

Characterization of landraces of Custard apple (*Annona squamosa* L.)

THESIS

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Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur

In partial fulfillment of the requirements for the Degree of

MASTER OF SCIENCE

In

AGRICULTURE

(HORTICULTURE FRUIT SCIENCE)

By

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Jabalpur, (M.P.)

2018

CERTIFICATE- I

This is to certify that the thesis entitled “**Characterization of landraces of Custard apple (*Annona squamosa* L.)**” submitted in partial fulfillment of the requirement for the degree of **MASTER OF SCIENCE IN AGRICULTURE, HORTICULTURE- FRUIT SCIENCE** of the Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.) is a record of the bonafide research work carried out by **Mr. Guddoo Singh** under my guidance and supervision. The subject of the thesis has been approved by the student’s Advisory Committee and Director of Instruction, J.N.K.V.V., Jabalpur (M.P.).

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

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This is to certify that the thesis entitled “**Characterization of landraces of custard apple (*Annona squamosa* L.)**” submitted by **Mr. Guddoo Singh** Krishi Vishwa Vidyalaya, Jabalpur in partial fulfillment of the requirements for the degree of Master of Science in Agriculture in the Department of Horticulture, Fruit Science has been, after evaluation, approved by the External Examiner and by the Student’s Advisory Committee after an oral examination on the same.

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I, Guddoo Singh S/o Shri Ram Siya certify the work embodied in thesis entitled “**Characterization of landraces of custard apple (*Annona squamosa* L.)**” is my own first hand bonafide work carried out by me under the guidance of Dr.Vijay Agrawal, Scientist, Department of Horticulture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.) during 2016-17.

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Place : Jabalpur

Date :

(Guddoo Singh)

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ABBREVIATION

%	:	Percent
°B	:	Degree Brix
°C	:	Degree centigrade
CD	:	Critical Difference
Df	:	Degree of freedom
<i>et al.</i>	:	And others
Fig.	:	Figure
RH	:	Relative humidity
SS	:	Sum of Square
Max.	:	Maximum
Min.	:	Minimum
No.	:	Number
Mg	:	Milligram
d.f.	:	Degree of freedom
Kg	:	Kilogram
i.e.	:	That is
MSS	:	Mean sum of square
i.e	:	That is
Viz.	:	Namely
TSS	:	Total Soluble Solids
CRD	:	Completely Randomized Design

INTRODUCTION

Custard apple (*Annona squamosa* L.), also known as *Sitaphal* or *Sharifa* 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 (Lizana and Reginato, 1990) and *squamosa* means scaly referring to the scale like structure of the fruit surface. It has about 135 genera and 2500 species distributed worldwide. Its commercial importance is so great that some botanists have considered it to be a native fruit of the country. However, this is a secondary centre of diversity, created during the last 500 years (Pinto et al., 2005). In India, it is presently grown in an area of 22000 ha with production of 165 MT (Anonymous, 2015). In MP cultivated area 3,590 ha with production 37.00 MT (NHB 2014-15).

Custard apple is a small, semi or late deciduous, much branched shrub or small tree 3 to 8 meters tall with a broad, open crown or irregularly spreading branches and a short trunk, not buttressed at base. The leaves are deciduous, alternate, 2-ranked and having minutely hairy petioles. The shape of leaves is ovate and pointed at the apex. The fruits a compound fruit which is heart shaped and ranges from 150-500g weight. The fruit is easily broken or cut open, exposing the snow white, juicy flesh, of pleasing aroma and delicious, sub-acid flavour and containing many hard, brown or black bean-like glossy seeds. Custard apple being very hardy, survives well under drought, salinity and marginal soil conditions. It grows very well even on shallow soils.

Custard apple is generally classified as semi wild fruit by virtue of its spontaneous spread in forests, wastelands and uncultivated places. The fruits are generally used as fresh, while some products or mixed fruits have high nutritive value as well as high medicinal value. It is considered as beneficial for cardiac disease, diabetes hyperthyroidism and cancer. It contain carbohydrate (23.5 g), moisture (73.30%), protein (16.6 g), mineral (0.9 g), fiber (3.1 g), calcium (17 mg), phosphorus (47 mg), iron (1.5 g) and

vitamin-C (37 mg), these values are based on 100 g fruit pulp. Custard apple fruits ripens within four days after harvest. (Gopalan et al., 1987)

Custard apple (*Annona squamosa* L.) is nutritional rich and largely valued for its taste. Majority of fruits are cultivated in unorganized sector around the hilly areas while some organized farmers also grow custard apple. The investigation is carried out to find the suitability of custard apple on the basis of different physical and chemical characteristics such as fruit weight, number of seeds, seed weight, rind yield and pulp yield, TSS, acidity, total sugar and ascorbic acid. It is improvement against various morphological and physico-chemical attributes like fruits shape, size, colour, pulp colour, fruit weight, pulp weight, sugar, acidity etc.

It is essential from the view point of hastening diversity of orchard and also in product range based on custard apple fruits. Under such situation, there is a need to popularize custard apple so that its amenability to come well under stress environment can be befittingly utilized. Keeping these points in view, a survey work was being conducted on October–November 2016 covering Jabalpur and Sagar district to assess the fruit quality of wild landraces of Custard apple. It is an attempt to explore the quality status of germplasm under natural conditions so as to draw inferences as regard to the existing quality attributes of the crop with a view to have an account of its further improvement.

Genetic variation is essential for long term survival of species and it is a critical feature in conservation. To expedite the crop improvement programme, it is necessary to identify and trap the natural variability through surveys and the variability should be conserved *ex situ* and *in situ* to utilize in the further hybridization programmes. Proper study is necessary to build up the understanding of this crop so that sustainable efforts can be put forward to enhance production, accelerate research and develop capabilities to make *Annona* as a profitable enterprise amongst fruit growers of the India.

Keeping in view the present investigation was carried out to “Characterization of landraces of custard apple” (*Annona squamosa* L.) with the following objectives:

1. To Characterized the landraces of custard apple based on morphological traits.
2. To study the physico-chemical characteristics of landraces.
3. To assess the genetic variability of custard apple landraces.

REVIEW OF LITERATURE

The success of any programme mainly depends on the right selection of material and its skillful management. It is only possible when we possess knowledge of previous work done in the concerned field. In custard apple very meager contribution has been made to the literature regarding to genetic variability in morphological, physical and chemical parameter in past. The relevant literature related to various aspects of present investigation in other fruit crops has been reviewed under the following heads:

2.1 Genetic variability

2.2 Phenotypic and genotypic coefficient of variation

2.3 Heritability and genetic advance

2.1 Genetic variability

Leal et al. (1990) stated that custard apple is generally consumed fresh as a dessert fruit. The edible portion is 28-37% of the total fruit weight; seeds correspond to 31-41% and rind to 23-40%.

Pal and Kumar (1995) reported that the fruits of annona (*Annona squamosa* L.) cvs. Barbados seedling and Washington-97 were analyzed at 15 days intervals after flowering to harvest maturity and at ripe stage. Fruits took 120 ± 5 days to reach harvest maturity and then another of 2–5 days to the ripe stage. Fruits exhibited a double sigmoid growth curve and a climacteric respiration. Physical characters were recorded as fruit weight, size, density, T.S.S., percentage of edible pulp, peel, seed and central stalk and biochemical constituents like dry matter, alcohol, insoluble solids, total and individual sugars, total acids, citric acid, total soluble amino acids, total tannins, vitamins A and C, chlorophylls and minerals (P, K, Fe, Na, Ca, Mg). Sugar/acid ratio and the appearance of a yellow colour in the edible pulp may be considered as acceptable harvest criteria.

Ghosh et al. (2001) reported that the a experiment 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).

Dikshit et al. (2008) reported that twenty one accessions of custard apple germplasm were 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).

Varu and Barad (2011) reported that the analysis of variance revealed highly significant genotypic differences for all characters depicting greater diversity among different selections with Sindhan as a check. The variations in height and spread were significant and maximum height (4.61 m) was recorded in Selection-18, but was at par with Selection-7, 19 and 22. Tree height was lowest in selection-29. Maximum plant spreads, N-S and E-W (5.11 and 5.22 m, respectively) were also recorded in Selection-18 and were at par with Selection-7, 21 and 22. Higher tree height and tree spread are the favorable characters which increase the fruit yield. Among the selections and check, the earliest flowering was observed in Selection-6 during 1st and 2nd reproductive flushes (21.17 and 87.33 days, respectively) and 127.08 days in Selection-1 during 3rd reproductive flush. Significantly earliest fruit setting (18.42 days) was recorded in Selection-11, but was found to be at par with selection-1, 6 and 7. Days to fruit maturity was observed to be non-significant. Selection-6 and 1 were found earlier than all other selections for flowering and fruit setting. Large amount of

variation was recorded on fruit growth characters at marketable stage viz., fruit weight, fruit length and width. Maximum fruit weight (159.93 g) was noted in Selection-19, but was at par with Selection-18, 20, 1, 3 and Sindhan (check). Similarly, highest fruit length and girth were registered in Sindhan, and was at par with Selection-18, 19, 20 and 21. The differences in number of fruit were significant and maximum fruit number was in Selection-18 and was at par with Selection-12 and 15. Similarly, lowest number of fruit was recorded in Selection-5. The variation in number of fruits per tree might be due to genetic diversity amongst number of shoot, shoot length, number of flower per shoot, fruit set percentage and fruit retention percentage. The fruit yield per tree was maximum in Selection-18, but found to be at par with Selection-11 and 12. The yield per tree was low in Selection-29, 4 and Selection-5. The significant variation in yield per tree might be due to fruit set percentage, fruit retention percentage, fruit length and girth, fruit weight and number of fruit per tree.

Rao and Subramanyam (2011) reported that the thirty five germplasm of custard apple have been evaluated for scarce rainfall zone under rainfed at Horticultural Research Station, Anantapur for 3 years from 2005 to 2007 in 10 years old trees for their growth and yield. The plant height per tree (3.2 m) was recorded highest in Phythota-3 followed by MMR-9 (2.91 m). Highest stem girth was recorded (37 cm) in Atemoya x Washington followed by MMR-8 (35.2 cm). Maximum plant spread was recorded in Bangalore (9.5 m³) followed by Atemoya x Balanagar (7.9 m³). The number of fruits was recorded highest (51.4) in Balanagar SR followed by Phythota-3 (45.3). The fruit yield was recorded highest (15.7 kg) in Ramaphal followed by MMR-10 (15 kg). Highest fruit weight per tree was recorded (278.9 g) in Atemoya X Balanagar followed by Y. Palli – 12 (270.6 g). Highest pulp weight (148 g) was recorded in Y. Palli – 12 followed by NLD-5 (123 g). Maximum peel weight (150 g) was observed in MMR – 9 followed by Ramaphal (124.1 g). Highest seed weight (22.6 g) was recorded in Balanagar SR followed by Bellary (20.9 g). Maximum T.S.S was observed (25.9%) in NLD –8 followed by NLD – 10 (25%). Out of 35 germplasm evaluated the varieties viz. Atemoya X Balanagar (highest fruit weight), Y. Palli

– 12 (highest pulp weight), NLD – 8 (maximum T.S.S), Balanagar SR (more number of fruits per tree) and Ramaphal (highest yield per tree) can be recommendable for scarce rainfall zone under rain fed conditions in poor fertile soils.

Girwani et al. (2011) reported that in *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' × 'Balanagar') was earliest to mature. Maximum fruit weight (250 g) was recorded in Hybrid-1 ('17/4 Atemoya' × 'Balanagar') followed by Hybrid-6 ('15/3 Red Sitaphal' × 'Atemoya') (225 g) and Hybrid-4 ('1/6 British Guinea' × 'Atemoya') (220 g). Among all the hybrids, maximum number of fruits per tree (94) was recorded in Hybrid-1 ('17/4 Atemoya' × 'Balanagar') followed by Hybrid-6 ('15/3 Red Sitaphal' × 'Atemoya') (67). The TSS ranged from 22 to 28°Brix and was found to be maximum in Hybrid-2 ('15/2 Red Sitaphal' × 'Pondapple'), while the seed content per fruit was also minimum (20) in this hybrid. Based on overall performance the Hybrid-1 ('17/4 Atemoya' × 'Balanagar') and Hybrid-3 ('15/3 Red Sitaphal' × 'Atemoya') and Hybrid-2 ('15/2 Red Sitaphal' × 'Pondapple') were found to be excellent in quality with pleasant aroma, smooth pulp texture with less seed, good sugar acid blend and shelf life.

Bhatnagar et al. (2012) reported that the analysis of variance showed highly significant differences for all the characters studied and therefore the presence of inherent genetic variation among all the genotypes. 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 landrace collected from Kelwara and Rajsamand sites (18.1°Brix) followed by those from Baran site (17.9°Brix). The physical parameter determines the quality of fruit and there was significant variation among germplasms. The fruit weight ranged from minimal 89.5 g in germplasms collected from Chittorgarh to maximum 149.8 g in those collected from Baran. The pulp weight minimum 21.5 g in landrace from Chittorgarh and maximum 47.0 g in those collected from Baran site. The minimum seed weight 11.5 g was observed in Jhalawar and maximum 13.3 g in Deola and Udaipur site. The seed number per fruit varied from 35.3 to 42.0. Existence of variability in landraces indicates ample scope for improvement of annonas found adapted under sub mountainous tracts of Aravalli hills.

Hashmi and Pawar (2012) reported that the suitability of custard apple fruits for organized farming on the basis of different physical and chemical characteristics. Gross weight of custard apple fruit from the different locations varied in the range 131.3g to 184.5g. The mean weight of fruit was found as 160.45 g. The number of seeds per fruit is directly proportional to gross weight and size of individual fruit with certain exceptions. The mean per cent weight of seed was 22.45. It ranged from 18.9 to 26.4 per cent indicating the effect of different locations on weight of seeds per fruit. Mean weight of pulp was recorded as 41.53 per cent at different locations. The higher yield of fruit pulp (50.00%) recorded by the fruits collected from the organized orchards of Padaskheda supports the observation of more yield of pulp because of intensive cultivation practices under controlled conditions. The effect of locations on per cent weight of rind indicate that the mean value of weight of rind is 36.11 per cent. Total Soluble solids indicate that per cent TSS content of all samples were more than 22°Brix. The mean value of total soluble solids

content was found 24.3°Brix which specifies the process able status of pulp. The per cent acidity was recorded in range from 0.23 to 0.28%. The pH of custard apple fruit was found to be in the range of 4.8 to 5.4 with an average value of 5.1. The total sugar content of the pulp notifying the quality of the fruit was recorded in the range of 18.1 to 22.0 per cent with average value of 19.5%. The ascorbic acid content of the fruit pulp was found to be comparatively less which justifies custard apple as a poor source of vitamin C. It ranged from 16.0 to 18.4 with an average mean value of 17.38 mg/ 100g of pulp.

Kolekar and Tagad (2012) studied the physico chemical analysis of custard apple. The chemical composition of custard apple pulp was found that the average weight of greenish yellow coloured custard apple fruit was about 168 g., with the average length of 5.4 cm, and breadth of 4.3 cm. The number of seeds was 26, the weight of peel 82.44 g., and weight of pulp 85.44 g. The percent Juice was 30.58% and the percent of waste index was 58.42%. Weight, length, breadth, of fruit may vary according to climatic conditions and from fruit to fruit. The percentage of peel less than the percentage of pulp will be more and vice-versa.

Othman et al. (2014) reported that the fruits were harvested at the mature ripe stage and kept in open air storage over several days. The determinations were done immediately after fruit arrival at the laboratory and thereafter at intervals of two days from the day of harvest. The results showed that soursop (*Annona muricata* L.) fruits had high moisture content (73.1% – 82.1%), low titratable acidity (0.10 – 1.25%), low crude fat (0.42 mg/100 g-fw), moderate ash content (0.87 mg/100 g-fw) and crude fiber content (6.09 mg/100 g-fw), high ascorbic acid content (34.0 – 19.7 mg/100 g-fw), high total sugars content (34.3% – 45.3%), reducing sugar content (18.9% – 39.2%) and sucrose content (15.5% – 30.0%). Of the macro elements Na, Ca and K, the average content were 895.6, 870.3 and 367.5 mg/100 g-fw respectively. Heavy metals (Fe, Zn, Cu, Pb and Cd) content was very low in the soursop fruits, ranging between <0.0015 mg/100 g-fw for Cd and 0.82 mg/100 g-fw for Fe. During storage, the moisture content, titratable acidity level and sugars content in the

fruit were all increasing whereas the ascorbic acid content was decreasing. There were no significant changes during storage for levels of crude fat, fiber, ash, mineral elements and heavy metals. The findings from this study suggest that this fruit from coast region of Tanzania can contribute nutritionally to the health of the consumer.

Mishra et al. (2015) reported that the strawberry (*Fragaria* × *ananassa* Duch.) genotypes were evaluated to study genetic variation and the relationship between yield and its component using a randomized complete block design during 2013-14. The results showed significant variance among genotypes of all traits.

Kad et al. (2016) reported that the physical and morphological properties of custard apple such as weight of fruit and seed were found to be 238.68 and 0.30 g, respectively. Peel, carpellary pulp, gritty pulp and seeds were found to be 46.77, 35.36, 11.63 and 6.24 per cent, respectively. Number of seeds, total weight of pulp, fruit to pulp ratio and pulp to seed ratio recorded were 49.50, 113.29 g, 2.14 and 8.18, respectively. Linear dimensions of 100 randomly selected fruits viz., length, breadth and thickness of were 84.00, 74.25 and 65.15 mm, respectively. Size and sphericity of custard apple fruit were found to be 74.04 mm and 0.88, respectively. Linear dimensions viz., length, breadth and thickness of custard apple seeds recorded were 13.698, 8.29 and 6.10 mm respectively at an initial moisture content (15.40 % d.b.) and same were decreased with decrease in moisture content to 12.50 and 10.25 % (d.b.), respectively. Similarly, seed size (8.83 mm), sphericity (0.65) and angle of repose (29.470) also decreased to 8.09 mm, 0.62 and 25.840, respectively with decrease in moisture content from 15.40 to 10.25 % (d.b.). Hardness and cohesiveness of custard apple pulp was recorded 596.67g and 0.31, respectively. Stickiness, which is the product of hardness and cohesiveness, was found to be 184.34 g.

Dandsena and Banik (2016) reported that the custard apple (*Annona squamosa*) called Sitafal in hindi, is fruit well known for its delicious taste are

heart shaped with light green skin and a soft creamy white flesh. Custard apple is harvested in several installments, but the best harvesting stage is when the firm fruit begins to develop colour. It is generally picked when it becomes creamy yellow between the segments and begins to crack slightly. The fruit has the tendency to burst open if kept on the tree for a long time. Custard apple is highly perishable and cannot be stored for long time. It can be stored successfully for 9 weeks at 7-10°C with 85% to 95% RH. Lower storage temperature induces chilling injury. Custard apple has a shelf life of four days after harvest, Cold storage or low temperature storage of the products is preferred.

Nagar et al. (2017) reported that the fourteen guava (*Psidium guajava* L.) hybrids were evaluated for selected nine biochemical characters using CRD in three repetitions. Analysis of variance suggested the existence of significant amount of variability among *Psidium* hybrids for all the characters under study.

2.2 Phenotypic and genotypic coefficient of variation

Saulo et al. (2006) evaluated eight fruits of sugar apple 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.

Silva et al. (2007) evaluate that the yield (during the first three crops) and quality (first crop) of fruits from twenty half-sibling custard apple tree progenies, selected from home orchards. An additional objective was to estimate genetic parameters for the traits evaluated. A micro sprinkling-irrigated experiment was

conducted in Mossoró-RN, Brazil, as random blocks with five replications. In characteristics evaluated for periods longer than a year (diameter, height and mean weight of fruits, number of fruits ha⁻¹ and fruit yield (kg ha⁻¹), and a split-plot design was adopted, with progenies considered as plots and annual cropping seasons as subplots. The best progenies in terms of fruit yield (A3 and A4) are not necessarily the best for fruit dimensions and fruit mean weight (A2, FE4, JG1, JG2, SM1, SM7, and SM8). These progenies show great potential to be used in future studies on crosses or on vegetative propagation. In this regard, progeny JG2 should be highlighted as promising in terms of yield and fruit size. The progenies are not different with regard to percentages (in relation to mean fruit mass) of pericarp, endocarp, seeds, and receptacle, in the fruit, and fruit volume, number of seeds/fruit, and total soluble solids content in the fruit pulp, but progeny FE4 presents higher total titratable acidity in the fruit pulp.

Bhowmick and Banik (2008) reported that an experiment which was carried out with nine mango cultivars at Varietal Block of Horticultural Research Station, Mondouri, BCKV, Nadia, W. B. with Randomized Block Design to determine the genetic variability and correlation coefficient for among different fruit physico chemical characteristics. Among the different characters the lowest range was recorded with acidity and it was highest for weight. Phenotypic coefficient of variation was more than that of genotypic counterpart for each of the characteristics.

Majumder et al. (2012) reported that the sixty mango genotypes were studied to find out their variability, heritability and genetic advance. Significant variations were observed in twenty characters. There were also considerable differences between the genotypic and the phenotypic coefficients of variation for almost all the characters which indicated the influence of environment on the expression of these traits. Among the studied characters, GCV and PCV were high for weight of harvested fruits per plant, per cent fruit harvest per inflorescence, per cent initial fruit set per inflorescence, number of fruits per plant and number of main branches per inflorescence.

Bhatnagar et al. (2012) reported that the estimates of genotypic and phenotypic coefficient of variation provide a parameter for comparison of characters regarding the extent of genetic variation. The genotypic coefficient of variation percentage in fruit weight was 16.4 % whereas phenotypic coefficient of variation was 16.9 % which show that influence of environment on different genotypes is more than gene traits. Likewise the GCV of pulp weight of custard apple genotypes were 19.0% whereas, PCV was found to be 19.3%. The studies show that both genotypic characters and phenotypic characters can be utilized for selection based on phenotypic characters.

Mishra et al. (2015) reported that the strawberry (*Fragaria* × *ananassa* Duch.) genotypes were evaluated to study genetic variation and the relationship between yield and its component using a randomized complete block design during 2013-14. The phenotypic coefficient of variation (PCV) for all the characters was slightly higher than genotypic coefficient of variation (GCV), which signified the presence of environmental influence to some degree in the phenotypic expression of characters. Dry fruit weight had the highest PCV (52.47) and GCV (48.26).

Patel et al. (2015) reported that the eleven genotype of guava under mid-hill subtropics of Meghalaya during 2011 and 2012 with respect to plant growth, floral and yield related traits. Being an open pollinated and heterozygous crop, wide range of phenotypic variation along with high heritability and genetic advance has been observed among the genotypes.

Himabindu et al. (2016) reported that the genetic variability, heritability and genetic advance for different characters in thirty four diverse cultivars of mango. The study was conducted at Horticultural research station, Venkataramannagudem for evaluating the variability of mango cultivars in Randomized block design. All the characters showed very small difference between genotypic coefficient of variation (GCV) and respective phenotypic coefficient of variation (PCV), indicated that all the characters were least affected by environment. The high phenotypic coefficient of variation and

genotypic coefficient of variation were observed for fruit length, fruit diameter, fruit weight, fruit skin thickness, peel weight, pulp to stone ratio, pulp to peel ratio, pulp weight, edible to non-edible ratio, stone weight, stone per cent, stone length, embryo weight, total sugars, reducing sugars, non-reducing sugars, titratable acidity, ascorbic acid, TSS: acid ratio, β - carotone and total phenols.

Saroj et al. (2017) reported that the diversity of fifty accession of pomegranate selected from more than two year old plants of Horticulture Instructional Farm and AICRP on Arid Zone Fruits, S. D. Agricultural University Sardar krushi nagar during Ph.D. work in the year 2010-2014. On the basis of morphological analysis of fifty accessions of pomegranate the variety Bhagwa ranked first in respect of fruits per plant and other yield contributing characters under study except leaf area. Phenotypic and genotypic coefficients of variation were high for number of fruits per plant followed by number of flowers per plant, leaf area and number of primary branches per plant.

Nagar et al. (2017) reported that the fourteen guava (*Psidium guajava* L.) hybrids which were evaluated for selected nine biochemical characters using CRD in three repetitions. Among the different hybrids of guava, the highest vitamin – C was found in hybrid Allahabad Safeda x Mishri (321.33 mg/100g), total soluble solids in Allahabad Safeda x Chittidar (13.67°B), total sugar in Allahabad Safeda x Tehsildar (12.51%), non- reducing sugar in Allahabad Safeda x Tehsildar (7.09%), reducing sugar in Allahabad Safeda x Apple Colour (7.06%) and pectin was noted Allahabad Safeda x Apple Colour (0.87%) while lowest titrable acidity in Allahabad Safeda x Dholka (0.329%). Ascorbic acid recorded significantly higher amount of genotypic variance (1247.32) and phenotypic variance (1490.06) suggesting the high magnitude of variability for these traits. Genotypic coefficient of variation and phenotypic coefficient of variation were medium (10-20) for most of the traits with highest value for non-reducing sugar (25.10% and 25.30%) indicating existence of higher magnitude of variability for these characters.

2.3 Heritability and genetic advance

Samodia and Pareek (2006) reported that the extent of genetic variability, heritability and genetic advance with respect of growth, fruit yield and quality traits in 25 pomegranate hybrids/ open pollinated progenies were studied. Fruit yield per plant, number of fruits per plant, fruit weight and weight of 100 arils were recorded high heritability along with large amount of genetic advance. Thus selection of progenies based on performance would be effective for these characters.

Silva et al. (2007) evaluate that the yield (during the first three crops) and quality (first crop) of fruits from twenty half-sibling custard apple tree progenies, selected from home orchards. An additional objective was to estimate genetic parameters for the traits evaluated. Narrow-sense heritability estimates were relatively high for all characteristics in which there was variability between progenies, with higher values for number of fruits ha^{-1} (80 %) and fruit yield (78 %). Relatively high coefficients of genotypic variation (around 20%) were observed for number of fruits ha^{-1} and fruit yield, with lower values for the other characteristics.

Bhowmick and Banik (2008) reported that the an experiment was carried out with nine mango cultivars at Varietal Block of Horticultural Research Station, Mondouri, BCKV, Nadia, W. B. The estimated heritability showed a wide range of variation, *i.e.*, 37.10 – 95.41 per cent. The genetic advance as percentage of mean also revealed high degree of variation (9.03 – 33.93).

Majumder et al. (2012) reported that the sixty mango genotypes which were studied to find out their variability, heritability and genetic advance. All the characters showed considerably high heritability which ranged from 56.21 to 98.24% and the genetic advance as percentage of mean was high for the maximum traits. High heritability coupled with high genetic advance was observed in weight of harvested fruits per plant, per cent initial fruit set per inflorescence, per cent of flowering shoot, number of inflorescences per shoot, percent fruit harvest per inflorescence, number of main branches per

inflorescence, number of fruits per plant, number of inflorescences per shoot, plant height (cm), and percent perfect flowers which indicated that these characters were less influenced by environment confirming predominance of additive gene action and therefore, selection in favour of these characters would be feasible for yield improvement of mango.

Bhatnagar et al. (2012) reported that the heritability estimates were high especially for the characters such as fruit weight, pulp weight and number of seeds. This indicates that selection based on phenotypic performance may be useful for these characters. According to Johnson et al. (1955), high heritability along with considerable genetic gain is more useful than heritability alone in predicting the resultant effect of selection.

Mishra et al. (2015) reported that the strawberry (*Fragaria* × *ananassa* Duch.) genotypes were evaluated to study genetic variation and the relationship between yield and its component using a randomized complete block design during 2013-14. The estimates of narrow sense heritability (h^2) were observed to be lower than those of broad sense heritability (H^2) for all the characters. Genetic advance was recorded as maximum for fruit yield per plant (76.84%), whereas genetic advance as percent of mean was highest for dry fruit weight (84.09). Highest heritability (98.44%) was coupled with higher genetic advance (76.84) estimated for fruit yield per plant, which indicated that the character is controlled by additive genes and therefore further improvement could be brought by selection.

Patel et al. (2015) reported that the eleven genotype of guava under mid-hill subtropics of Meghalaya during 2011 and 2012 with respect to plant growth, floral and yield related traits. High heritability and genetic advance has been observed among the genotypes. High heritability estimates associated with high genetic advance as percentage of mean were obtained for fruit yield which indicated that selection of this character would be more effective. Such association may be attributed to the action of additive genes.

Himabindu et al. (2016) reported that the genetic variability, heritability and genetic advance for different characters in thirty four diverse cultivars of mango. High heritability coupled with high genetic advance were observed for all characters studied indicating these characters are governed by additive gene action and phenotypic selection may be more fruitful. Hence, direct selection may be followed for the improvement of mango for these characters.

Saroj et al. (2017) reported that the diversity of fifty accession of pomegranate selected from more than two year old plants. The heritability (broad sense) estimates were high for number of fruits per plant followed by number of flowers per plant and leaf area. The genetic advance expressed in per cent of mean was high for number of fruits per plant and number of flowers per plant; moderately high for leaf area, stem girth, number of primary branches per plant, N-S plant spread and E-W plant spread whereas, it was low for plant height.

MATERIALS AND METHODS

This chapter comprises the details about the materials used and the methods adopted during the course of present investigation entitled “Characterization of landraces of custard apple (*Annona squamosa* L.)” was carried out in Rabi season during the year 2016-17.

3.1 Experimental site

The experiment was conducted at Post Harvest Laboratory, Department of Horticulture, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.).

3.2 Experimental material

The experimental material includes eighteen landraces of custard apple collected from Jabalpur and Sagar district. Landraces are presented in Table 3.1.

Table 3.1: Details of landraces of custard apple used in the study

Treatments	Location
T1	MJC-01
T2	MJC-02
T3	MJC-03
T4	MJC-04
T5	SGC-01
T6	SGC-02
T7	SGC-03
T8	SGC-04
T9	SGC-05
T10	SGC-06

T ₁₁	SGC-07
T ₁₂	JBC-01
T ₁₃	JBC-02
T ₁₄	JBC-03
T ₁₅	JBC-04
T ₁₆	JBC-05
T ₁₇	JBC-06
T ₁₈	JBC-07

3.3 Experimental details

The experiment was laid out in Completely Randomized Design (CRD) with three blocks. Each block consists of eighteen landraces of custard apple. The other details are given as below:-

Crop	:	Custard apple (<i>Annona squamosa</i> L.)
Treatment	:	Eighteen
Design	:	CRD
No. of blocks	:	3
Season	:	<i>Rabi</i> (2016)

3.4 Sampling

Three fruits were randomly selected from each landraces and block for the study.

3.5 Observation recorded

The data recorded on various parameters were subdivided into three categories during the period of experimentation. The data were recorded as per standard procedure.

3.5.1 Morphological characters

The morphological characters of each landraces (plant, fruit and seed basis) of the experiment were recorded on the following heads.

3.5.1.1 Plant characters:

3.5.1.1.1 Plant type

All the landraces/genotypes were observed and categorized in to two group's i.e. erect, and spreading.

3.5.1.1.2 Shape of canopy

Shape of canopy of custard apple landraces/genotypes were observed and categorized into two group's i.e. upright and spreading.

3.5.1.1.3 Age of plant

Age of plants was recorded from 6 years to more than 20 years.

3.5.1.2 Fruit traits

3.5.1.2.1 Fruit shape

The fruit shape were observed visually and categorized into three category i.e. round, cordate and broadly cordate.

3.5.1.2.2 Fruit colour

The fruit colour were observed visually and categorized into five category i.e. whitish green, light green, green, light brown and light yellow.

3.5.1.2.3 Areole shape

The areole shape were observed visually and categorized into tuberculate.

3.5.1.2.4 Depth of furrow

The depth of furrow were observed visually and categorized into two categories i.e. medium and large.

3.5.1.3 Seed trait

3.5.1.3.1 Seed colour

Based on seed colour genotypes were categorized in two distinct groups i.e. light brown and brown.

3.5.2 Physical parameters

3.5.2.1 Number of fruits plant⁻¹

The number of fruits harvested from selected plants in each landraces was collected during each picking counted and totaled together and average fruits per plant were calculated.

3.5.2.2 Fruit length (mm)

The length of the fruits was measured from stem end to calyx end in millimeter with the help of vernier calipers.

3.5.2.3 Fruit width (mm)

The width of the fruits was measured from the cut pieces in center of fruits with the help of vernier calipers.

3.5.2.4 Fruit weight (g)

The weight of fruit was taken with the help of electronic weighing machine and average weight of fruit was calculated.

3.5.2.5 Volume of fruit (ml)

The volume of fruit was recorded by water displacement method with the help of measuring cylinder and was expressed in milliliters.

3.5.2.6 Weight of seed (g)

The weight of seeds in selected fruits from observational plants weighted and average seeds weight per fruit was calculated.

3.5.2.7 Number of seeds fruit⁻¹

Number of seeds per fruit were counted and then average to obtain the mean number of seeds per fruit.

3.5.2.8 Pulp per cent

The pulp weight of fruit was recorded after the pulp extraction and average pulp per cent was calculated.

$$\text{Pulp \%} = \frac{\text{Weight of pulp}}{\text{Total weight of fruit}} \times 100$$

3.5.2.9 Peel weight (g)

The peel weight of fruit was taken with the help of electronic weighing machine and average weight of peel was calculated.

3.5.2.10 Seed (%)

The weight of seeds in selected fruits was weighted and average seeds per cent were calculated.

$$\text{Seed \%} = \frac{\text{Weight of Seed}}{\text{Total weight of fruit}} \times 100$$

3.5.2.11 Ratio

The ratio of different characters for comparative study was also recorded. These are as follows:

- **Pulp: Seed ratio**
- **Pulp: Peel ratio**
- **TSS: Acidity ratio**

3.5.3 Chemical characters

3.5.3.1 Total soluble solids (°Brix)

T.S.S of filtered juice was measured by hand refractometer of 0 to 32 Brix range. Few drops of juice were put on prism of refractometer with the help of clean glass rods. The cover of refractometer was folded lightly and looked

through eye piece with projector inlet facing towards light, the point where the boundary line of shaded area interacts with the unshaded area was the scale was noted. The specimen chamber was cleaned with muslin cloth after every use. The reading was taken at room temperature (A.O.A.C. 1970).

3.5.3.2 Ascorbic acid (mg/100gm)

The ascorbic acid content of fresh fruits pulp was determined by grinding the known quantity of the fruit pulp with 4% metaphosphoric acid and filtered through filter paper and titrating with 2, 6-dichlorophenol indophenol dye solution (A.O.A.C., 1990) until the stable faint pink colour was obtained.

Standardization of 2, 6-dichlorophenol indophenol dye solution was done by titrating it against standard ascorbic acid solution. For this purpose 100 mg of ascorbic acid was dissolved in 4% metaphosphoric acid and the volume was made to 100 ml from this 10 ml of ascorbic acid solution was used for titration. The result was calculated by the following formula and expressed in mg ascorbic acid (vitamin C) per 100 g of fruit pulp.

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Titer} \times \text{dye equivalent} \times \text{dilution}}{\text{Weight of sample}} \times 100$$

(A) Method of preparation of fruit solution: A homogenous sample of pulp was prepared after crushing the fruit. Twenty ml of Juice sample was diluted to 100 ml and this solution was used for estimating the following parameters.

- Sugar
 - a. Reducing sugar
 - b. Non reducing sugar
 - c. Total sugar
- Acidity %

(B) Method of preparation of Fehling's solution:

(i) Fehling's solution "A": Transferred 34.639 g of copper sulphate (A.R) to a clean and dry 500 ml volumetric flask. Added 0.5 ml of concentrated sulphuric acid and dissolved copper sulphate by adding 200 ml of distilled water made the volume to the mark.

(ii) Fehling's solution "B": Dissolved 173.0 g of pure sodium potassium tritrate (Rochelle salt) and 50g of sodium hydroxide to 500 ml in volumetric flask.

Estimation of sugar:

3.5.3.3 Reducing sugars (%)

Reducing sugar in the fruit juice were estimated by the methods as suggested by Nelson (1944)

5 ml each of Fehling's 'A' and 'B' solutions were taken in a 300 ml conical flask and diluted with 40 ml of distilled water. The fruit solution taken in a burette was added slowly in hot (boiling) Fehling's solution, till the slight red colour appeared. Now three drops of methylene blue indicator was added and titration was continued till a brick red precipitate appeared vanishing the blue colour colouration.

3.5.3.4 Total sugar (%)

Hydrolysis was done by taking 20 ml of the extract prepared for the estimation of reducing sugar. 5 ml of concentrated HCL was added in it and boiled on water bath for 30 minutes at 70⁰C to 90⁰C. The solution was cooled and excess of HCL was neutralized by adding sodium carbonate (Na₂CO₃) solution. The solution was transferred in a 100 ml volumetric flask and volume was made up to mark with distilled water. This solution was taken in a burette with the Fehling's solution similar as reducing sugar. The reading obtained would represent the total sugar (Reducing and Non-reducing sugar) in the fruit juice. Hence reducing sugar content was subtracted from the total sugar for calculating the **non-reducing sugar** in the fruit juice.

3.5.3.5 Acidity (%)

Acidity was estimated by simple acid alkaline titration method as described in A.O.A.C. (1970). Took 20 ml flask, added distilled water to make up the volume up to 100 ml and shaken well to dissolve. 25 ml of diluted fruit juice was taken by pipette and transferred in to a 250 ml beaker. Add 3 drops of phenolphthalein indicator to the solution. Filled the burette with N/10 NaOH solution and titrated the juice with alkali solution, drop by drop with content stirring till the pink end point is reached. End point readings (3 to 4) were recorded and the percentage acidity was calculated by the formula given below

$$\text{Acidity \%} = \frac{\text{Titrated value} \times \text{Normality of alkali solution} \times \text{volume made up} \times 64 \times 100}{\text{Weight of sample taken} \times 1000}$$

3.6 Statistical analysis

The data obtained in respect of all the characters have been subjected to the following statistical analysis.

3.6.1 Mean: It was calculated by using following formula.

$$\text{Mean} = \frac{\sum x}{N}$$

where,

$\sum x$ = The sum of all the observation

N = Number of observation

3.6.2 Analysis of variance

The data based on the mean of individual fruits of landraces selected for observation were statistically analysed described by Panse

and Sukhatme (1985) to find out overall total variability present in the material under study for each character and for all the populations. The first and foremost step is to carry out analysis of variance to test the significance of differences among the populations. The skeleton of analysis of variance used is given below.

Table 3.2: ANOVA for Complete Randomized Design

Source of variation	d.f.	Sum of square	Mean sum of square	F value	F_t 5% or 1% table value
Landraces	L-1	LSS	LMS	LMS/EMS	-
Error	(B-1)(L-1)	ESS	EMS	-	-
Total	BL-1	TSS	-	-	-

where,

L = Number of landraces

d.f. = Degree of freedom

LSS = Sum of square due to landraces

ESS = Error sum of square

TSS = Total sum of square

LMS = Landraces mean sum of square

EMS = Error mean sum of square

A significant value of 'F' test indicates that the test entries differ significantly among themselves, which requires computing C.D.

$$C.V. = \frac{\sqrt{EMS}}{GM} \times 100$$

$$SE_{\pm} = \sqrt{\frac{EMS}{B}}$$

$$SE_{diff} = \sqrt{\frac{2 EMS}{B}}$$

CD at 5% prob. Level = SE diff x $t_{5\%}$ table value

where,

C.V. % = Co-efficient of variation

$SE_{\pm}$ = Standard error of means

S E diff = Standard error of difference

GM = Grand mean

C.D. = Critical difference

$t_{5\%}$ = t, table value 5% probability level at error d.f.

Estimation of mean, components of variance, phenotypic, genotypic and environmental coefficient of variation, heritability, genetic advance and genetic advance as percentage of mean:

The mean of different characters were calculated by conventional method:

$$\text{Mean} = \frac{\sum x}{N}$$

where,

$\sum x_i$ = The sum of all the observation for i^{th} character.

N = Number of observations.

Range was recorded by observing the lowest and the highest mean values for each character.

Where, X_1 = Lower limit
 X_n = Upper limit
 Range = X_1 to X_n

Table 3.3: The component of variance was calculated as follows:

S. No.	Source	M.S.S.	Expected M.S.S.
1.	Replication	-	-
2.	Genotypes	M_i	$\sigma^2_{ei} + r. \sigma^2_{gi}$
3.	Error	E_i	σ^2_{ei}

$$\sigma^2_{gi} = \frac{M_i - E_i}{r}$$

$$\sigma^2_{ei} = E_i$$

$$\sigma^2_{pi} = \sigma^2_{gi} + \sigma^2_{ei}$$

where,

σ^2_{gi} = Genotypic variance for i^{th} character.

σ^2_{ei} = Environmental variance for i^{th} character.

σ^2_{pi} = Phenotypic variance for i^{th} character.

Phenotypic and genotypic coefficient of variation (expressed in %) were calculated by using the formula given by Burton (1952). Genotypic coefficient of variation (GCV) was calculated as below:

$$GCV\% = \frac{\sqrt{\sigma^2_{gi}}}{\bar{X}_i} \times 100$$

Phenotypic coefficient of variation (PCV)

$$PCV\% = \frac{\sqrt{\sigma^2_{pi}}}{\bar{X}_i} \times 100$$

where,

$\bar{X}_i$ = General mean of the i^{th} character under consideration

σ^2_{gi} and σ^2_{pi} = Genotypic and phenotypic standard deviation of the i^{th} character respectively

Heritability and genetic advance

Heritability (broad sense) which is ratio of genotypic variance to the total phenotypic variance is symbolized as h^2 (BS) and expressed in percentage. Estimation of heritability was done as per the formula given by Hanson et al. (1956).

$$h^2 \text{ (BS)} = \frac{\sigma^2_{gi}}{\sigma^2_{pi}} \times 100$$

or

$$= \frac{\text{Genotypic variance of the } i^{\text{th}} \text{ character}}{\text{Phenotypic variance of the } i^{\text{th}} \text{ character}}$$

Expected genetic advance was calculated by using the method suggested by Johnson et al. (1955) at 5% selection intensity.

$$\text{Genetic advance (GA)} = K \cdot P_i \cdot h^2_i$$

Genetic advance as percentage of mean was calculated as follows:

$$\frac{\text{Genetic advance}}{\bar{X}_i}$$

where,

K = Selection intensity its value at 5% selection level is 2.06

P_i = Phenotypic standard deviation of the i^{th} character

h^2_i = Broad sense heritability (fraction) of the i^{th} character

$\bar{X}_i$ = General mean of the i^{th} character under consideration

RESULTS

The results obtained from the present investigation “Characterization of landraces of custard apple (*Annona squamosa* L.)” are presented under the following heads:

- 4.1 Characterization of custard apple landraces based on morphological traits.
- 4.2 Analysis of variance
- 4.3 Genetic variability
 - 4.3.1 Range and mean performance
 - 4.3.2 Coefficient of variation
 - 4.3.3 Heritability and genetic advance

4.1 Characterization of custard apple landraces based on morphological traits.

Characterization of custard apple landraces based on morphological traits at plant, fruit and seed level are as follows.

4.1.1 Plant traits:

4.1.1.1 Plant type

A wide range of variation exhibited for plant type (Table 4.1). Based on plant type, custard apple landraces were categorized into two group's i.e. erect, and spreading. Genotypes MJC-01, SGC-02, SGC-03, SGC-05, SGC-06, JBC-02, JBC-03 and JBC-04 are erect plant types, while genotypes MJC-02, MJC-03, MJC-04, SGC-01, SGC-04, SGC-07, JBC-01, JBC-05, JBC-06 and JBC-07 exhibited spreading plant types.

Table 4.1: Categorization of custard apple landraces based on plant type

Erect	Spreading
MJC-01, SGC-02, SGC-03, SGC-05, SGC-06, JBC-02, JBC-03 and JBC-04.	MJC-02, MJC-03, MJC-04, SGC-01, SGC-04, SGC-07, JBC-01, JBC-05, JBC-06 and JBC-07.

4.1.1.2 Shape of canopy

Variations were observed among the genotypes for the expression of shape of canopy i.e. upright and spreading. Shape of canopy was observed to be upright in genotype MJC-01, SGC-02, SGC-03, SGC-05, SGC-06 and JBC-02. Genotypes MJC-02, MJC-03, MJC-04, SGC-01, SGC-04, SGC-07, JBC-01, JBC-03, JBC-04, JBC-05, JBC-06 and JBC-07 showed spreading canopy (Table 4.2).

Table 4.2: Categorization of custard apple landraces based on shape of canopy

Upright	Spreading
MJC-01, SGC-02, SGC-03, SGC-05, SGC-06 and JBC-02.	MJC-02, MJC-03, MJC-04, SGC-01, SGC-04, SGC-07, JBC-01, JBC-03, JBC-04, JBC-05, JBC-06 and JBC-07.

4.1.1.3 Age of plant

A wide range (6 year to more than 20 years) of variation exhibited for age of plant (Table 4.3). Genotype JBC-04 exhibited minimum 6 year old and genotypes SGC-01, SGC-02, JBC-02, JBC-05, JBC-06 and JBC-07 were recorded maximum ages (more than 20 years).

Table 4.3: Categorization of custard apple landraces based on age of plant

S. No.	Genotype	Age of plant (Year)	S. No.	Genotype	Age of plant (Year)
1	MJC-01	8	10	SGC-06	15
2	MJC-02	6	11	SGC-07	20
3	MJC-03	15	12	JBC-01	15
4	MJC-04	15	13	JBC-02	More than 20
5	SGC-01	More than 20	14	JBC-03	8
6	SGC-02	More than 20	15	JBC-04	6
7	SGC-03	10	16	JBC-05	More than 20
8	SGC-04	8	17	JBC-06	More than 20
9	SGC-05	10	18	JBC-07	More than 20

4.1.2 Fruit traits**4.1.2.1 Fruit shape**

Considerable variability was observed for fruit shape i.e. round, cordate and broadly cordate (Table 4.4). Genotypes MJC-03, SGC-02, SGC-06 and JBC-03 showed cordate fruit shape, whereas genotypes MJC-02 and SGC-05 had broadly cordate fruit shape. The rest of the genotypes exhibited round fruit shape.

Table 4.4: Categorization of custard apple landraces based on fruit shape

Round	Cordate	Broadly cordate
MJC-01, MJC-04, SGC-01, SGC-03, SGC-04, SGC-07, JBC-01, JBC-02, JBC-04, JBC-05, JBC-06 & JBC-07	MJC-03, SGC-02, SGC-06 & JBC-03,	MJC-02 & SGC-05

4.1.2.2 Fruit colour

Based on intensity of fruit colour, genotypes were categorized as whitish green, light green, green, light brown and light yellow (Table 4.5). Genotypes MJC-01 and SGC-05 were recorded in whitish green and light yellow fruit colour respectively. While, genotypes SGC-02 & JBC-03 were exhibited green fruit and genotypes MJC-02 & MJC-03 were noted light brown fruit. The remaining genotypes showed light green fruit colour.

Table 4.5: Categorization of custard apple landraces based on fruit colour

Whitish green	Light green	Green	Light brown	Light yellow
MJC-01	MJC-04, SGC-01, SGC-03, SGC-04, SGC-06, SGC-07, JBC-01, JBC-02, JBC-04, JBC-05, JBC-06 & JBC-07	SGC-02 & JBC-03	MJC-02 & MJC-03	SGC-05

4.1.2.3 Areole shape

No variation was observed among the genotypes for areole shape, all the genotypes exhibited tuberculate areole shape.

4.1.2.4 Depth of furrow

Genotypes were categorized into two groups based on depth of furrow i.e. medium and large (Table 4.6). Genotypes MJC-01, SGC-01, SGC-05, SGC-07, JBC-02 and JBC-05 were recorded in medium depth of furrow. The remaining genotypes showed large depth of furrow.

Table 4.6: Categorization of custard apple landraces based on depth of furrow

Medium	Large
MJC-01, SGC-01, SGC-05, SGC-07, JBC-02 & JBC-05	MJC-02, MJC-03, MJC-04, SGC-02, SGC-03, SGC-04, SGC-06, JBC-01, JBC-03, JBC-04, JBC-06 JBC-07

4.1.3 Seed trait

4.1.3.1 Seed colour

Based on seed colour genotypes were categorized in two distinct groups i.e. light brown and brown (Table 4.7). Genotypes MJC-01, MJC-04, SGC-05, JBC-02, JBC-03 and JBC-04 were recorded in light brown seed colour. The remaining genotypes showed brown seed colour.

Table 4.7: Categorization of custard apple landraces based on seed colour

Light brown	Brown
MJC-01, MJC-04, SGC-05, JBC-02, JBC-03 & JBC-04	MJC-02, MJC-03, SGC-01, SGC-02, SGC-03, SGC-04, SGC-06, SGC-07, JBC-01, JBC-05, JBC-06 & JBC-07

4.2 Analysis of variance

The analysis of variance for all the characters studies has been presented in Table 4.8. The mean differences due to genotypes were highly significant for all the characters indicating the presence of genetic diversity in the material.

Seven characters viz. fruit weight, volume of fruit, number of fruits plant⁻¹, number of seeds fruit⁻¹, peel weight, TSS: acidity ratio and pulp percentage had the values of higher magnitude

**Table 4.8: Analysis of variance for different characters in custard apple
(mean sum of squares)**

Source of variance	D.F.	No. of fruit plant ⁻¹	Fruit length (mm)	Fruit width (mm)	Fruit weight (g)
Genotypes	17	2615.099**	105.227**	103.278**	3124.442**
Error	36	67.529	13.270	4.416	22.658

Source of variance	D.F.	Volume of fruit (ml)	Weight of seed (g)	No. of seeds fruit ⁻¹	Pulp per cent
Genotypes	17	2781.620**	88.193**	669.815**	203.064**
Error	36	318.148	3.200	47.421	6.527

Source of variance	D.F.	Peel weight (g)	Seed (%)	Pulp: seed ratio	Pulp: peel ratio
Genotypes	17	408.688**	17.908**	14.937**	0.422**
Error	36	115.645	0.287	2.702	0.067

Source of variance	D.F.	Total soluble solids (^o Brix)	Acidity (%)	Ascorbic acid (mg/100gm)	Total sugar (%)
Genotypes	17	15.460**	0.0187**	13.061**	44.085**
Error	36	1.513	0.0018	1.120	2.175

Source of variance	D.F.	Reducing sugar (%)	Non reducing sugar (%)	TSS : acidity ratio
Genotypes	17	10.792**	67.024**	314.417**
Error	36	0.892	1.180	52.171

4.3 Genetic variability

4.3.1 Range and mean performance

Range maximum and minimum and mean performance of the eighteen genotypes for all the nineteen characters are depicted in Table 4.9a, b and c.

4.3.1.1 Number of fruits plant⁻¹

The maximum number of fruits plant⁻¹ was observed in MJC-04 (150.43), while it was least in genotype MJC-01 (40.40). The average number of fruits plant⁻¹ was 74.78 and it ranged from 40.40 to 150.43.

4.3.1.2 Fruit length (mm)

The fruit length varied from 51.15 to 69.06 mm with a mean value of 60.93 mm. Genotypes MJC-04 produced considerably big fruit (69.06 mm), while genotypes JBC-04 (51.15 mm) produced small fruit.

4.3.1.3 Fruit width (mm)

Fruit width ranged from 55.50 to 76.76 mm and the average was calculated to be 68.12 mm. Fruit width was found to be highest in JBC-05 (76.76 mm) and it was recorded to be least in JBC-02 (55.50 mm).

4.3.1.4 Fruit weight (g)

The heaviest fruits were observed in genotypes MJC-02 (198.50g) and lightest was noted in JBC-02 (91.75 g). The weight of fruit lied between 91.75 g to 198.50 g, while the average weight of fruit was 147.09 g.

4.3.1.5 Volume of fruit (ml)

Volume of fruit varied from 87.33 to 186.67 ml with an overall mean performance of 138.74 ml. The maximum 186.67 ml volume of fruit was recorded in genotypes MJC-02, while it was recorded minimum in JBC-02 (87.33 ml).

Table 4.9a: Mean performance of physical characters of custard apple

Genotypes	No. of fruit plant⁻¹	Fruit length (mm)	Fruit width (mm)	Fruit weight (g)	Volume of fruit (ml)	Weight of seed (g)
MJC-01	40.40	63.70	73.82	162.00	158.33	10.50
MJC-02	50.55	68.39	76.04	198.50	186.67	22.67
MJC-03	125.34	68.93	74.97	190.33	183.33	18.33
MJC-04	150.43	69.06	72.24	184.83	170.00	21.67
SGC-01	70.74	65.07	70.95	171.50	156.67	22.00
SGC-02	50.44	58.43	64.75	115.67	105.00	11.00
SGC-03	102.43	55.55	63.97	134.00	116.83	14.17
SGC-04	50.45	53.18	59.13	102.20	100.00	13.33
SGC-05	56.44	65.25	70.74	155.00	121.67	17.67
SGC-06	80.39	59.33	68.00	145.67	141.67	10.67
SGC-07	106.42	61.97	64.83	135.17	163.33	7.50
JBC-01	70.57	56.41	66.31	140.67	127.33	9.25
JBC-02	71.79	53.34	55.50	91.75	87.33	6.00
JBC-03	52.72	55.67	65.73	125.00	120.00	11.00
JBC-04	53.22	51.15	62.85	99.75	97.50	6.00
JBC-05	82.98	69.02	76.76	185.67	166.67	17.83
JBC-06	55.02	60.35	72.52	147.17	150.00	10.83
JBC-07	75.68	61.99	67.08	162.83	145.00	9.75
S.Em±	4.74	2.10	1.21	2.75	10.30	1.03
C.D.5% level	13.47	5.97	3.44	7.80	29.23	2.93

4.3.1.6 Weight of seed (g)

Weight of seed ranged from 6.0 to 22.67 g with an overall mean performance of 13.34 g. The maximum 22.67 g was noted in genotype MJC-02, while minimum 6.0 g exhibited in genotype JBC-02.

4.3.1.7 Number of seeds fruit⁻¹

The maximum number of seeds fruit⁻¹ was observed in SGC-05 (62.67), while it was least in genotype SGC-07 (15.33). The average number of seeds fruit⁻¹ was 39.06 and it ranged from 15.33 to 62.67.

Table 4.9b: Mean performance of physical characters of custard apple

Genotypes	No. of seeds fruit ⁻¹	Pulp (%)	Peel weight (g)	Seed (%)	Pulp: seed ratio	Pulp: peel ratio
MJC-01	30.50	64.41	67.33	5.73	12.97	1.95
MJC-02	59.33	63.25	69.33	11.50	5.55	1.81
MJC-03	54.67	60.66	66.67	9.60	6.38	1.80
MJC-04	56.33	55.94	70.00	11.97	5.01	1.58
SGC-01	44.67	46.88	73.17	12.76	3.43	1.04
SGC-02	36.33	45.09	61.50	10.05	5.60	0.83
SGC-03	53.00	41.53	64.17	10.52	4.19	0.93
SGC-04	34.67	37.15	46.67	10.02	3.23	0.80
SGC-05	62.67	41.20	64.50	11.72	3.85	0.98
SGC-06	35.33	43.59	70.17	6.50	6.25	0.90
SGC-07	15.33	40.31	72.83	5.56	8.20	0.74
JBC-01	33.00	42.12	60.50	6.40	6.30	0.97
JBC-02	17.33	49.74	36.73	6.34	7.90	1.23
JBC-03	38.33	44.48	46.17	8.81	5.27	1.20
JBC-04	17.33	44.84	43.25	5.97	7.50	1.04
JBC-05	54.00	43.90	75.50	9.31	5.05	1.08
JBC-06	27.00	41.87	72.00	7.23	5.66	0.90
JBC-07	33.33	42.67	71.00	6.39	5.96	0.96
S.Em±	3.98	1.48	6.21	0.31	0.95	0.15
C.D.5% level	11.28	4.19	17.62	0.88	2.69	0.43

4.3.1.8 Pulp per cent

Percentage of pulp ranged from 37.15% to 64.41% with an overall mean performance of 47.20%. The maximum 64.41% was noted in genotype MJC-01, while minimum 37.15% exhibited in genotype SGC-04.

4.3.1.9 Peel weight (g)

The maximum peel weight was observed in genotype JBC-05 (75.50g) and minimum was noted in JBC-02 (36.73 g). The weight of peel lied between 36.73 g to 75.50 g, while the average weight of peel was 62.86 g.

4.3.1.10 Seed (%)

Seed percentage ranged from 5.56% to 12.76% with an overall mean performance of 8.69%. The maximum 12.76% was noted in genotype SGC-01. While minimum 5.56% exhibited in genotype SGC-07.

4.3.1.11 Pulp: seed ratio

Ratio of pulp and seed lied between 3.23 to 12.97 and the average ratio was 6.02. The maximum ratio of pulp and seed was observed in genotype MJC-01 (12.97) and minimum was noted in SGC-04 (3.23).

4.3.1.12 Pulp: peel ratio

Ratio of pulp and peel varied from 0.74 to 1.95 and the average ratio was 1.15. The maximum ratio of pulp and peel was observed in genotype MJC-01 (1.95) and minimum was noted in SGC-07 (0.74).

4.3.1.13 Total soluble solids (⁰Brix)

The maximum (24.0 ⁰Brix) total soluble solids were observed in genotypes SGC-03 and SGC-06, while it was least in genotype MJC-02 (15.33 ⁰Brix). The average total soluble solids were 20.28 ⁰Brix and it ranged from 15.33 to 24.0 ⁰Brix.

4.3.1.14 Acidity (%)

The maximum acidity was observed in MJC-02 (0.61%), while it was least in genotype SGC-03 (0.29%). The average acidity was 0.42% and it ranged from 0.29 to 0.61%.

4.3.1.15 Ascorbic acid (mg/100gm)

Ascorbic acid was observed maximum in JBC-01 (30.0 mg/100gm), however, it was minimum (21.67 mg/100gm) in genotype SGC-02. It's ranged from 21.67 to 30.0 mg/100gm with an overall mean performance of 25.25 mg/100gm.

Table 4.9c: Mean performance of chemical characters of custard apple

Genotypes	Total soluble solids (°Brix)	Acidity (%)	Ascorbic acid (mg/100gm)	Total sugar (%)	Reducing sugar (%)	Non reducing sugar (%)	TSS: acidity ratio
MJC-01	20.00	0.39	24.17	44.03	14.33	29.70	51.73
MJC-02	15.33	0.61	23.17	34.70	13.97	20.73	50.95
MJC-03	21.00	0.32	24.33	37.13	11.80	25.33	74.12
MJC-04	21.33	0.44	26.00	43.33	13.23	30.10	49.74
SGC-01	18.33	0.53	26.67	32.50	13.50	19.00	34.83
SGC-02	23.33	0.52	21.67	37.00	19.20	17.67	45.13
SGC-03	24.00	0.29	28.17	43.33	14.53	28.67	63.73
SGC-04	18.67	0.43	26.83	39.67	13.67	26.00	43.31
SGC-05	18.33	0.34	26.33	43.43	11.33	31.77	55.53
SGC-06	24.00	0.39	24.17	39.33	14.67	24.67	61.89
SGC-07	18.67	0.37	27.50	37.50	14.83	22.50	50.46
JBC-01	18.67	0.49	30.00	42.00	12.93	29.03	37.83
JBC-02	21.00	0.43	23.67	41.00	14.00	27.00	49.81
JBC-03	19.67	0.44	25.00	43.33	11.60	31.67	45.05
JBC-04	19.67	0.38	23.17	37.50	13.00	24.50	32.26
JBC-05	21.67	0.39	25.17	31.33	15.60	15.67	55.55
JBC-06	19.00	0.38	23.17	37.33	13.50	24.00	50.00
JBC-07	22.33	0.41	25.33	40.00	17.00	23.00	54.56
S.Em±	0.71	0.03	0.61	0.85	0.55	0.63	4.17
C.D.5% level	2.02	0.07	1.73	2.42	1.55	1.78	11.84

4.3.1.16 Total sugar (%)

Total sugar was observed maximum in MJC-01 (44.03%), however, it was minimum (31.33%) in genotype JBC-05. It's ranged from 31.33 to 44.03% with an overall mean performance of 39.14%.

4.3.1.17 Reducing sugar (%)

Reducing sugar ranged from 11.33 to 19.20% with an overall mean performance of 14.04%. The maximum (19.20%) reducing sugar was observed in SGC-02 and it was noted minimum in genotype SGC-05 (11.33%).

4.3.1.18 Non reducing sugar (%)

Non reducing sugar ranged from 15.67 to 31.77% with an overall mean performance of 25.06%. The maximum (31.77%) reducing sugar was observed in SGC-05 and it was observed minimum in genotype JBC-05 (15.67%).

4.3.1.19 TSS: acidity ratio

Ratio of TSS and acidity varied from 32.26 to 74.12 and the average ratio was 50.36. The maximum (74.12) ratio of TSS and acidity was observed in genotype MJC-03 and minimum (32.26) was noted in JBC-04.

4.3.2 Coefficient of variations

Estimation of components of genetic parameters of variation for physical parameters (yield attributes) and chemical parameters (quality) exhibited a wide range of variation for the characters studies (Table 4.10). Result indicated that the value of phenotypic coefficient of variations were of higher in magnitude than that of genotypic coefficient of variation for all the characters showing that the environment had an important role in influencing the expression of the characters,

4.3.2.1 Phenotypic coefficient of variations

The phenotypic coefficient of variation ranged from 8.94% for ascorbic acid to 43.25% for pulp and seed ratio. The phenotypic coefficient of variations was highest for characters viz., pulp and seed ratio (43.25%), weight of seed

(42.09%), number of seeds fruit⁻¹ (40.87%), number of fruits plant⁻¹ (40.49%) and pulp: peel ratio (37.40%). However, it was exhibited in low for characters like ascorbic acid (8.94%) followed by fruit width (8.97%), total sugar (10.27%), fruit length (10.88%), TSS (12.24%), reducing sugar (14.58%), pulp per cent (17.98%) and non reducing sugar (19.19%). The rest of the characters such as seed per cent (28.56%), volume of fruit (24.33%), TSS: acidity ratio (23.46%), peel weight (23.24), fruit weight (22.10%) and acidity per cent (21.03%) exhibited moderate phenotypic coefficient of variation.

4.2.2.2 Genotypic coefficient of variation

It is revealed from the Table 4.10 that genotypic coefficient of variation varied from 7.90% for ascorbic acid to 39.90% for weight of seed.

High genotypic coefficient of variation was noted for weight of seed (39.90%) followed by number of fruits plant⁻¹ (38.97%), number of seeds fruit⁻¹ (36.88%) and pulp and seed ratio (33.54%). Ascorbic acid (7.90%), fruit width (8.43%), fruit length (9.09%), total sugar (9.55%), TSS (10.63%), reducing sugar (12.94%), peel weight (15.72%), pulp per cent (17.15%), acidity per cent (18.44%), TSS: acidity ratio (18.57%) and non reducing sugar (18.69%) showed lowest genotypic coefficient of variation. While it was moderate for rest of the characters such as pulp: peel ratio (29.87%), seed per cent (27.89%), fruit weight (21.86%) and volume of fruit (20.65%).

4.2.3 Heritability

The heritability (BS) was computed for each of the characters by the variance components for estimating their relative magnitudes of genotypic and phenotypic variability contributed through environmental factors. The estimates of heritability (BS) for all the characters have been discussed as follows (Table 4.10). It was partitioned as very high (above 90%), high (70-90%), medium (50-70%) and low (less than 50%).

Table 4.10: Estimates of genetic parameters of variations for various characters in custard apple

Characters	Grand Mean	Range		Coefficient of variations		Heritability % (BS)	Genetic Advance	GA as % of mean
		Min.	Max.	Phenotypic	Genotypic			
No. of fruit plant ⁻¹	74.78	40.40	150.43	40.49	38.97	92.63	57.78	77.26
Fruit length (cm)	60.93	51.15	69.06	10.88	9.09	69.79	9.53	15.64
Fruit width (cm)	68.12	55.50	76.76	8.97	8.43	88.18	11.10	16.30
Fruit weight (g)	147.09	91.75	198.50	22.10	21.86	97.86	65.52	44.55
Volume of fruit (ml)	138.74	87.33	186.67	24.33	20.65	72.08	50.12	36.12
Weight of seed (g)	13.34	6.00	22.67	42.09	39.90	89.85	10.39	77.91
No. of seeds fruit ⁻¹	39.06	15.33	62.67	40.87	36.88	81.40	26.77	68.53
Pulp per cent	47.20	37.15	64.41	17.98	17.15	90.94	15.90	33.69
Peel weight (g)	62.86	36.73	75.50	23.24	15.72	45.79	13.78	21.92
Seed (%)	8.69	5.56	12.76	28.56	27.89	95.34	4.88	56.10
Pulp: seed ratio	6.02	3.23	12.97	43.25	33.54	60.15	3.23	53.59
Pulp: peel ratio	1.15	0.74	1.95	37.40	29.87	63.78	0.57	49.14
Total soluble solids (⁰ Brix)	20.28	15.33	24.00	12.24	10.63	75.45	3.86	19.02
Acidity (%)	0.42	0.29	0.61	21.03	18.44	76.92	0.14	33.32
Ascorbic acid (mg/100gm)	25.25	21.67	30.00	8.94	7.90	78.04	3.63	14.38
Total sugar (%)	39.14	31.33	44.03	10.27	9.55	86.53	7.16	18.30
Reducing sugar (%)	14.04	11.33	19.20	14.58	12.94	78.72	3.32	23.65
Non reducing sugar (%)	25.06	15.67	31.77	19.19	18.69	94.90	9.40	37.52
TSS : acidity ratio	50.36	32.26	74.12	23.46	18.57	62.62	15.24	30.27

Result indicated that the heritability estimates were observed very high for fruit weight (97.86%), seed per cent (95.34%), non reducing sugar (94.90%), number of fruits plant⁻¹ (92.63%) and pulp per cent (90.94%) and high for weight of seed (89.85%) followed by fruit width (88.18%), total sugar (86.52%), number of seeds fruit⁻¹ (81.40%), reducing sugar (78.72%), ascorbic acid (78.04%), acidity per cent (76.92%), TSS (75.45%) and volume of fruit (72.08). While, it was moderate for fruit length (69.79%), pulp: peel ratio (63.78%), TSS: acidity ratio (62.62%) and pulp and seed ratio (60.15%). Peel weight (45.79%) showed lowest heritability.

4.2.4 Genetic advance

Based on the estimate of heritability (BS) expected genetic advance was computed on the hypothetical selection at five per cent best individual (K= 2.06). Due to masking influence of environment upon characters concerned, values of genetic advance exhibited high fluctuations. Therefore, to attain relative comparison of the characters in relation to environment, genetic advance as percentage of mean was calculated to predict the genetic gain (Table 4.10).

Genetic advance as percentage of mean ranged between 14.38% for ascorbic acid to 77.91% for weight of seed. The highest estimate of genetic advance as percentage of mean was recorded for weight of seed (77.91%), number of fruits plant⁻¹ (77.26%), number of seeds fruit⁻¹ (68.53%), seed per cent (56.10%) and pulp and seed ratio (53.59%). Pulp and peel ratio (49.14%), fruit weight (44.55%), non reducing sugar (37.52%), volume of fruit (36.12%) pulp per cent (33.69%) and acidity per cent (33.32%) showed moderate value of genetic advance as percentage of mean. Whereas, low estimates were observed for ascorbic acid (14.38%), fruit length (15.64%), fruit width (16.30%), total sugar (18.30%), TSS (19.02%), peel weight (21.92%) reducing sugar (23.65%) and TSS and acidity ratio (30.27%).

DISCUSSION

The experimental findings of the present investigation “Characterization of landraces of custard apple (*Annona squamosa* L.)” have been discussed on the following heads in the light of the available literature.

5.1 Characterization of landraces of custard apple based on morphological characters.

Characterization of landraces of custard apple was performed based on morphological characters of plant, fruit and seed. Distinguishing genotypes on the basis of morphological characters is one of the most common criteria.

5.1.1 Plant type

A wide range of variation exhibited for plant type. Based on plant type, custard apple landraces were categorized into two group's i.e. erect, and spreading. Genotypes MJC-01, SGC-02, SGC-03, SGC-05, SGC-06, JBC-02, JBC-03 and JBC-04 are erect plant types, while genotypes MJC-02, MJC-03, MJC-04, SGC-01, SGC-04, SGC-07, JBC-01, JBC-05, JBC-06 and JBC-07 exhibited spreading plant types indicated that the expression of the character was not uniform. These observations are in agreement with the result of Varu and Barad (2011) and Rao and Subramanyam (2011).

5.1.2 Shape of canopy

Variations were observed among the genotypes for the expression of shape of canopy i.e. upright and spreading. Shape of canopy was observed to be upright in genotype MJC-01, SGC-02, SGC-03, SGC-05, SGC-06 and JBC-02. Genotypes MJC-02, MJC-03, MJC-04, SGC-01, SGC-04, SGC-07, JBC-01, JBC-03, JBC-04, JBC-05, JBC-06 and JBC-07 showed spreading canopy indicated that the expression of the character was not uniform. The findings are in agreement with the result of Varu and Barad (2011) and Rao and Subramanyam (2011).

5.1.3 Age of plant

A wide range (6 year to more than 20 years) of variation exhibited for age of plant (Table 4.3). Genotype JBC-04 exhibited minimum 6 year old and genotypes SGC-01, SGC-02, JBC-02, JBC-05, JBC-06 and JBC-07 were recorded maximum ages (more than 20 years) indicated that the expression of the trait was variable.

5.1.4 Fruit shape

Considerable variability was observed for fruit shape i.e. round, cordate and broadly cordate (Table 4.4). Genotypes MJC-03, SGC-02, SGC-06 and JBC-03 showed cordate fruit shape, whereas genotypes MJC-02 and SGC-05 had broadly cordate fruit shape. The rest of the genotypes exhibited round fruit shape indicated that the expression of this character was greater diversity. The findings are in agreement with the result of Girwani et al. (2011) and Bhatnagar et al. (2012).

5.1.5 Fruit colour

Based on intensity of fruit colour, genotypes were categorized as whitish green, light green, green, light brown and light yellow (Table 4.5). Genotypes MJC-01 and SGC-05 were recorded in whitish green and light yellow fruit colour respectively. While, genotypes SGC-02 & JBC-03 were exhibited green fruit and genotypes MJC-02 & MJC-03 were noted light brown fruit. The remaining genotypes showed light green fruit colour indicated that the expression of this character was greater diversity. The findings are in agreement with the result of Girwani et al. (2011), Bhatnagar et al. (2012) and Kolekar and Tagad (2012).

5.1.6 Areole shape

No variation was observed among the genotypes for areole shape, all the genotypes exhibited tuberculate areole shape. The findings are in agreement with the result of Girwani et al. (2011), Bhatnagar et al. (2012) and Dandsena and Banik (2016).

5.1.7 Depth of furrow

Genotypes were categorized into two groups based on depth of furrow i.e. medium and large (Table 4.6). Genotypes MJC-01, SGC-01, SGC-05, SGC-07, JBC-02 and JBC-05 were recorded in medium depth of furrow. The remaining genotypes showed large depth of furrow. It's revealed that genotypes exhibited significant difference for depth of furrow. The findings are in agreement with the result of Bhatnagar et al. (2012).

5.1.8 Seed colour

Based on seed colour genotypes were categorized in two distinct groups i.e. light brown and brown (Table 4.7). Genotypes MJC-01, MJC-04, SGC-05, JBC-02, JBC-03 and JBC-04 were recorded in light brown seed colour. The remaining genotypes showed brown seed colour. Seed colour is stable and uniform attribute, hence, it may be used to verify the genotypes.

5.2 Analysis of variance

The main objective of the present investigation was to study the diversity present in eighteen landraces of custard apple. The estimates of mean sum of square due to landraces were highly significant for all the characters (Table 4.8), indicating the presence of genetic diversity in the existing material. The findings of Varu and Barad (2011), Bhatnagar et al. (2012), Majumder et al. (2012), Mishra et al. (2015) and Nagar et al. (2017) are similar to that of the present findings.

5.3 Genetic variability

5.3.1 Mean performance of the genotypes

The mean performance of the genotypes (Table 4.9a, b and c) revealed a wide range of variability for all the characters. The variation was highest for number of fruit plant⁻¹ (40.40 to 150.43) followed by fruit weight (91.75 g to 198.50 g), volume of fruit (87.33 to 186.67 ml), number of seeds fruit⁻¹ (15.33 to 62.67), TSS and acidity ratio (32.26 to 74.12), peel weight (36.73 g to 75.50 g), pulp percentage (37.15% to 64.41%), fruit width (55.50 to 76.76 mm), fruit

length (51.15 to 69.06 mm), weight of seed (6.0 to 22.67 g), non reducing sugar (15.67 to 31.77%) and total sugar (31.33 to 44.03%). The findings were quite similar to as reported by Varu and Barad (2011), Rao and Subramanyam (2011), Girwani et al. (2011) for number of fruit plant⁻¹, Pal and Kumar (1995), Ghosh et al. (2001), Dikshit et al. (2008), Varu and Barad (2011), Rao and Subramanyam (2011), Girwani et al. (2011), Bhatnagar et al. (2012), Hashmi and Pawar (2012), Kolekar and Tagad (2012), Kad et al. (2016) for fruit weight, Pal and Kumar (1995) for volume of fruit, Ghosh et al. (2001), Dikshit et al. (2008), Girwani et al. (2011), Bhatnagar et al. (2012), Hashmi and Pawar (2012), Kolekar and Tagad (2012), Kad et al. (2016) for number of seeds fruit⁻¹, Pal and Kumar (1995) for TSS and acidity ratio, Leal et al. (1990), Pal and Kumar (1995), Rao and Subramanyam (2011), Hashmi and Pawar (2012), Kolekar and Tagad (2012), Kad et al. (2016) for peel weight, Leal et al. (1990), Pal and Kumar (1995), Dikshit et al. (2008) Rao and Subramanyam (2011), Bhatnagar et al. (2012), Hashmi and Pawar (2012), Kolekar and Tagad (2012), Kad et al. (2016) for pulp percentage, Pal and Kumar (1995), Ghosh et al. (2001), Varu and Barad (2011), Kolekar and Tagad (2012), Kad et al. (2016) for fruit length and width, Rao and Subramanyam (2011), Hashmi and Pawar (2012), Kad et al. (2016) for weight of seed, Pal and Kumar (1995), Ghosh et al. (2001) for non reducing sugar, Pal and Kumar (1995), Ghosh et al. (2001), Hashmi and Pawar (2012), Othman et al. (2014) for total sugar.

5.3.2 Coefficient of variation

In the present findings phenotypic coefficient of variation were observed to be higher than the corresponding genotypic coefficient of variation for all the characters studied, however, the differences was narrow which implied their relative resistance to environmental variation. It also described that genetic factors were predominantly responsible for expression of those attributes and selection could be made effective on the basis of phenotypic performance. The finding of Bhowmick and Banik (2008), Majumder et al. (2012), Bhatnagar et al. (2012), and Mishra et al. (2015) were similar to that of the present findings.

5.3.2.1 Phenotypic coefficient of variations

The phenotypic coefficient of variation range from 8.94% for ascorbic acid to 43.25% for pulp and seed ratio. The phenotypic coefficient of variations was highest for characters viz., pulp and seed ratio (43.25%), weight of seed (42.09%), number of seeds fruit⁻¹ (40.87%), number of fruits plant⁻¹ (40.49%) and pulp: peel ratio (37.40%), indicating that selection can be predicted to improvement in the custard apple for these characters. The findings are in close harmony with the result of Majumder et al. (2012) and Saroj et al. (2017) for number of fruits plant⁻¹, Himabindu et al. (2016) for pulp and seed ratio, pulp: peel ratio and weight of seed.

However, it was exhibited in low for characters like ascorbic acid (8.94%) followed by fruit width (8.97%), total sugar (10.27%), fruit length (10.88%), TSS (12.24%), reducing sugar (14.58%), pulp per cent (17.98%) and non reducing sugar (19.19%) which indicated that there is limited scope for improvement.

The rest of the characters such as seed per cent (28.56%), volume of fruit (24.33%), TSS: acidity ratio (23.46%), peel weight (23.24), fruit weight (22.10%) and acidity per cent (21.03%) exhibited moderate phenotypic coefficient of variation. The finding of Bhatnagar et al. (2012), Mishra et al. (2015), Himabindu et al. (2016) for fruit weight, Himabindu et al. (2016) for peel weight, seed per cent, acidity per cent and TSS: acidity ratio, Nagar et al. (2017) for most of the characters was similar to the present finding.

5.3.2.2 Genotypic coefficient of variation

It is revealed from the Table 4.10 that genotypic coefficient of variation varied from 7.90% for ascorbic acid to 39.90% for weight of seed.

High genotypic coefficient of variation was noted for weight of seed (39.90%) followed by number of fruits plant⁻¹ (38.97%), number of seeds fruit⁻¹ (36.88%) and pulp and seed ratio (33.54%). The findings are in close harmony

with the result of Majumder et al. (2012) and Saroj et al. (2017) for number of fruits plant⁻¹, Himabindu et al. (2016) for pulp and seed ratio and weight of seed.

While it was observed lowest in the characters i.e. ascorbic acid (7.90%), fruit width (8.43%), fruit length (9.09%), total sugar (9.55%), TSS (10.63%), reducing sugar (12.94%), peel weight (15.72%), pulp per cent (17.15%), acidity per cent (18.44%), TSS: acidity ratio (18.57%) and non reducing sugar (18.69%), indicated that there is limited scope for improvement.

Rest of the characters viz., pulp: peel ratio (29.87%), seed per cent (27.89%), fruit weight (21.86%) and volume of fruit (20.65%) were showed moderate genotypic coefficient of variation. The finding of Bhatnagar et al. (2012), Mishra et al. (2015), Himabindu et al. (2016) for fruit weight, Himabindu et al. (2016) for peel weight, seed per cent, acidity per cent and TSS: acidity ratio, Nagar et al. (2017) for most of the characters was similar to the present finding.

5.3.3 Heritability

Heritability which denotes the proportion of genetically controlled variability expressed by a programme for a particular character or a set of character is very important biometrical tool for guiding plant breeders for adoption of appropriate breeding procedures. High heritability in broad sense is helpful in identifying appropriate character for selection and enables the breeder to select superior genotypes on the basis of phenotypic expression of quantitative characters. The estimated values of heritability in broad sense were classified as very high (more than 90%), high (70- 90%), medium (50-70%) and low (less than 50%).

The value of heritability (broad sense) was recorded very high for fruit weight (97.86%), seed per cent (95.34%), non reducing sugar (94.90%), number of fruits plant⁻¹ (92.63%) and pulp per cent (90.94%). However, it was recorded high for weight of seed (89.85%) followed by fruit width (88.18%), total sugar (86.52%), number of seeds fruit⁻¹ (81.40%), reducing sugar (78.72%), ascorbic acid (78.04%), acidity per cent (76.92%), TSS (75.45%) and volume of

fruit (72.08). The results were in close proximate to that of Samodia and Pareek (2006) and Bhatnagar et al. (2012) for fruit weight, Samodia and Pareek (2006), Silva et al. (2007), Majumder et al. (2012) and Saroj et al. (2017) for number of fruits plant⁻¹, Bhatnagar et al. (2012) for pulp per cent and number of seeds fruit⁻¹. High values of broad sense heritability for these characters, expressed that they were least influenced by environmental modification. It reflected that the phenotypes were the true representative of their genotypes and selection based on phenotypic performance would be reliable.

It was moderate for fruit length (69.79%), pulp: peel ratio (63.78%), TSS: acidity ratio (62.62%) and pulp and seed ratio (60.15%), which indicated that selection based on phenotypic performance would be rewarding.

Low estimate of heritability was recorded for peel weight (45.79%).

5.3.4 Genetic advance

Heritability indicates only the effectiveness with which selection of a genotype can be based on phenotypic performance, but fails to indicate the genetic progress. Heritability estimates along with genetic gains are more effective and reliable in predicting the improvement through selection (Johnson et al., 1955). Estimates of genetic advance helps to predict the extent of improvement that can be achieved for improving the different characters. The estimated values of genetic advance as percent of mean were classified as high (more than 50%), moderate (30-50%) and low (less than 30%).

Genetic advance as percentage of mean ranged from 14.38% for ascorbic acid to 77.91% for weight of seed. The results were in consonance with Bhowmick and Banik (2008). The highest estimate of genetic advance as percentage of mean was recorded for weight of seed (77.91%), number of fruits plant⁻¹ (77.26%), number of seeds fruit⁻¹ (68.53%), seed per cent (56.10%) and pulp and seed ratio (53.59%). The results were in consonance with Samodia and Pareek (2006), Majumder et al. (2012) and Saroj et al. (2017) for number of fruits plant⁻¹.

Pulp and peel ratio (49.14%), fruit weight (44.55%), non reducing sugar (37.52%), volume of fruit (36.12%) pulp per cent (33.69%) and acidity per cent (33.32%) showed moderate value of genetic advance as percentage of mean. The findings were in agreement to the findings of Samodia and Pareek (2006) for fruit weight.

Low estimates were recorded for ascorbic acid (14.38%), fruit length (15.64%), fruit width (16.30%), total sugar (18.30%), TSS (19.02%), peel weight (21.92%) reducing sugar (23.65%) and TSS and acidity ratio (30.27%).

High heritability coupled with high genetic advance as percentage of mean for traits like weight of seed followed by number of fruits plant⁻¹, number of seeds fruit⁻¹ and seed per cent. It Suggested that the preponderance of additive genes. It also indicated higher response for selection to high yields as these characters are governed by additive gene actions. The findings were in agreement to the findings of Samodia and Pareek (2006) Majumder et al. (2012) for number of fruits plant⁻¹.

High heritability supplemented with moderate genetic advances as percentage of mean were manifested by fruit weight, non reducing sugar, volume of fruit, pulp per cent and acidity per cent, which might be attributed to additive gene action conditioning their expression and phenotypic selection for their amenability can be brought about.

High heritability coupled with low genetic advance as percentage of mean was observed for ascorbic acid, fruit width, total sugar, TSS and reducing sugar. This revealed the predominance of non-additive gene action in the expression of these characters.

Low estimates of heritability coupled with low genetic advances as percentage of mean were displayed by peel weight indicated that these character was highly influenced by environmental effects and consequently its selection would be ineffective.

SUMMARY, CONCLUSION AND SUGGESTIONS

FOR FURTHER WORK

6.1 Summary

The present investigation entitled “Characterization of landraces of custard apple (*Annona squamosa* L.)” was carried out during *Rabi* season of 2016-2017 at Post Harvest Laboratory, Department of Horticulture, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.). The experimental material for the present investigation was comprised of eighteen landraces of custard apple were collected from the Jabalpur and Sagar district for detailed study on the basis of plant type, fruiting behavior and size of fruits. Fruits of custard apple landraces were collected and study on morphological, physical and chemical characteristics of fruits. Design of the experiment in Completely Randomized Design (C.R.D.) and replicated in three blocks. Observations were recorded on the basis of three random competitive fruits per plants selected from each genotype/ landraces separately for morphological, physical and chemical characters were evaluated as per standard procedure. On the basis of results, the present investigation is summarized as follows:

Expression of eight distinguish morphological characters were observed visually at plant, fruit and seed levels to categorize the genotypes/ landraces.

At plant and fruit level, the expression of six morphological characters was observed to categorize the landraces. Plant type, shape of canopy, age of plant, fruit shape, areole shape and depth of furrow are the most stable and uniform distinguishing characters for verification of custard apple landraces.

Fruit colour and seed colour are the uniform characters but their expressions are observed by the fluctuating environment .Therefore,

these traits should be used only as an indicator not as marker to verify the genetic purity.

The estimates of mean sum of square due to landraces were highly significant for all the characters, indicating the presence of genetic diversity in the existing material.

Among physical and chemical parameters of the fruits revealed that maximum fruit weight (198.50 g), fruit volume (186.67ml) and minimum seed weight (6.0 g) and peel weight (36.75 g) was observed in MJC -02. Landraces MJC -04 was noted maximum number of fruit plant⁻¹ (150.43) and fruit length (69.06 mm). Landraces SGC -07 exhibited lowest number of seeds fruit⁻¹ (15.33) and seed percentage (5.56%). Fruit width was registered maximum (76.76 mm) in JBC -05. Significantly highest pulp percentage, ratio of pulp: seed and pulp: peel was recorded 64.41%, 12.97 and 1.95 in MJC -01 respectively, ascorbic acid (30.0 mg/100 gm) and total sugar (44.03%) was also recorded maximum in this landraces. However, highest TSS (24°0 Brix) and lowest acidity (0.29 %) was observed in SGC -03.

A wide range of variability was observed for all the traits. The variation was highest for number of fruit plant⁻¹ followed by fruit weight, volume of fruit, number of seeds fruit⁻¹, TSS and acidity ratio, peel weight, pulp percentage, fruit width, fruit length, weight of seed, non reducing sugar and total sugar.

The present study revealed that the phenotypic coefficient of variation was higher than the corresponding genotypic coefficient of variation for all the traits which might be due to interaction of the genotypes with the environment to some degree or other explaining environmental factors influencing the expression of these characters. Highest genotypic coefficient of variation was noted for weight of seed followed by number of fruits plant⁻¹, number of seeds fruit⁻¹ and pulp and seed ratio. The high values of GCV suggested greater phenotypic and genotypic variability among the landraces and responsiveness of the attributes for making further improvement by selection. However, low estimates of GCV was noted

characters like ascorbic acid, fruit width, fruit length, total sugar, TSS, reducing sugar, peel weight, pulp per cent, acidity per cent, TSS: acidity ratio and non reducing sugar, which indicated that there is limited scope for improvement.

High heritability coupled with high genetic advance as percentage of mean for traits like weight of seed followed by number of fruits plant⁻¹, number of seeds fruit⁻¹ and seed per cent. Suggested that the preponderance of additive genes. It also indicated higher response for selection to high yields as these characters are governed by additive gene actions.

High heritability supplemented with moderate genetic advances as percentage of mean were manifested by fruit weight, non reducing sugar, volume of fruit, pulp per cent and acidity per cent, which might be attributed to additive gene action conditioning their expression and phenotypic selection for their amenability can be brought about.

High heritability coupled with low genetic advance as percentage of mean was observed for ascorbic acid, fruit width, total sugar, TSS and reducing sugar. This revealed the predominance of non-additive gene action in the expression of these characters.

Low estimates of heritability coupled with low genetic advances as percentage of mean were displayed by peel weight indicated that these character was highly influenced by environmental effects and consequently its selection would be ineffective.

6.2 Conclusion

At plant and fruit level, the expression of six morphological characters was observed to categorize the landraces plant type, shape of canopy, age of plant, fruit shape, areole shape and depth of furrow are the most stable and uniform distinguishing characters for verification of custard apple landraces.

Fruit colour and seed colour are the uniform characters but their expressions are observed by the fluctuating environment .Therefore,

these traits should be used only as an indicator not as marker to verify the genetic purity.

Among physical and chemical parameters of the fruits revealed that maximum fruit weight (198.50 g), fruit volume (186.67 ml) and minimum seed weight (6.0 g) and peel weight (36.75 g) was observed in MJC -02. Landraces MJC -04 was noted maximum number of fruit plant⁻¹ (150.43) and fruit length (69.06 mm). Landraces SGC -07 exhibited lowest number of seeds fruit⁻¹ (15.33) and seed percentage (5.56%). Fruit width was registered maximum (76.76mm) in JBC -05. Significantly highest pulp percentage, ratio of pulp: seed and pulp: peel was recorded 64.41%, 12.97 and 1.95 in MJC -01 respectively, ascorbic acid (30.0 mg/100gm) and total sugar (44.03%) was also recorded maximum in this landraces. However, highest TSS (24°0 Brix) and lowest acidity (0.29 %) was observed in SGC -03.

The estimates of mean sum of square due to landraces were highly significant for all the characters, indicating the presence of genetic diversity in the existing material.

A wide range of variability was observed for all the traits. The variation was highest for number of fruit plant⁻¹ followed by fruit weight, volume of fruit, number of seeds fruit⁻¹, TSS and acidity ratio, peel weight, pulp percentage, fruit width, fruit length, weight of seed, non reducing sugar and total sugar.

The phenotypic coefficient of variation was higher than the corresponding genotypic coefficient of variation for all the traits which might be due to interaction of the landraces with the environment to some degree or other explaining environmental factors influencing the expression of these characters. Highest genotypic coefficient of variation was noted for weight of seed followed by number of fruits plant⁻¹, number of seeds fruit⁻¹ and pulp and seed ratio. The high values of GCV suggested greater phenotypic and genotypic variability among the landraces and responsiveness of the attributes for making further improvement by selection.

High heritability coupled with high genetic advance as percentage of mean for traits like weight of seed followed by number of fruits plant⁻¹, number of seeds fruit⁻¹ and seed per cent. Suggested that the preponderance of additive genes. It also indicated higher response for selection to high yields as these characters are governed by additive gene actions.

6.3 Suggestions for further work

1. Stability of distinct traits of custard apple should be established over the years.
2. An unambiguous characteristics pattern of custard apple landraces should be obtained through DNA finger printing.
3. Landraces of custard apple JMC-02, JMC-04, JMC-01, JBC-05, SGC - 07 and SGC -03 may be considered well in selection for the improvement of crop.
4. Traits identified for high heritability coupled with high or moderate genetic gain may be considered well in selection for the improvement of crop.

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CURRICULUM VITAE

The author of this thesis **Mr. Guddoo Singh** S/o Shri Ram Siya was born on 11th July, 1991 at Vill. Prathvipura Post and Teh. Lahar Distt. Bhind (M.P.). He passed the High School Examination in the year 2006 acquiring 55.20 percent marks from S.C.S.T.H.S. School Siddhpura Bhind (MP) and Higher Secondary Examination in the year 2008 acquiring 70.66 percent marks from S.C.S.T.H.S. School Siddhpura Bhind (MP). He joined the College of Agriculture, Rewa, in the year 2011 and successfully completed the degree of B.Sc. (Agri.) from JNKVV, Jabalpur during the year June, 2015 with 7.15 OGPA out of 10.00 point scale.



In the year 2015, he took admission in college of Agriculture, Jabalpur for M.Sc. (Agri.) Horticulture degree programme in Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur for specialization in Horticulture (Fruit Science). He has successfully completed all the courses requirements for master's degree with 7.00 OGPA out of 10.00 point scale.

For the fulfillment of the master's degree Programme, he was allotted a research problem entitled “**Characterization of landraces of custard apple (*Annona squamosa* L.)**” This is duly completed by his and presented in the form of this thesis.



MJC-1,2,3,4



SGC-1,2,3,4,



SGC-5



SGC-6



SGC-7



JBC-1

Plate No. 1: Showing variability in fruit shape, fruit colour and depth of furrow.

Continue.....



JBC-2



JBC-3



JBC-4



JBC-5



JBC-6



JBC-7

