13	15.00
25.	IGCA-25	338.75	6.35	28.25	128.00	18.25	3.72	8.77	154.75	2.17	16.00
26.	IGCA-26	329.25	5.90	28.00	131.75	18.00	3.47	10.00	161.50	2.20	13.50
27.	IGCA-27	330.50	6.40	27.50	130.50	17.50	3.92	10.38	170.75	1.88	15.00
28.	IGCA-28	339.75	6.33	30.00	132.50	20.00	3.17	7.55	164.50	2.55	12.75
29.	IGCA-29	305.75	6.30	29.50	132.25	18.50	3.22	8.50	171.75	3.05	13.50

1. No. of Alternate Leaf
 6. Fruit Width (cm)
 2. Length of Leaf (cm)
 7. Fruit Length (cm)
 3. No. of Flowers Per Branch
 8. Fruit Weight (g)
 4. Days to 50 % Maturity
 9. Length of Pedicel (cm)
 5. Total No. of Fruits
 10. Pedicel Thickness

Contd...

Contd...

S. No.	Name of Genotypes	11	12	13	14	15	16	17	18	19	20
1.	IGCA-1	3.15	5.47	18.00	6.50	27.50	33.75	240.75	163.26	340.00	149.57
2.	IGCA-2	3.20	5.47	18.25	5.75	28.75	26.48	233.60	158.94	346.00	148.87
3.	IGCA-3	3.17	5.43	17.25	5.00	26.25	26.60	232.14	157.77	341.00	149.55
4.	IGCA-4	3.20	5.53	17.00	5.50	26.00	26.26	230.82	156.87	342.50	150.17
5.	IGCA-5	2.17	3.50	18.50	7.00	30.75	27.63	118.80	84.24	299.25	111.83
6.	IGCA-6	2.33	3.28	21.50	8.50	34.25	32.51	91.80	65.03	300.00	103.00
7.	IGCA-7	1.70	2.55	18.75	8.50	31.25	27.97	94.92	67.15	293.25	102.17
8.	IGCA-8	1.73	2.28	21.25	8.75	30.50	24.56	92.16	65.19	285.75	119.25
9.	IGCA-9	1.63	2.47	17.00	6.75	31.50	32.90	90.12	63.75	299.50	103.00
10.	IGCA-10	3.17	5.00	15.25	7.00	28.00	29.83	227.24	154.44	343.00	149.23
11.	IGCA-11	3.22	4.85	18.50	7.50	27.00	26.26	228.96	155.61	339.00	149.68
12.	IGCA-12	3.20	4.83	15.25	7.50	28.25	26.60	223.26	151.83	340.75	135.00
13.	IGCA-13	1.83	4.83	21.50	8.50	31.50	24.22	217.57	147.78	342.50	145.75
14.	IGCA-14	1.80	2.58	21.25	7.75	34.00	23.88	89.64	63.75	299.75	101.17
15.	IGCA-15	1.73	2.95	22.50	8.00	33.00	24.10	90.12	63.75	301.00	102.08
16.	IGCA-16	1.60	3.17	18.00	8.00	32.25	24.22	86.40	60.44	299.75	102.25
17.	IGCA-17	1.65	3.30	18.25	8.00	31.25	22.48	86.88	61.71	304.00	102.25
18.	IGCA-18	2.17	5.32	18.50	8.25	27.00	32.56	91.80	65.11	301.00	102.00
19.	IGCA-19	2.55	5.28	18.00	6.50	29.75	26.60	211.21	143.46	344.25	147.50
20.	IGCA-20	2.90	5.43	18.50	7.00	27.00	26.44	209.09	141.75	343.25	150.67
21.	IGCA-21	3.28	5.82	20.00	5.25	25.00	27.46	299.18	205.02	364.00	152.17
22.	IGCA-22	2.53	5.20	17.50	6.25	28.00	26.26	203.92	138.78	351.00	149.39
23.	IGCA-23	1.30	3.17	21.25	8.25	30.50	28.01	88.56	77.40	287.25	102.00
24.	IGCA-24	1.27	2.70	18.50	8.25	33.75	56.21	75.24	53.21	288.75	101.67
25.	IGCA-25	1.55	3.20	17.50	8.00	34.50	63.00	74.28	52.87	289.75	106.75
26.	IGCA-26	1.45	3.33	18.00	8.50	33.50	91.12	77.64	54.91	287.75	101.58
27.	IGCA-27	1.88	3.75	18.50	8.25	33.75	61.68	73.68	52.53	296.50	102.25
28.	IGCA-28	2.13	3.60	18.50	8.00	35.00	31.41	78.96	56.01	296.50	101.50
29.	IGCA-29	2.92	3.70	21.50	8.50	34.00	29.20	82.44	58.40	288.25	107.58

11. Length of Pericarp (cm) 12. Weight of Pericarp (g) 13. Seed Length (mm) 14. Seed Width (mm) 15. No. of Seeds/ Fruit
 16. Seed Weight(g) 17. Pulp Weight (g) 18. Areole Weight(g) 19. No. of Fruits/ Tree 20. Fruit Yield/ Plant (kg)

Contd...

Contd...

S.No.	Name of Genotypes	1	2	3	4	5	6	7	8	9	10
30.	IGCA-30	342.75	5.85	28.00	133.50	17.50	3.22	9.55	191.75	2.17	12.25
31.	IGCA-31	335.75	6.85	26.25	132.75	16.25	3.30	9.77	182.25	2.50	14.50
32.	IGCA-32	343.50	5.32	27.00	137.00	16.75	3.47	9.98	184.50	2.50	14.50
33.	IGCA-33	330.25	5.65	28.50	131.50	18.25	2.70	8.63	177.50	2.28	13.50
34.	IGCA-34	340.75	6.82	27.50	131.50	17.50	2.75	7.68	185.00	2.20	12.25
35.	IGCA-35	340.50	6.22	27.50	133.25	16.00	2.58	7.45	186.75	2.22	11.50
36.	IGCA-36	308.75	6.30	26.00	131.75	16.00	3.25	9.93	155.25	2.53	12.75
37.	IGCA-37	333.25	5.57	25.50	135.25	15.25	3.20	10.00	186.75	2.17	12.75
38.	IGCA-38	351.75	6.00	30.00	132.50	20.00	2.35	7.55	187.00	2.25	12.00
39.	IGCA-39	347.75	6.10	27.75	131.25	17.50	2.40	7.53	198.75	2.45	13.00
40.	IGCA-40	353.25	6.50	27.75	134.25	17.75	2.63	10.50	193.00	2.50	13.75
41.	IGCA-41	296.75	6.43	25.50	134.75	15.25	2.92	9.85	193.50	2.45	12.75
42.	IGCA-42	327.50	6.18	28.00	133.75	18.00	2.80	8.18	192.50	2.47	10.75
43.	IGCA-43	307.75	6.95	26.00	132.25	16.00	3.00	8.52	194.50	2.45	11.75
44.	IGCA-44	339.75	6.65	28.25	133.25	16.75	2.60	9.50	204.00	1.82	12.50
45.	IGCA-45	266.75	6.93	27.00	132.25	14.50	3.40	9.43	198.25	1.63	11.75
46.	IGCA-46	327.50	6.40	27.75	133.75	17.00	3.38	9.02	156.25	2.33	10.25
47.	IGCA-47	232.00	6.10	28.75	133.00	17.75	3.28	9.45	156.50	2.47	11.50
48.	IGCA-48	283.75	6.45	27.25	133.50	17.25	2.80	8.57	154.00	2.80	10.50
49.	IGCA-49	271.75	6.35	26.50	131.25	16.50	2.67	8.63	162.00	1.33	12.75
50.	IGCA-50	339.50	6.55	26.75	133.00	15.75	2.28	7.70	164.75	1.20	12.00
51.	IGCA-51	304.25	6.40	26.50	129.75	13.75	2.50	8.48	163.25	1.85	11.75
52.	IGCA-52	244.75	6.07	27.00	131.25	15.50	2.83	8.68	192.75	1.80	12.00
53.	IGCA-53	180.50	5.68	27.25	132.25	17.25	3.17	8.75	175.50	2.22	12.00
54.	IGCA-54	265.75	4.97	24.25	133.50	14.00	2.80	8.65	154.50	1.70	12.25
55.	IGCA-55	257.00	4.97	24.50	133.25	12.50	2.63	8.75	156.50	1.25	12.50
56.	IGCA-56	261.00	5.60	26.25	133.50	14.25	3.03	7.65	196.25	1.50	11.75
57.	IGCA-57	283.50	4.50	25.75	135.50	14.25	2.17	7.93	154.75	1.10	11.25
58.	IGCA-58	153.50	5.07	27.75	133.50	15.25	2.38	8.45	156.50	1.50	10.50
59.	IGCA-59	176.75	4.77	25.75	131.25	13.00	2.30	5.43	176.50	1.70	11.25
60.	IGCA-60	318.25	5.80	26.25	131.75	14.50	2.33	7.35	132.25	1.48	12.75
	SEm ±	19.85	0.35	0.90	2.27	0.70	0.10	0.29	7.01	0.07	0.47
	CD at 5%	55.40	0.99	2.52	6.34	1.95	0.28	0.81	19.57	0.19	1.32
	CV	12.38	10.46	6.08	3.94	7.76	6.00	6.09	6.02	6.12	5.75

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Contd...

S. No.	Name of Genotypes	11	12	13	14	15	16	17	18	19	20
30.	IGCA-30	1.60	2.80	18.25	8.25	31.25	32.56	92.04	65.11	293.00	107.42
31.	IGCA-31	1.80	2.80	19.75	8.50	34.00	31.03	87.48	62.05	290.50	101.75
32.	IGCA-32	1.52	3.20	18.75	7.75	33.00	30.01	88.11	60.01	296.50	110.92
33.	IGCA-33	1.45	3.28	21.50	7.25	33.25	30.17	85.20	60.35	291.75	103.83
34.	IGCA-34	1.52	2.80	21.75	6.75	33.50	31.49	88.80	62.99	285.50	107.50
35.	IGCA-35	1.80	2.83	21.50	7.25	34.50	31.71	89.64	63.41	296.75	101.50
36.	IGCA-36	1.52	3.15	21.50	8.50	34.25	26.44	74.52	52.87	296.00	104.33
37.	IGCA-37	1.65	3.13	21.75	8.25	33.75	31.19	87.96	62.39	298.25	103.08
38.	IGCA-38	1.55	4.13	21.50	7.50	31.00	31.03	90.66	62.05	296.75	106.33
39.	IGCA-39	1.80	2.67	21.50	8.25	32.25	30.85	87.00	61.71	296.75	101.08
40.	IGCA-40	1.85	3.15	21.50	7.50	33.25	32.72	92.64	65.45	298.25	105.42
41.	IGCA-41	1.52	3.22	24.00	8.25	32.75	32.90	92.88	65.79	297.75	101.25
42.	IGCA-42	1.80	2.75	21.75	7.75	33.50	32.72	92.40	65.45	298.00	104.50
43.	IGCA-43	1.80	2.65	21.50	7.75	33.75	33.07	93.36	66.13	287.50	109.83
44.	IGCA-44	1.82	2.53	21.50	7.50	32.00	38.53	95.28	67.49	294.25	106.50
45.	IGCA-45	1.60	3.15	21.50	8.00	34.25	34.63	95.16	67.49	297.50	101.42
46.	IGCA-46	1.65	2.28	22.25	7.50	32.25	39.07	85.12	52.96	299.00	101.58
47.	IGCA-47	1.55	3.33	21.50	8.00	33.00	69.72	82.01	53.21	297.50	103.92
48.	IGCA-48	2.80	2.60	21.50	7.50	34.75	42.12	78.61	52.53	287.25	103.42
49.	IGCA-49	1.52	2.70	23.75	7.75	34.75	34.72	83.23	55.25	320.00	101.50
50.	IGCA-50	1.20	2.78	24.00	7.50	34.00	33.58	83.86	55.93	298.50	100.83
51.	IGCA-51	1.85	2.88	23.75	8.25	34.25	32.60	83.86	49.13	296.25	101.83
52.	IGCA-52	1.80	2.45	22.25	8.50	33.25	31.88	89.48	65.79	294.25	104.00
53.	IGCA-53	1.50	2.55	22.50	8.25	33.00	61.13	89.32	59.67	278.25	102.25
54.	IGCA-54	1.88	2.63	23.00	8.00	33.25	69.16	82.55	52.53	302.50	109.08
55.	IGCA-55	1.55	2.67	23.25	7.50	34.00	67.48	73.90	65.31	289.75	102.00
56.	IGCA-56	1.52	2.15	28.25	8.50	33.75	65.68	78.58	48.45	295.50	103.50
57.	IGCA-57	1.42	2.33	26.50	8.75	34.50	31.88	68.25	47.77	294.00	101.25
58.	IGCA-58	1.82	2.55	26.00	8.50	35.25	31.88	70.89	48.19	294.00	102.25
59.	IGCA-59	1.80	2.17	26.25	8.25	34.75	30.22	64.50	48.45	302.75	107.25
60.	IGCA-60	1.80	2.20	26.00	8.50	35.25	30.85	67.65	44.97	297.75	104.50
	SEm ±	0.04	0.11	0.64	0.27	0.85	1.03	3.22	2.29	7.69	3.14
	CD at 5%	0.12	0.29	1.77	0.76	2.37	2.88	9.00	6.40	21.47	8.75
	CV	4.34	6.10	6.20	7.07	5.39	6.35	5.63	5.85	5.04	5.51

APPENDIX-VI: Mean performance of Custard Apple Genotypes in Northern Bastar of Chhattisgarh for qualitative traits of fruit yield and its components during the year 2014-15

S. No.	Name of Genotypes	1	2	3	4	5	6	7	8	9	10
1.	IGCA-1	25.25	23.20	19.45	3.75	0.32	5.50	53.00	7.13	35.94	149.57
2.	IGCA-2	26.48	23.80	19.43	4.38	0.33	6.00	53.00	8.82	36.06	148.87
3.	IGCA-3	25.53	23.40	19.48	3.93	0.32	4.75	53.00	8.73	36.02	149.56
4.	IGCA-4	24.80	21.53	18.75	2.78	0.34	5.50	53.00	8.79	36.02	150.17
5.	IGCA-5	24.53	20.73	16.25	4.48	0.35	3.50	48.00	4.30	34.04	111.83
6.	IGCA-6	23.33	21.38	15.28	6.10	0.36	3.50	47.88	2.82	33.91	103.00
7.	IGCA-7	24.48	20.65	14.13	6.53	0.35	4.25	48.50	3.40	34.32	102.17
8.	IGCA-8	21.33	18.35	13.78	4.58	0.41	4.25	48.00	3.75	33.96	119.25
9.	IGCA-9	22.10	18.38	13.70	4.68	0.34	4.75	48.00	2.74	33.96	103.00
10.	IGCA-10	26.35	21.95	18.15	3.80	0.32	5.25	53.00	7.62	36.02	149.23
11.	IGCA-11	24.65	22.08	17.75	4.33	0.31	5.50	53.00	8.72	36.02	149.68
12.	IGCA-12	25.45	22.45	17.78	4.68	0.31	4.50	53.00	8.39	36.04	135.00
13.	IGCA-13	26.20	22.18	18.18	4.00	0.35	4.25	53.00	8.98	36.00	145.75
14.	IGCA-14	22.23	19.10	15.25	3.85	0.45	3.50	47.93	3.75	34.09	101.17
15.	IGCA-15	21.23	18.25	13.70	4.55	0.46	3.50	48.00	3.74	33.96	102.08
16.	IGCA-16	21.33	18.73	13.58	5.15	0.45	3.75	48.00	3.57	33.59	102.25
17.	IGCA-17	20.13	17.80	13.65	4.15	0.43	3.75	48.00	3.86	34.10	102.25
18.	IGCA-18	20.20	18.20	13.85	4.35	0.45	3.75	48.00	2.82	34.05	102.00
19.	IGCA-19	24.50	22.13	18.23	3.90	0.32	4.75	53.00	7.94	36.00	147.50
20.	IGCA+20	25.93	23.20	19.53	3.68	0.31	4.25	53.53	7.91	35.89	150.67
21.	IGCA+21	28.13	23.48	19.25	4.23	0.21	7.25	53.20	10.90	35.95	152.17
22.	IGCA+22	26.48	23.35	19.23	4.13	0.24	6.75	53.00	7.76	36.07	149.39
23.	IGCA+23	22.23	18.28	13.15	5.13	0.45	4.00	48.00	3.17	41.93	102.00
24.	IGCA+24	20.15	17.83	13.73	4.10	0.46	3.25	48.00	1.45	33.95	101.67
25.	IGCA+25	24.40	17.88	14.20	3.68	0.31	3.75	48.00	1.18	34.17	106.75
26.	IGCA+26	26.35	18.28	14.15	4.13	0.33	3.25	48.08	0.85	34.00	101.58
27.	IGCA+27	24.03	19.20	14.23	4.98	0.32	3.75	44.28	1.19	31.59	102.25
28.	IGCA+28	21.18	17.23	13.30	3.93	0.34	3.25	48.00	2.51	34.06	101.50
29.	IGCA+29	20.20	18.00	14.20	3.80	0.46	3.00	48.00	2.82	34.00	107.58

1. Total Soluble Solids(° Brix) 2. Total Sugar (%) 3. Reducing Sugar (%) 4. Non-reducing Sugar (%) 5. Acidity (%)
6. Keeping Days (Shelf life) 7. Pulp Ratio 8. Pulp-Seed Ratio 9. Peel percentage 10. Fruit Yield Per Plant
Contd...

Contd. ...

S. No.	Name of Genotypes	1	2	3	4	5	6	7	8	9	10
30.	IGCA-30	22.25	18.15	13.15	5.00	0.35	3.00	48.00	2.83	33.96	107.42
31.	IGCA-31	22.80	18.28	14.53	3.75	0.34	2.75	48.00	2.82	34.05	101.75
32.	IGCA-32	22.18	17.40	14.13	3.28	0.35	5.00	48.13	2.93	32.72	110.92
33.	IGCA-33	21.30	17.50	14.33	3.18	0.41	3.00	48.00	2.82	34.00	103.83
34.	IGCA-34	20.18	17.43	13.68	3.75	0.42	3.00	48.00	2.82	34.05	107.50
35.	IGCA-35	20.48	17.23	13.50	3.73	0.36	3.50	48.00	2.83	33.96	101.50
36.	IGCA-36	22.08	18.20	14.23	3.98	0.41	3.75	48.00	2.82	34.06	104.33
37.	IGCA-37	23.20	18.30	13.60	4.70	0.42	3.00	47.15	2.82	33.45	103.08
38.	IGCA-38	21.45	18.03	14.38	3.65	0.45	3.50	45.03	2.92	33.23	106.33
39.	IGCA-39	22.45	18.30	14.48	3.83	0.41	3.50	44.65	2.82	31.68	101.08
40.	IGCA-40	22.83	19.25	14.50	4.75	0.35	3.00	48.00	2.83	33.91	105.42
41.	IGCA-41	23.30	18.58	14.33	4.25	0.37	3.75	44.98	2.82	34.00	101.25
42.	IGCA-42	22.18	19.50	13.25	6.25	0.42	3.00	45.63	2.82	34.00	104.50
44.	IGCA-43	19.28	17.38	13.53	3.85	0.46	3.00	45.45	2.82	34.00	109.83
44.	IGCA-44	21.40	17.23	13.20	4.03	0.42	3.75	44.45	2.48	33.16	106.50
45.	IGCA-45	22.35	16.85	11.60	5.25	0.42	3.00	45.85	2.75	34.04	101.42
46.	IGCA-46	23.18	18.23	13.28	4.95	0.43	3.50	43.45	2.18	33.89	101.58
47.	IGCA-47	23.15	17.70	14.15	3.55	0.42	3.25	42.78	1.18	34.00	103.92
48.	IGCA-48	21.20	17.50	12.58	4.93	0.41	3.00	44.60	1.87	34.11	103.42
49.	IGCA-49	22.30	17.98	12.90	5.10	0.41	3.00	44.85	2.40	34.11	101.50
50.	IGCA-50	22.20	17.03	12.25	4.78	0.41	3.25	43.63	2.50	33.95	100.83
51.	IGCA-51	22.45	18.68	12.38	6.30	0.41	3.00	52.80	2.57	31.11	101.83
52.	IGCA-52	22.35	19.25	13.75	5.50	0.45	3.25	43.38	2.81	34.14	104.00
53.	IGCA-53	22.60	17.90	13.03	4.88	0.41	3.00	45.13	1.58	34.00	102.25
54.	IGCA-54	22.25	18.08	13.30	4.78	0.41	3.00	42.63	1.19	34.00	109.08
55.	IGCA-55	22.95	16.95	13.18	3.78	0.42	3.50	43.18	1.10	41.76	102.00
56.	IGCA-56	23.18	19.13	14.85	4.28	0.38	3.50	40.78	1.20	26.69	103.50
57.	IGCA-57	22.23	18.15	12.15	6.00	0.42	3.25	45.65	2.14	31.57	101.25
58.	IGCA-58	20.18	17.60	12.33	5.28	0.45	3.00	45.30	2.22	31.46	102.25
59.	IGCA-59	23.23	17.48	12.28	5.20	0.38	3.00	38.85	2.14	28.48	107.25
60.	IGCA-60	21.48	17.78	12.10	5.68	0.42	3.00	44.55	2.20	34.00	104.50
	SE_m ±	0.83	0.47	0.44	0.06	0.01	0.22	2.69	0.13	1.99	3.14
	CD at 5%	2.31	1.31	1.22	0.16	0.04	0.62	7.53	0.35	5.57	8.75
	CV	7.39	5.11	6.02	2.56	6.61	11.67	11.17	6.68	12.04	5.51

APPENDIX-VII: Mean performance of Custard Apple Genotypes in Northern Bastar of Chhattisgarh for quantitative traits of fruit yield and its components (pooled data) year 2013-14 and 2014-15

S. No.	Name of Genotypes	1	2	3	4	5	6	7	8	9	10
1.	IGCA-1	352.00	6.90	32.00	109.25	21.25	4.38	11.63	454.75	3.38	24.75
2.	IGCA-2	325.25	6.75	32.50	108.50	22.25	4.47	12.18	441.25	3.53	23.00
3.	IGCA-3	316.50	6.38	33.00	107.75	22.75	4.53	12.02	438.00	3.50	22.50
4.	IGCA-4	332.75	5.95	34.75	111.00	24.50	4.55	11.60	435.25	3.50	25.25
5.	IGCA-5	352.75	6.57	31.00	109.00	20.00	3.67	11.45	247.00	2.25	23.50
6.	IGCA-6	326.25	6.20	31.00	109.00	21.00	4.28	10.95	192.00	3.55	23.75
7.	IGCA-7	337.00	7.15	27.50	116.50	16.00	3.53	9.07	196.00	3.45	20.75
8.	IGCA-8	341.50	5.18	28.00	114.75	17.25	3.40	8.50	192.25	2.45	18.75
9.	IGCA-9	332.50	6.32	29.75	115.50	19.25	3.57	10.98	188.00	3.50	14.75
10.	IGCA-10	337.00	7.85	30.25	116.50	20.25	4.32	12.30	429.00	3.45	14.50
11.	IGCA-11	358.25	8.05	30.25	120.25	20.00	3.38	9.75	432.25	2.28	17.75
12.	IGCA-12	333.50	8.15	30.25	116.75	20.00	3.55	11.05	421.50	2.28	21.75
13.	IGCA-13	339.00	8.13	29.50	118.75	19.25	4.55	10.95	410.75	1.90	24.50
14.	IGCA-14	332.50	7.18	29.50	117.50	19.50	3.43	8.23	189.75	2.25	22.75
15.	IGCA-15	338.75	5.38	28.25	124.00	18.00	3.47	7.75	188.25	1.85	18.50
16.	IGCA-16	328.50	6.28	29.00	118.75	18.50	4.28	10.30	180.25	2.60	24.25
17.	IGCA-17	346.50	6.35	29.00	118.00	18.75	3.47	10.30	181.50	3.17	23.00
18.	IGCA-18	348.75	5.68	29.00	109.00	19.00	4.28	12.30	191.00	2.45	24.75
19.	IGCA-19	346.25	7.93	32.25	108.75	21.75	4.60	12.52	398.75	3.17	25.25
20.	IGCA-20	346.00	7.95	38.75	106.00	28.50	4.28	12.35	394.75	3.57	24.75
21.	IGCA-21	354.25	8.15	42.00	108.25	31.75	4.70	12.32	570.00	3.63	25.75
22.	IGCA-22	359.00	7.53	42.00	106.00	32.00	3.75	11.13	385.00	2.58	23.50
23.	IGCA-23	353.75	5.35	30.25	115.00	19.50	3.45	7.82	184.75	1.45	14.75
24.	IGCA-24	316.00	6.25	29.25	117.00	19.00	3.47	8.20	157.00	2.17	15.50
25.	IGCA-25	339.50	6.00	29.00	120.25	16.00	3.83	8.77	155.00	1.85	14.75
26.	IGCA-26	330.25	6.05	31.50	114.75	16.50	3.65	10.32	161.75	2.25	14.00
27.	IGCA-27	331.25	6.20	31.50	117.25	15.50	4.45	10.30	154.25	1.85	15.25
28.	IGCA-28	339.50	6.28	28.25	117.50	27.00	3.25	7.55	165.00	1.75	13.25
29.	IGCA-29	305.75	5.98	28.75	115.00	16.00	3.15	8.50	172.00	2.63	13.75

1. No. of Alternate Leaf
 2. Length of Leaf (cm)
 3. No. of Flowers Per Branch
 4. Days to 50 % Maturity
 5. Total No. of Fruits
 6. Fruit Width (cm)
 7. Fruit Length (cm)
 8. Fruit Weight (g)
 9. Length of Pedicel (cm)
 10. Pedicel Thickness

Contd...

Contd...

S. No.	Name of Genotypes	11	12	13	14	15	16	17	18	19	20
1.	IGCA-1	3.20	5.55	18.50	6.75	27.75	27.44	242.19	163.71	344.00	149.50
2.	IGCA-2	3.25	5.53	18.50	6.25	29.00	28.28	233.86	158.85	348.25	148.25
3.	IGCA-3	3.25	5.50	17.75	5.50	26.50	29.88	232.14	157.68	342.00	151.50
4.	IGCA-4	3.28	5.57	17.50	6.00	26.25	26.31	230.68	156.69	342.25	148.50
5.	IGCA-5	2.25	3.55	18.75	6.75	31.25	34.07	122.74	83.98	299.25	104.50
6.	IGCA-6	2.40	3.33	22.00	8.75	35.50	33.66	92.16	65.28	302.25	105.50
7.	IGCA-7	1.85	2.28	18.25	8.75	31.75	33.32	94.08	66.64	295.25	105.00
8.	IGCA-8	1.82	2.28	21.75	8.25	30.75	33.40	92.28	65.37	289.25	105.50
9.	IGCA-9	1.73	2.50	17.00	6.75	32.00	33.55	90.24	63.92	301.50	146.75
10.	IGCA-10	3.22	3.95	15.50	7.25	27.50	26.52	227.37	154.44	345.25	148.75
11.	IGCA-11	3.30	4.85	18.50	7.25	27.50	26.22	229.09	155.61	343.50	150.25
12.	IGCA-12	3.25	4.88	15.75	7.50	28.50	27.58	223.40	151.74	344.75	145.50
13.	IGCA-13	1.85	4.75	22.50	8.25	32.00	28.05	217.70	147.87	344.75	145.25
14.	IGCA-14	1.85	2.40	21.75	7.50	34.25	33.55	92.27	63.67	300.00	104.00
15.	IGCA-15	1.82	2.83	22.75	8.25	33.50	33.26	87.52	64.01	301.25	104.00
16.	IGCA-16	1.65	3.20	18.25	8.00	32.50	33.78	86.52	61.28	299.50	102.75
17.	IGCA-17	1.70	3.28	18.75	8.25	31.25	33.69	87.12	61.71	300.75	101.50
18.	IGCA-18	2.25	5.43	18.75	7.75	27.25	33.35	91.68	64.94	299.75	101.75
19.	IGCA-19	2.58	5.35	18.50	6.75	29.25	26.60	211.34	143.55	347.50	148.75
20.	IGCA-20	2.75	5.50	18.50	7.50	27.50	24.27	209.57	142.11	349.75	150.42
21.	IGCA-21	3.35	5.85	15.50	5.75	25.75	23.88	302.10	205.20	376.00	152.25
22.	IGCA-22	2.57	5.15	18.00	6.50	28.25	24.22	204.05	138.60	350.00	146.75
23.	IGCA-23	1.35	3.25	21.50	7.75	32.25	34.15	88.68	62.82	292.25	112.25
24.	IGCA-24	1.35	2.78	18.75	7.75	34.50	34.32	75.36	53.38	295.75	102.00
25.	IGCA-25	1.58	3.25	18.50	8.25	34.25	33.16	85.28	52.70	290.25	109.00
26.	IGCA-26	1.50	3.40	18.50	7.75	33.25	34.42	79.84	55.00	286.50	112.25
27.	IGCA-27	1.88	3.88	18.75	7.75	33.75	33.56	74.04	52.44	296.25	102.25
28.	IGCA-28	2.22	3.20	21.00	7.75	32.00	33.22	79.20	56.10	297.25	107.25
29.	IGCA-29	3.10	3.25	21.25	8.25	33.00	35.07	83.11	60.00	289.75	102.50

11. Length of Pericarp (cm) 12. Weight of Pericarp (g) 13. Seed Length (mm) 14. Seed Width (mm) 15. No. of Seeds per Fruit
 16. Seed Weight (g) 17. Pulp Weight (g) 18. Areole Weight (g) 19. No. of Fruits/ Tree 20. Fruit Yield per Plant (kg)

Contd...

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S. No.	Name of Genotypes	1	2	3	4	5	6	7	8	9	10
30.	IGCA-30	341.50	6.10	27.25	117.75	14.75	3.38	9.55	192.00	2.22	12.50
31.	IGCA-31	339.50	6.90	27.00	115.75	14.50	3.38	9.82	182.50	2.38	14.75
32.	IGCA-32	347.25	5.75	26.50	119.25	14.50	3.72	10.73	176.25	2.57	14.75
33.	IGCA-33	329.75	6.13	29.00	115.00	15.25	2.78	8.63	177.75	2.33	14.00
34.	IGCA-34	341.25	6.45	27.75	118.50	14.50	2.85	7.68	185.50	2.28	12.50
35.	IGCA-35	340.75	7.72	31.50	118.50	15.25	2.67	7.45	187.00	2.25	11.75
36.	IGCA-36	308.00	6.68	30.75	118.25	15.75	3.38	9.93	155.50	2.38	13.00
37.	IGCA-37	332.75	7.53	28.00	115.50	15.00	3.17	10.00	183.50	2.25	13.25
38.	IGCA-38	352.00	6.72	31.50	118.00	19.75	2.35	7.55	183.00	2.30	12.25
39.	IGCA-39	348.25	7.35	29.25	115.75	17.75	2.50	7.53	181.50	1.73	13.50
40.	IGCA-40	353.50	6.72	30.75	118.25	17.75	2.70	10.50	191.75	1.52	14.00
41.	IGCA-41	297.25	5.97	30.75	112.75	13.50	2.85	10.55	195.75	1.75	13.25
42.	IGCA-42	321.50	7.18	28.25	115.75	17.25	3.10	8.18	195.50	1.52	12.00
43.	IGCA-43	236.75	7.73	27.50	117.00	15.75	3.17	8.52	196.25	1.75	13.50
44.	IGCA-44	336.00	7.68	27.50	116.75	15.75	2.72	9.50	199.00	1.85	12.75
45.	IGCA-45	289.00	7.28	27.75	118.25	15.25	3.47	9.43	199.50	1.67	12.00
46.	IGCA-46	300.00	5.72	28.00	114.25	18.00	3.45	9.02	177.25	1.63	12.75
47.	IGCA-47	282.75	6.40	27.00	115.25	16.75	3.45	9.45	176.25	2.00	12.00
48.	IGCA-48	280.75	7.20	27.25	118.50	16.00	2.80	8.57	183.25	1.75	12.50
49.	IGCA-49	284.00	5.75	25.25	116.50	15.50	2.70	8.63	184.25	1.38	13.25
50.	IGCA-50	281.75	6.28	25.75	116.50	15.50	2.45	7.70	179.00	1.25	12.50
51.	IGCA-51	271.00	7.27	25.75	115.50	15.00	2.75	8.48	183.50	1.88	12.00
52.	IGCA-52	279.75	8.07	25.75	116.25	15.75	2.70	8.68	184.25	1.88	12.50
53.	IGCA-53	263.75	6.72	26.25	116.25	16.25	2.70	8.75	179.75	1.95	12.50
54.	IGCA-54	254.25	7.38	30.75	118.00	15.00	2.90	8.65	174.75	1.83	14.00
55.	IGCA-55	271.50	7.38	27.50	119.25	14.50	2.65	8.75	178.75	1.30	13.50
56.	IGCA-56	281.50	7.38	28.50	116.75	14.50	2.40	7.65	172.50	1.73	12.50
57.	IGCA-57	283.25	7.60	27.75	118.75	15.75	2.38	7.93	192.50	1.15	12.50
58.	IGCA-58	276.00	6.80	31.25	115.25	12.25	2.58	8.45	186.00	1.55	12.00
59.	IGCA-59	275.75	6.23	27.50	117.50	12.75	2.40	5.43	167.25	1.73	11.25
60.	IGCA-60	343.00	6.32	27.00	115.25	11.00	2.45	7.35	173.00	1.55	12.25
	SEM ±	11.85	0.29	0.77	1.97	0.55	0.10	0.19	5.10	0.08	0.44
	CD at 5%	32.95	0.80	2.14	5.47	1.53	0.27	0.54	14.18	0.22	1.21
	CV	10.53	12.45	7.34	4.53	8.41	8.36	5.75	6.24	9.85	7.64

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S. No.	Name of Genotypes	11	12	13	14	15	16	17	18	19	20
30.	IGCA-30	1.67	2.88	18.75	8.50	32.00	33.43	92.16	62.67	290.00	102.25
31.	IGCA-31	1.85	2.83	20.50	8.25	34.25	33.84	87.60	60.25	289.50	112.25
32.	IGCA-32	1.58	3.22	20.00	7.75	32.75	33.56	84.60	58.42	290.75	101.50
33.	IGCA-33	1.50	3.00	21.00	7.75	33.00	33.69	85.32	58.45	298.00	102.00
34.	IGCA-34	1.58	2.85	21.75	6.25	33.25	33.36	89.04	60.21	286.00	101.75
35.	IGCA-35	1.85	2.85	21.75	7.50	34.25	33.03	86.06	61.15	296.50	103.75
36.	IGCA-36	1.58	3.17	22.00	8.25	33.50	33.99	79.95	60.19	298.50	101.75
37.	IGCA-37	1.68	3.33	19.50	8.00	34.25	33.20	88.08	63.32	301.50	101.25
38.	IGCA-38	1.58	3.82	21.50	7.75	32.50	34.04	87.84	64.05	298.50	103.25
39.	IGCA-39	1.85	2.75	21.25	8.50	32.75	33.81	87.12	63.16	295.00	101.25
40.	IGCA-40	1.82	3.22	22.50	7.75	32.50	33.93	84.65	65.47	299.25	104.00
41.	IGCA-41	1.55	3.28	21.50	8.50	31.50	34.26	86.00	61.48	300.00	106.50
42.	IGCA-42	1.85	3.33	21.50	8.00	32.00	33.21	83.79	60.06	299.00	102.25
43.	IGCA-43	1.82	2.75	21.75	7.50	32.00	33.11	92.27	58.57	291.50	105.75
44.	IGCA-44	1.85	3.67	18.75	7.25	32.50	34.07	85.47	59.98	287.75	102.50
45.	IGCA-45	1.65	3.13	22.50	7.75	33.25	34.19	85.37	59.82	298.50	104.50
46.	IGCA-46	1.73	2.50	22.75	7.75	33.00	33.52	83.74	52.34	300.00	103.00
47.	IGCA-47	1.58	3.42	22.25	8.25	30.25	33.59	83.40	51.90	298.00	102.00
48.	IGCA-48	1.47	3.13	23.00	7.75	29.50	34.29	85.50	53.33	287.50	103.00
49.	IGCA-49	1.60	2.80	23.00	8.00	33.50	34.24	81.28	56.52	291.50	104.50
50.	IGCA-50	1.48	2.70	22.75	7.75	32.75	33.06	85.88	56.47	294.50	107.25
51.	IGCA-51	1.88	2.85	23.00	7.75	33.75	34.34	80.28	55.57	297.00	101.50
52.	IGCA-52	1.75	2.58	22.50	7.75	33.50	33.95	85.79	57.56	284.75	104.75
53.	IGCA-53	1.80	2.60	22.25	7.75	33.50	34.35	82.23	54.74	288.75	103.00
54.	IGCA-54	1.85	2.85	22.75	7.75	31.25	34.40	80.93	51.19	299.50	102.75
55.	IGCA-55	1.63	2.85	22.25	7.75	31.50	35.43	82.28	54.26	285.75	103.25
56.	IGCA-56	1.60	2.50	21.75	8.25	30.50	35.55	79.57	52.35	288.25	103.25
57.	IGCA-57	1.58	2.45	24.00	8.50	31.75	34.90	79.58	50.41	293.00	108.50
58.	IGCA-58	1.80	2.67	24.00	8.75	30.50	35.35	75.82	50.99	292.50	104.00
59.	IGCA-59	1.77	2.40	23.50	8.50	31.75	34.65	78.12	49.78	308.25	105.00
60.	IGCA-60	1.85	2.38	22.75	8.75	30.75	35.12	72.29	47.46	293.25	106.50
	SEM ±	0.05	0.09	0.51	0.21	0.64	2.69	2.29	1.69	5.14	2.42
	CD at 5%	0.14	0.25	1.42	0.58	1.77	7.48	6.38	4.71	14.28	6.74
	CV	7.07	7.45	7.00	7.61	5.66	22.33	5.67	6.08	4.76	6.05

APPENDIX-VIII: Mean performance of Custard Apple Genotypes in Northern Bastar of Chattisgarh for qualitative traits of fruit yield and its components (pooled data) year 2013-14 and 2014-15

S. No.	Name of Genotypes	1	2	3	4	5	6	7	8	9	10
1	IGCA-1	25.200	23.250	19.425	3.825	0.3175	5.250	53.260	8.835	36.000	149.500
2	IGCA-2	26.300	23.775	19.400	4.375	0.3275	6.000	53.000	8.273	36.000	148.250
3	IGCA-3	25.425	23.375	19.450	3.925	0.3175	4.500	53.000	7.770	36.000	151.500
4	IGCA-4	24.850	22.175	18.800	3.375	0.3325	5.500	53.000	8.770	36.000	148.500
5	IGCA-5	21.910	20.743	16.225	5.000	0.3475	3.500	49.690	3.610	34.000	104.500
6	IGCA-6	21.865	20.785	16.450	5.775	0.3550	3.500	48.000	2.737	34.000	105.500
7	IGCA-7	21.840	20.215	15.450	5.800	0.3450	4.250	48.000	2.820	34.000	105.000
8	IGCA-8	21.233	18.300	14.300	4.000	0.4125	3.750	48.000	2.763	34.000	105.500
9	IGCA-9	21.557	20.150	15.200	4.950	0.3375	5.000	48.000	2.690	34.000	146.750
10	IGCA-10	26.475	22.825	18.175	4.650	0.3150	5.750	53.000	8.573	36.000	148.750
11	IGCA-11	25.450	22.825	17.775	5.050	0.3100	5.250	53.000	8.740	36.000	150.250
12	IGCA-12	25.500	23.150	17.675	5.475	0.3150	4.250	53.000	8.097	36.000	145.500
13	IGCA-13	26.200	23.150	18.175	4.975	0.2900	4.250	53.000	7.762	36.000	145.250
14	IGCA-14	22.275	19.225	15.225	4.000	0.4450	3.750	48.665	2.750	33.567	104.000
15	IGCA-15	21.275	18.225	14.225	4.000	0.4575	3.500	46.497	2.637	34.000	104.000
16	IGCA-16	21.350	18.750	13.575	5.175	0.4475	4.000	48.000	2.565	34.000	102.750
17	IGCA-17	20.175	17.825	14.175	3.650	0.4225	3.500	48.000	2.593	34.000	101.500
18	IGCA-18	20.275	18.175	14.225	3.950	0.4450	4.000	48.000	2.750	34.000	101.750
19	IGCA-19	24.525	22.175	18.225	3.950	0.3175	4.750	53.000	7.940	36.000	148.750
20	IGCA-20	25.950	23.225	19.450	3.775	0.3150	4.000	53.090	8.635	36.000	150.420
21	IGCA-21	28.075	23.450	19.300	4.150	0.2150	6.500	55.013	12.65	36.000	152.250
22	IGCA-22	26.125	23.250	19.225	4.025	0.2375	6.250	53.000	8.423	36.000	146.750
23	IGCA-23	22.225	18.225	13.200	5.025	0.2975	4.250	48.000	2.603	34.000	112.250
24	IGCA-24	20.175	17.775	13.725	4.050	0.4500	3.250	48.000	2.197	34.000	102.000
25	IGCA-25	26.250	17.493	14.317	3.175	0.3700	3.500	47.013	2.570	34.000	109.000
26	IGCA-26	26.325	18.250	14.125	4.125	0.3725	3.250	49.357	2.327	34.000	112.250
27	IGCA-27	25.200	16.000	13.757	4.950	0.3675	3.500	48.000	2.205	34.000	102.250
28	IGCA-28	21.425	17.175	13.275	3.900	0.3675	3.500	48.000	2.385	34.000	107.250
29	IGCA-29	20.250	17.715	13.533	4.000	0.4500	3.000	48.317	2.373	34.883	102.500
30	IGCA-30	22.250	18.275	13.125	5.150	0.3500	4.250	48.000	2.757	32.635	102.250
31	IGCA-31	21.543	18.275	14.450	3.825	0.3325	4.250	48.000	2.595	33.005	112.250

1. Total Soluble Solids(° Brix) 2. Total Sugar (%) 3. Reducing Sugar (%) 4. Non-reducing Sugar (%) 5. Acidity (%)
6. Keeping Days (Shelf life) 7. Pulp Ratio 8. Pulp-Seed Ratio 9. Peel percentage 10. Fruit Yield Per Plant (kg)

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Contd...

S. No.	Name of Genotypes	1	2	3	4	5	6	7	8	9	10
32	IGCA-32	22.23	17.43	14.15	3.27	0.41	5.00	48.00	2.53	33.14	101.50
33	IGCA-33	23.23	16.78	13.64	3.23	0.42	3.75	48.00	2.55	32.88	102.00
34	IGCA-34	20.20	17.43	13.65	3.77	0.42	4.50	48.00	2.67	32.46	101.75
35	IGCA-35	20.23	17.17	13.45	3.73	0.37	3.50	46.03	2.61	32.72	103.75
36	IGCA-36	21.45	17.49	13.24	4.00	0.42	3.75	51.42	2.35	38.70	101.75
37	IGCA-37	21.25	18.25	13.57	4.67	0.42	3.00	48.00	2.66	34.51	101.25
38	IGCA-38	21.50	17.24	13.54	3.47	0.45	3.50	48.00	2.58	34.99	103.25
39	IGCA-39	22.50	18.33	14.53	3.80	0.42	3.50	48.00	2.58	34.80	101.25
40	IGCA-40	21.84	18.49	14.03	4.73	0.38	3.50	44.17	2.50	34.15	104.00
41	IGCA-41	20.99	18.78	13.96	5.07	0.39	3.25	43.97	2.52	31.41	106.50
42	IGCA-42	22.15	18.79	12.85	6.23	0.41	3.00	42.94	2.53	30.72	102.25
44	IGCA-43	20.20	16.19	13.07	3.83	0.45	3.00	47.02	2.78	29.85	105.75
44	IGCA-44	20.86	15.66	12.93	3.97	0.42	3.25	42.98	2.51	30.14	102.50
45	IGCA-45	21.93	16.43	12.90	5.75	0.41	3.00	42.84	2.50	29.99	104.50
46	IGCA-46	23.20	16.21	13.07	6.13	0.42	3.25	47.37	2.51	29.59	103.00
47	IGCA-47	22.27	15.77	13.46	4.30	0.42	3.25	48.02	2.48	29.69	102.00
48	IGCA-48	19.26	15.38	12.37	4.93	0.41	3.25	46.88	2.51	29.47	103.00
49	IGCA-49	20.18	14.42	12.40	3.90	0.43	3.00	44.16	2.38	30.85	104.50
50	IGCA-50	21.047	17.71	13.09	4.70	0.40	3.25	48.17	2.61	31.82	107.25
51	IGCA-51	21.14	15.78	12.51	6.87	0.42	3.00	43.94	2.36	31.21	101.50
52	IGCA-52	20.38	15.13	12.75	5.75	0.45	3.00	48.64	2.53	32.81	104.75
53	IGCA-53	20.56	15.65	12.94	5.10	0.43	3.00	47.76	2.40	32.00	103.00
54	IGCA-54	21.01	15.05	12.86	6.05	0.42	3.00	48.61	2.39	30.38	102.75
55	IGCA-55	20.94	14.89	12.39	4.00	0.41	3.00	48.27	2.36	31.83	103.25
56	IGCA-56	20.98	15.51	11.78	4.30	0.42	3.00	47.39	2.27	30.68	103.25
57	IGCA-57	20.13	14.27	11.45	5.23	0.41	3.00	41.69	2.29	26.26	108.50
58	IGCA-58	19.48	14.41	11.36	4.95	0.45	3.00	41.69	2.15	27.93	104.00
59	IGCA-59	21.26	15.08	12.70	5.20	0.42	3.00	47.88	2.30	31.47	105.00
60	IGCA-60	20.14	15.15	11.82	5.00	0.44	3.00	41.98	2.08	27.93	106.50
	SEm ±	0.54	0.40	0.33	0.17	0.01	0.17	1.82	0.16	1.33	2.42
	CD at 5%	1.49	1.12	0.93	0.47	0.03	0.46	5.05	0.45	3.70	6.74
	CV	6.69	6.09	6.45	10.56	6.83	12.39	10.72	12.13	11.18	6.05

Appendix IX: Tree habit, branching pattern, growth parameters and organoleptic evaluation of custard apple genotypes

S. No.	Name of genotypes	Tree habit	Plant height (m)	Canopy spread (m)		Canopy height (m)	Trunk girth (cm)	Branching pattern	Hedonic rating by organoleptic evaluation				
				E-W	N-S				Fruit Colour	Appearance	Aroma	Taste	Overall acceptability
1.	IGCA-1	Upright and open	11.75	4.35	4.24	6.55	11.25	Acute	8.00	8.00	8.25	8.25	8.00
2.	IGCA-2	Upright and compact	11.45	4.52	4.22	6.59	12.35	Acute	7.50	8.00	8.00	8.25	8.75
3.	IGCA-3	Upright and open	11.60	4.36	4.24	6.90	13.65	Acute	8.00	8.00	8.00	8.50	8.00
4.	IGCA-4	Upright and open	10.60	4.45	4.33	6.34	11.60	Acute	8.00	8.00	8.00	8.50	8.00
5.	IGCA-5	Upright and open	10.80	4.57	4.44	6.62	13.60	Acute	7.50	7.50	7.00	6.50	7.50
6.	IGCA-6	Upright and open	10.60	4.54	4.40	6.34	14.65	Acute	7.50	7.50	6.75	7.25	7.50
7.	IGCA-7	Upright and open	12.05	4.35	4.38	6.91	12.85	Acute	7.75	7.25	6.50	6.75	7.50
8.	IGCA-8	Upright and open	10.30	4.36	4.32	6.62	15.55	Acute	7.50	7.50	6.50	6.50	7.50
9.	IGCA-9	Upright and compact	10.40	4.43	4.30	6.62	12.70	Acute	7.50	7.50	7.00	6.00	7.00
10.	IGCA-10	Upright and open	13.00	4.28	4.29	6.67	14.40	Acute	7.50	8.00	8.00	8.50	8.50
11.	IGCA-11	Upright and compact	10.20	4.26	4.41	6.70	14.80	Acute	7.75	7.50	7.75	7.75	8.25
12.	IGCA-12	Upright and open	12.95	4.28	4.29	6.70	13.00	Acute	8.00	8.50	7.75	8.50	8.50
13.	IGCA-13	Upright and compact	10.20	4.36	4.38	6.54	13.80	Acute	8.25	8.25	8.00	6.75	8.25
14.	IGCA-14	Upright and open	13.05	4.47	4.30	6.90	12.85	Acute	7.00	8.50	7.00	5.50	7.50
15.	IGCA-15	Upright and open	12.15	4.43	4.43	6.00	11.85	Acute	7.50	7.50	7.50	5.75	7.75
16.	IGCA-16	Upright and open	11.00	4.44	4.23	6.78	11.95	Acute	7.50	8.00	7.25	6.00	7.50
17.	IGCA-17	Upright and open	10.90	4.36	4.35	6.88	12.60	Acute	7.50	7.75	7.75	6.50	7.75

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18.	IGCA-18	Upright and compact	10.80	4.35	4.34	6.70	12.90	Acute	7.50	8.00	7.50	6.50	7.50
19.	IGCA-19	Upright and open	11.80	4.57	4.34	6.88	13.85	Acute	8.00	8.00	8.00	8.25	8.50
20.	IGCA-20	Upright and open	12.40	4.45	4.40	6.57	14.65	Acute	8.00	8.50	8.00	8.00	8.25
21.	IGCA-21	Upright and compact	10.30	4.35	4.33	6.61	15.50	Acute	7.25	9.00	8.50	8.75	8.50
22.	IGCA-22	Upright and open	12.45	4.42	4.43	6.84	13.65	Acute	7.75	8.25	8.25	8.00	8.25
23.	IGCA-23	Upright and open	11.05	4.35	4.35	6.44	12.55	Acute	8.00	8.00	8.00	6.50	8.00
24.	IGCA-24	Upright and compact	12.85	4.46	4.36	6.39	13.70	Acute	7.50	7.50	7.00	6.00	7.75
25.	IGCA-25	Upright and open	10.20	4.25	4.31	6.59	12.60	Acute	7.00	8.50	6.50	5.50	7.25
26.	IGCA-26	Upright and open	10.30	4.43	4.36	6.88	12.70	Acute	7.50	8.50	6.50	5.75	7.75
27.	IGCA-27	Upright and open	10.30	4.36	4.36	6.67	11.90	Acute	7.50	7.25	7.25	5.50	7.50
28.	IGCA-28	Upright and compact	10.25	4.46	4.34	4.97	14.55	Acute	7.50	7.00	7.25	6.00	7.75
29.	IGCA-29	Upright and open	10.20	4.44	4.44	6.77	12.70	Acute	7.50	7.00	7.00	6.00	7.75
30.	IGCA-30	Upright and open	10.10	4.36	4.35	6.60	11.50	Acute	7.50	6.50	7.50	6.50	7.75
31.	IGCA-31	Upright and open	10.20	4.47	4.41	6.84	12.60	Acute	7.50	7.00	7.00	6.25	7.75
32.	IGCA-32	Upright and open	10.30	4.43	4.36	6.60	13.70	Acute	7.50	6.50	7.50	7.00	6.50
33.	IGCA-33	Upright and compact	10.85	4.40	4.33	6.78	12.60	Acute	7.50	7.25	7.50	6.75	7.50
34.	IGCA-34	Upright and compact	10.20	4.38	4.38	6.60	13.65	Acute	7.50	7.25	7.50	6.50	7.50
35.	IGCA-35	Upright and open	10.75	4.45	4.33	6.60	13.80	Acute	7.50	7.50	7.00	6.75	7.25

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36.	IGCA-36	Upright and open	10.30	4.45	4.36	6.59	12.95	Acute	7.50	7.50	7.00	6.50	7.50
37.	IGCA-37	Upright and open	10.20	4.57	4.29	6.60	13.50	Acute	7.25	7.50	7.50	6.50	7.25
38.	IGCA-38	Upright and open	10.30	4.54	4.34	6.50	13.00	Acute	7.50	7.75	7.50	6.75	7.25
39.	IGCA-39	Upright and open	10.35	4.36	4.30	6.60	12.55	Acute	7.50	7.50	7.75	6.75	7.25
40.	IGCA-40	Upright and compact	10.45	4.43	4.43	6.60	13.50	Acute	7.50	7.00	7.50	6.50	7.25
41.	IGCA-41	Upright and open	10.25	4.34	4.31	6.47	12.70	Acute	7.50	7.00	7.50	6.50	7.50
42.	IGCA-42	Upright and compact	10.20	4.35	4.36	6.55	12.95	Acute	7.50	6.50	7.50	6.50	7.50
43.	IGCA-43	Upright and open	10.25	4.44	4.35	6.79	12.65	Acute	7.50	6.50	8.00	6.50	7.25
44.	IGCA-44	Upright and open	10.30	4.39	4.33	6.59	12.90	Acute	7.50	6.50	7.50	6.75	7.25
45.	IGCA-45	Upright and compact	10.15	4.45	4.32	6.40	13.60	Acute	7.50	6.50	7.50	6.75	7.50
46.	IGCA-46	Upright and open	10.35	4.57	4.34	6.50	13.65	Acute	7.50	6.75	7.50	6.75	7.00
47.	IGCA-47	Upright and compact	10.30	4.37	4.36	6.58	14.40	Acute	7.50	6.50	7.50	7.00	6.50
48.	IGCA-48	Upright and open	10.25	4.57	4.37	6.67	12.95	Acute	7.50	7.00	7.50	7.00	7.50
49.	IGCA-49	Upright and compact	10.25	4.45	4.45	6.49	12.10	Acute	7.50	7.00	7.50	7.50	7.00
50.	IGCA-50	Upright and open	10.15	4.36	4.36	6.88	12.60	Acute	7.50	6.25	7.50	7.25	7.00
51.	IGCA-51	Upright and compact	10.20	4.45	4.43	6.59	15.70	Acute	7.50	7.00	7.50	7.00	7.00
52.	IGCA-52	Upright and open	10.20	4.49	4.29	6.87	12.55	Acute	7.50	7.00	7.50	7.75	7.00
53.	IGCA-53	Upright and open	10.30	4.40	4.35	6.50	14.80	Acute	7.75	7.00	7.50	6.75	7.25
54.	IGCA-54	Upright and compact	10.25	4.57	4.39	6.59	13.05	Acute	7.50	6.75	7.50	6.50	7.50

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55. IGCA-55	Upright and open	12.55	4.58	4.40	6.58	12.80	Acute	7.75	6.25	7.50	6.50	7.75
56. IGCA-56	Upright and open	10.25	4.46	4.33	6.79	13.35	Acute	7.50	6.75	7.50	6.75	6.50
57. IGCA-57	Upright and compact	10.15	4.47	4.34	6.99	12.95	Acute	7.50	7.00	7.50	6.50	7.25
58. IGCA-58	Upright and open	10.25	4.48	4.38	6.90	13.50	Acute	7.50	6.50	7.50	6.50	7.00
56. IGCA-59	Upright and compact	10.15	4.34	4.45	6.79	11.95	Acute	7.00	5.75	7.75	6.50	7.00
60. IGCA-60	Upright and open	10.15	4.60	4.40	6.93	12.60	Acute	7.00	7.00	7.50	6.50	7.75

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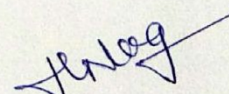
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