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Research Article

# Genetic Variability Studies in Wood Apple (*Feronia limonia* L.).

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**Abstract**

The present investigation entitled "GENETIC VARIABILITY STUDIES IN WOOD APPLE (*Feronialimonia*L.)." was carried out on thirty-two years old Wood apple orchard during the year 2017-2018 at Main Garden Department of Horticulture, Dr.Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The flowering and duration of flowering of studied available germplasm varied from first week of February to first week of March and Three weeks to Nine weeks from date of flowering respectively. The various other morphological characters varied in the following manner. The range of the fruit weight was found in between 190.5 to 389.9 g, range of pulp weight was found in between 103.7 to 262.7 g, pulp percentage was ranged between 51.60 to 66.9, fruit length was ranged between 9.4 to 13.6 cm, fruit diameter was ranged between 10.15 to 15.45, skull weight was ranged between 92 to 138.1, skull thickness was ranged between 3.17 to 3.87, pulp: skull ratio was ranged between 1.03 to 2.15, number of seeds per 100g pulp was ranged between 67.27 to 214.9, weight of seeds per 100g pulp was ranged between 3.73 to 9.9 (g), seed size was ranged between 2.27 to 3.2 (mm), total soluble solids was ranged between 11.17 to 13.47 (°Brix), acidity was ranged between 1.12 to 3.69 (%), TSS: acid ratio was ranged between 3.35 to 12.19, total sugar was ranged between 1.82 to 2.17 (%), reducing sugars was ranged between 1.15 to 1.29 (%), non-reducing sugars 0.62 to 0.91(%) and pectin content was ranged between 1.06 to 1.81 (%). The highest genotypic coefficient of variation was observed for TSS: acid ratio, acidity (%), and pulp weight. High GCV is an indication of greater range of variability among the population and the scope of improvement of these characters through simple selection. During present study characters like TSS: acid ratio, acidity, pectin content, number of seeds per 100g pulp, weight of pulp and fruit weight had high heritability values along with the high genetic advance.

**Keywords:** *Genetic variability, Underutilized fruit, Monotypic species.*

## Introduction

Wood apple (*Feronia limonia* L.) belongs to the family Rutaceae Swingle. Wood apple, a monotypic species, belongs to the sub-family - Aurantiodeae; tribe-Citreae; sub-tribe-Balsamocitrineae, which comes under hard shelled citroid fruit tree group. The generic name of wood-apple was assigned as *Limonia* but Swingle placed it to *Feronia*. Initially the scientific name was *Limonia acidissimia* L. but it was ultimately changed to *Feronia limonia* (L) Swingle (Reuther, *et al*., 1967). It is also known as Kavath, Elephant apple, Monkey fruit, Curd fruit and Katha Bael in India. Wood apple is reported to be native of India and Shri Lanka generally cultivated in both peninsulas. It is one of the very hardy trees found all over the plains of northern, central, eastern and southern regions of India especially in the semi arid and arid regions. More common in southern Maharashtra and Madhya Pradesh also occur in the western Himalaya up to an elevation of about 500 meter. It requires a monsoon climate with a distinct dry season for initial growth. (Lande, *et al*., 2010).

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Trimen, (1893) described it as a small tree of 10-15 m height and 0.8-1.6 m girth with deciduous nature having numerous branches with whitish bark and with sharp, straight ascending 1.2-3.8 cm long spines, pinnate (7.5-10.0 cm long), rachis and petiole flat, very narrowly winged, glabrous. Leaflets opposite in 2-3 pairs and usually with a terminal one nearly sessile (2.5-3.8 cm long), oval or ovate, obtuse, entire, glabrous where basal ones are the largest. Flowers are small; numerous in small paniculate, sessile cymes form the axis of the fallen inflorescence. Flowers are dull red usually unisexual, male and bisexual flowers are seen on the same inflorescence. Peduncle is slender and pubescent. Calyx is very small; petals ovate, acute, spreading and smooth. Stamens are 7-12 in number, filament is very short while anther is very large; disc is finely wooly; ovary with numerous ovules in each cell, style is very short and stigma is fusiform. Fruit is large (5.0-8.0 cm diameter), globose, hard, pericarp woody, rough, whitish, amphisarca. Seeds are compressed. The fruit of Wood apple exhibits excellent nutritional and medicinal properties. Traditionally the fruit has been used for relief against the diarrhea, dysentery, stomach aches, tumors, asthma, wounds, cardiac debility and hepatitis (Ilango and Chitra, 2009). Wood apple tolerates drought hence suitable for arid zones. Grown up trees also show tolerance to high (up to 48°C) and low temperatures (-15°C). The age of the plant varies from 13 to 70 years. The fruits obtained from the plants are edible and the pulp of the fruit is acid to sweet with coarse texture, seediness and fibrous. Yield potential in mother plants varying from 650 to 1085 kg of fruit/plant having the fruit weight between 130 and 325 g. Fruit length 7.3 to 8.9 cm while breadth between 7.2 to 8.4 cm. Fruit size (length × breadth) varies in relation to fruit weight (Ghosh. *et al*., 2010). Besides different medicinal and social uses of Wood apple, Wood apple seedlings can be successfully utilized as rootstock for Citrus species. Newly introduced species of citrus could be successfully budded on Wood apple seedling to induce precocity if desired for hybridization (Reuther. *et al*., 1967). Shanmugavellu, (1987) reported successful grafting of Sathgudi Orange (*Citrus sinensis)* on wood apple as rootstock. Budding and grafting wood apple on seedlings of wood apple also ensures precocity. Wood apple pulp is used for preparation of jelly, chutney and squash. Fruit syrup made by boiling pulp along with its seeds and sugar in water. Sugar syrup is concentrated to 13-15°Brix and filled in cans while it is still hot. Fruit has certain medicinal properties also. It is used as a stomachic and stimulant, pulp is applied externally against poisonous bites and leaves are carminative and yield an essential oil. Gum taken from trunk is used in water-colors, dyes and varnishes. Wood apple being a neglected plant, no systematic work on variety has been done. Moreover, it being a minor crop and grown on stray situation, sufficient importance was not given for enlisting varieties, evaluating varietal performance or improvement. In nature two types of fruits are produced by two distinctly different types of trees. One having smaller acidic fruits weighing between 200-250 g while the other producing larger (300-400 g) sweet fruits. The latter type is more aromatic (Gopalan. *et al*., 1971). The Vasantrao Naik Marathwada Agricultural University, Parbhani, Maharashtra has released a large fruited variety with an accession member of HB-10.

Wood apple is highly heterozygous, cross pollinated fruit crop. It is continuously propagated by seeds. Due to predominant cross pollination and seed propagation wide variation exits among the genotypes with respect to tree size, shape, flowering time, fruit length, fruit diameter and quality characters such as TSS, acidity etc. Hence, it is necessary to select the genotypes having the desirable characters among the various genotypes.

Present investigation was carried out to find out genetic variability on the basis of yield and yield attributes of different genotypes will helpful to conserve valuable germplasm and could be protected from being eroded, and its utilization in further wood apple

improvement programme. Due to cross pollination and predomination of seed propagation over a long period of time, it gives immense opportunity to locate elite trees having important horticultural traits. In spite of the fact, that Wood apple can withstand adverse climatic conditions and can be grown in various types of soils. Germplasm utilization of underutilized fruit crops and devising vegetative propagation methods for selected high yielding genotypes have been the major constrains for popularizing these nutritious sub-tropical fruits among the farmers (Arora and Rao, 1995). There are no advance cultivars available or selected in this important minor fruit species due to the lack of characterization and evaluation studies. Genetic variability of this fruit species is under threat due to the large scale urbanization, developmental activities and need to conserve the genetic variability of this minor nutritious crop by different *ex situ* and *in situ* approaches. It is felt necessary to develop Wood apple genotype having earliness, short stature, precocious bearer, high TSS and high pulp content. Variability and correlation study analysis in Wood apple genotypes helps to determine the yield contributing characters and nature of relationship with yield and thus helps in selection of some elite Wood apple genotypes. It acts as a base for genetic improvement through selection and thus helps in selection of elite Wood apple genotypes from available diverse genetic population. Therefore, the present investigation was planned to evaluate the variability of available Wood apple genotypes and to estimate the extent of genotypic and phenotypic variability among wood apple genotype.

## Material and Methods

The present investigation entitled "GENETIC VARIABILITY STUDIES IN WOODAPPLE (*Feronia limonia* L.)." was carried out on thirty-two years old Wood apple orchard during the year 2017-2018 at Main Garden Department of Horticulture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The details of materials used and methods followed during the course of investigations are summarized below. In the present investigation 22 genotypes were selected, which have produced flowers during February-March 2017. Out of 22 genotypes 9 genotypes are located in block number 11 and 13 genotypes are located in block number 49. They were coded in the following manner.

**Coding of Genotypes**

| ***Block No:- 11*** |
|---|
| 1-AKWa14-AKWa5 7-AKWa9 |
| 2-AKWa25-AKWa68-AKWa11 |
| 3-AKWa4 6-AKWa7 9-AKWa13 |
| ***Block No:- 49*** |
| 10-AKWa1413-AKWa1716-AKWa2019-AKWa23 |
| 11-AKWa1514-AKWa1817-AKWa2120-AKWa24 |
| 12-AKWa1615-AKWa1918-AKWa2221-AKWa25 |
| 22-AKWa26 |

One plant of each treatment selected, marked, and kept under observations for recording various observations. The observations recorded were as per the keys explained by Anon., 1980, Kaulgud*et al*. (1997), Rodríguez-Medina. *et al*., (2010) and Patil, (2014). Since the study is based on single plant observation, the samples for observations were collected from each direction i.e. East, West, South and North and each of these directions were considered as one replication. Further, the observed characteristics were subjected to RBD analysis.

## Results and Discussion

The quantitative morphological observations were recorded on randomly selected individual competitive tree from each genotype, in four replications viz., North, South, East, West direction. The data in respect to Stem Girth (cm), Tree Height (m), Bark color and Growth habit were recorded as a single replication and analyzed by using standard deviation. The characters regarding Number of fruit/tree, Length of fruit (cm), Fruit diameter (cm), Fruit weight (g), Number of fruits per kg, Skull Weight (g), Skull Thickness (mm), Weight of pulp (g), Pulp (%), Pulp: Shell ratio, Number of seeds per 100g pulp, Weight of seed per 100g pulp, Seed size (mm),Date of flower initiation, Duration of Flowering, Pulp colour, TSS (°Brix), Acidity (%), TSS/Acid ratio, Reducing sugars(%),Pectin content(%),Non-reducing sugars (%) and Total sugars (%)were recorded, statistically analyzed and are presented in this chapter under following headings

### Analysis of Variance

The analysis of variance was carried out for all the characters under study to know whether the genotypes included differed significantly among themselves. Analysis of variance for all the characters presented in the Table 1.

Mean sum of square (Table:1) revealed that for Number of primary branches, Number of secondary branches, regarding Number of fruit/tree, Length of fruit (cm), Fruit diameter (cm), Fruit weight (g), Number of fruits per kg, Skull Weight (g), Skull Thickness (mm), Weight of pulp (g), Pulp (%), Pulp: Shell ratio, Number of seeds per 100g pulp, Weight of seed per 100g pulp (g), Seed size (mm), Pulp colour, TSS (°Brix), Acidity (%), TSS/Acid ratio, Reducing sugars(%),Non-reducing sugars (%), Total sugars (%) and Pectin content(%)were significant at one percent and five percent level, which indicated genotypes studied were differed from each other. This indicated presence of substantial amount of genetic variability among the different Wood apple genotypes.

Singh. *et al*., (2016) also reported that in terms of fruit shape, size, colour and qualitative characters were highly significant in Wood apple.

### Genetic Variability Studies

With a view to understand the extent to which the observed variation was due to genetic factors, the mean, range, genotypic coefficient of variance (GCV), phenotypic coefficient of variance (PCV), expected genetic advance as per cent over mean (EGA), heritability ($h^2$), were worked out for the traits of 22 genotypes.

### Range of Mean Performance

Mean performance of the genotypes for thirty characters under study has been presented in Table 2, 3, 4 and 5.

**Table 1:** Analysis of variance of means for different characters

| Sr. No. | Character | Mean some square | | |
|---|---|---|---|---|
| | | Replication | Treatment | Error |
| 1 | Number of primary branches | 0.005 | 1.35** | 0.005 |
| 2 | Number of secondary branches | 7.94 | 2.77** | 3.42 |
| 3 | Number of fruit/tree | 50.98 | 12611.1** | 98.8 |
| 4 | Length of fruit (cm) | 0.036 | 0.10** | 7.02 |
| 5 | Fruit diameter (cm) | 0.009 | 0.04** | 0.13 |
| 6 | Fruit weight (g) | 1125.1 | 10542.6** | 1500.6 |
| 7 | Number of fruits per kg. | 0.42 | 2.18** | 0.19 |
| 8 | Skull Weight (g) | 534.7 | 973.8** | 0.04 |
| 9 | Skull Thickness (mm) | 0.007 | 0.12** | 0.06 |
| 10 | Weight of pulp (g) | 1647.5 | 6515.09** | 1.89 |
| 11 | Pulp (%) | 29.7 | 0.09** | 0.26 |
| 12 | Pulp: Skull ratio | 0.01 | 0.05** | 0.20 |
| 13 | Number of seeds per 100g pulp (g) | 1008.04 | 7409.2** | 865.7 |
| 14 | Weight of seed per 100g pulp(g) | 1.31 | 11.8** | 2.02 |
| 15 | Seed size (mm) | 0.03 | 0.24** | 0.03 |
| 16 | Yield per plant (Kg) | 119.09 | 2597.4** | 68.5 |
| 17 | TSS (Brix) | 1.15 | 1.77** | 0.40 |
| 18 | Acidity (%) | 0.03 | 2.55** | 0.08 |
| 19 | TSS: Acid ratio | 2.19 | 36.06** | 1.80 |
| 20 | Reducing sugars(%) | 0.05 | 0.004** | 0.001 |
| 21 | Non-reducing sugars (%) | 0.09 | 0.02** | 0.01 |
| 22 | Total sugars (%) | 0.13 | 0.02** | 0.008 |
| 23 | Pectin content (%) | 0.009 | 0.21** | 0.009 |

*-significant at 5% level **-significant at 5% and 1%level

**Table 2:** Mean performance of Wood apple genotypes based on tree and flowering characters

| Genotype | Stem girth (cm) | Tree height (m) | Number of primary branches | Number of secondary branches | Bark colour | Growth habit | Date of flower initiation | Duration of flowering | Pulp colour |
|---|---|---|---|---|---|---|---|---|---|
| AKWa1 | 157 | 11.3 | 4 | 15 | Dark black | Upright | 2nd week of feb. | 5 to 6 weeks | Brown |
| AKWa2 | 129 | 10.7 | 7 | 18 | Black | Upright | 1st week of feb. | 6 to 7 weeks | Brown |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| AKWa4 | 91 | 6.5 | 2 | 8 | Black | Spreading | 3rd week of feb. | 4 to 6 weeks | Light brown |
| AKWa5 | 141 | 9.6 | 3 | 17 | Black | Upright | 2nd week of feb. | 6 to 7 weeks | Light brown |
| AKWa6 | 96 | 9 | 4 | 11 | Black | Upright | 1st week of feb. | 7 to 8 weeks | Brown |
| AKWa7 | 118 | 10.3 | 3 | 10 | Light black | Upright | 4th week of feb. | 3 to 4 weeks | Light brown |
| AKWa9 | 133 | 8.6 | 6 | 16 | Dark black | Upright | 4th week of feb. | 6 to 7 weeks | Light brown |
| AKWa12 | 100 | 7.6 | 4 | 11 | Dark black | Upright | 4th week of feb. | 4 to 6 weeks | Light brown |
| AKWa13 | 107 | 8 | 2 | 10 | Dark black | Spreading | 2nd week of feb. | 5 to 7 weeks | Brown |
| AKWa14 | 160 | 11.6 | 5 | 18 | Black | Upright | 4th week of feb. | 6 to 9 weeks | Brown |
| AKWa15 | 157 | 11.7 | 6 | 12 | Light black | Upright | 1st week of march | 6 to 7 weeks | Dark brown |
| AKWa16 | 144 | 10.8 | 4 | 16 | Dark black | Upright | 3rd week of feb. | 5 to 7 weeks | Brown |
| AKWa17 | 129 | 9.8 | 3 | 15 | Black | Upright | 2nd week of feb. | 4 to 7 weeks | Light brown |
| AKWa18 | 164 | 11 | 3 | 13 | Light black | Spreading | 3rd week of feb. | 5 to 6 weeks | Brown |
| AKWa19 | 90 | 7.5 | 4 | 10 | Black | Upright | 1st week of march | 6 weeks | Dark brown |
| AKWa20 | 86 | 8.1 | 3 | 13 | Dark black | Upright | 1st week of march | 5 to 6 weeks | Dark brown |
| AKWa21 | 109 | 8.3 | 3 | 12 | Dark black | Upright | 2nd week of feb. | 7 to 8 weeks | Brown |
| AKWa22 | 173 | 10.2 | 4 | 13 | Black | Spreading | 3rd week of feb. | 4 to 6 weeks | Light brown |
| AKWa23 | 80 | 7.7 | 3 | 13 | Light black | Upright | 3rd week of feb. | 7 weeks | Light brown |
| AKWa24 | 158 | 11.8 | 5 | 13 | Dark black | Spreading | 4th week of feb. | 7 to 8 weeks | Light brown |
| AKWa25 | 142 | 10.4 | 8 | 20 | Black | Upright | 4th week of feb. | 4 to 6 weeks | Brown |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| AKWa26 | 106 | 10.9 | 6 | 14 | Black | Upright | 3rd week of feb. | 6 to 7 weeks | Brown |

The stem girth range of the studied genotypes was observed 80cm to 173cm.Where, significantly highest stem girth (173cm) was recorded in AKWa22, and it was at par with AKWa18 (164cm) respect to stem girth. AKWa23 has recorded least stem girth(80cm). The mean stem girth of twenty-two genotypes was found 125.9cm.Tree height recorded varied from 6.5m to 11.8m. The highest tree height (11.8m) was recorded by the genotype AKWa24, AKWa15 was also at par with the AKWa24 (11.7m). The minimum tree height (6.5m) was recorded by AKWa4. 9.6m was the mean tree height of twenty-two genotypes. Number of primary branches was ranged from 2 to 8. The genotype AKWa25 was recorded significantly maximum number of primary branches (8), AKWa2 (7) was also at par with the AKWa25. The genotype AKWa4 was recorded minimum number of primary branches (2).The mean of number of primary branches was found 3.7.Number of secondary branches was ranged from 8 to 20. The genotype AKWa25 was recorded significantly maximum number of secondary branches (20). AKWa2 (18) and AKWa14 (18) were also at par with the AKWa25. The genotype AKWa4 was recorded minimum number of secondary branches (8).The mean of number of secondary branches was found (12).There meager variation was observed with respect to bark colour there were three types of bark colour observed i. e. light black, dark black and black. Four genotypes had shown light black bark colour, eight genotypes had shown dark black bark colour and ten genotypes had shown black bark colour.

Growth habits of studied twenty-two genotypes were recorded in two types of habit i.e. upright and spreading. Seventeen genotypes showed upright growth habit and five genotypes showed spreading type of growth habit out of twenty-two wood apple genotypes. There huge variation was observed with respect to date of flower initiation among the genotypes under study. The date of flower initiation varied from first week of February to first week of March. The genotype AKWa15, AKWa19 and AKWa20 produced flowers during first week of March and all other studied genotypes produced flowers in various weeks of February. In which genotypes AKWa2 and AKWa6 were observed to produce flowers in first week of February. Duration of flowering in the studied genotypes of wood apple was observed in between three to nine months from date of flower initiation. In which maximum flowering duration was observed in genotype AKWa14 (6-9 weeks). And genotype AKWa7 showed least flowering duration i.e. 3 to 4 weeks from date of flower initiation. There meager variation was observed with respect to pulp colour there were three types of pulp colour observed in twenty-two genotypes i.e. light brown, dark brown and brown. Nine genotypes had showed light brown pulp colour, three genotypes had showed dark brown pulp colour and ten genotypes had showed brown pulp colour.

**Table 3:** Mean performance of Wood apple genotypes based on fruit characters

| Genotype | Fruit weight (g) | Weight of pulp (g) | Pulp (%) | Length of fruit (cm) | Fruit diameter (cm) | Number of fruits per kg. | Number of fruit/tree | Yield per plant (Kg) |
|---|---|---|---|---|---|---|---|---|
| AKWa1 | 297.4 | 196.5 | 65.7 | 11.9 | 12.3 | 3.4 | 246.7 | 72.2 |
| AKWa2 | 389.9 | 262.7 | 66.9 | 13.5 | 14.4 | 2.4 | 333 | 137.6 |
| AKWa4 | 293.7 | 177.4 | 60.2 | 12.1 | 14.5 | 3.8 | 153.2 | 41 |
| AKWa5 | 306.6 | 194.4 | 63.5 | 11.8 | 12.1 | 3.1 | 174.7 | 55.5 |
| AKWa6 | 352.3 | 216.4 | 61.3 | 13.2 | 13.8 | 2.7 | 198.5 | 72.9 |
| AKWa7 | 290.7 | 183.1 | 62.9 | 11.8 | 12.7 | 3.2 | 87.5 | 27.2 |
| AKWa9 | 287.4 | 156.6 | 54.1 | 12.6 | 12.1 | 3.5 | 112.7 | 33.2 |
| AKWa12 | 202.2 | 104.2 | 51.8 | 9.4 | 10.1 | 4.9 | 74 | 15.02 |
| AKWa13 | 335.2 | 209.8 | 62.5 | 12.9 | 14.1 | 2.8 | 103.7 | 37.3 |
| AKWa14 | 347.3 | 210.05 | 59.7 | 12.9 | 13.9 | 2.5 | 174.2 | 68.7 |
| AKWa15 | 380.7 | 254.9 | 66.7 | 13.6 | 15.4 | 2.6 | 165.2 | 63.7 |
| AKWa16 | 360 | 219.9 | 61.07 | 13.2 | 14.8 | 2.8 | 136.7 | 49.3 |
| AKWa17 | 317.8 | 175.9 | 54.5 | 12.3 | 13.2 | 3.2 | 153.2 | 47.3 |
| AKWa18 | 313.2 | 180.05 | 56.5 | 13.1 | 14.5 | 3.5 | 144 | 40.6 |
| AKWa19 | 314.9 | 196.5 | 62.5 | 12.7 | 14.1 | 3.4 | 130.2 | 39.05 |
| AKWa20 | 224.2 | 124.4 | 55.05 | 11.1 | 12.2 | 4.4 | 105.7 | 24.2 |
| AKWa21 | 297.9 | 182.1 | 52.02 | 12.4 | 13.4 | 3.2 | 152.7 | 47.4 |
| AKWa22 | 263.9 | 103.7 | 59.1 | 11.3 | 12.4 | 4.0 | 133.5 | 33.5 |
| AKWa23 | 190.5 | 157.1 | 53.7 | 10.6 | 10.7 | 5.3 | 99.5 | 18.8 |
| AKWa24 | 341.7 | 209.2 | 60.9 | 13.4 | 14.2 | 2.8 | 136.5 | 48.2 |
| AKWa25 | 297.4 | 168.1 | 56.6 | 12.5 | 13.3 | 3.6 | 165.2 | 45.1 |
| AKWa26 | 297.4 | 191.2 | 63.8 | 12.4 | 13.3 | 3.5 | 176.2 | 49.9 |
| Range | 190.5 - 389.9 | 103.7 - 262.7 | 51.8 - 66.9 | 9.4 - 13.6 | 10.15 - 15.45 | 2.47 - 5.32 | 74 - 333 | 15 - 137.6 |
| Mean | 304.6 | 185.2 | 59.6 | 12.33 | 13.2 | 3.43 | 152.6 | 48.5 |
| SE(m) | 19.3 | 16.6 | 2.77 | 0.55 | 0.61 | 0.22 | 4.97 | 4.13 |
| CV | 12.7 | 18 | 9.29 | 8.97 | 9.21 | 12.8 | 6.51 | 17.04 |
| CD(5%) | 54.7 | 47.1 | 7.83 | 1.56 | 1.73 | 0.62 | 14.05 | 11.6 |

The fruit weight of studied genotypes fall in between 190.5 to 389.9g. The highest fruit weight (389.9g) was found in the genotypeAKWa2.Minimum fruit weight (190.5g) was found in the genotype AKWa23.The mean fruit weight of twenty-two genotypes was 304.6g.Weight of pulp of studied genotypes was in between 103.7 to 262.7g. The highest weight of pulp (262.7g) was found in the genotype AKWa2. Minimum weight of pulp (103.7) was found in the genotype AKWa22. The mean weight of pulp of twenty-two genotypes was 185.2g.

Pulp percent of studied Wood apple genotypes was observed in between 51.8 to 66.9%. The genotype AKWa2 had highest pulp percent (66.9%) and the genotypes AKWa1 and AKWa15 were at par with AKWa2 with respect to pulp percent. The genotype AKWa12 had minimum pulp percent (51.8%).The mean pulp percent of twenty-two genotypes was found 59.6%.

Length of fruit of studied wood apple genotypes was observed in between 9.4 to 13.6cm. Significantly maximum length of fruit (13.6cm) was observed in genotype AKWa15. Genotypes AKWa2, AKWa6, AKWa16, AKWa18 and AKWa24 were at par with AKWa15 in respect to length of fruit. The genotype AKWa12 had minimum length of

fruit (9.4cm). The mean length of fruit of twenty-two genotypes was found 12.33cm.

The fruit diameter was found in between 10.15cm to 15.45cm.Significantly maximum fruit diameter (15.45cm) was observed in AKWa15.The minimum fruit diameter (10.15cm) was observed in AKWa12.The mean fruit diameter of twenty-two genotypes was 13.2cm.

Number of fruit per kg was counted in between 2.47 to 5.32. Significantly maximum number of fruit per kg (5.32) was counted in AKWa23. The minimum number of fruit per kg (2.47) was counted in AKWa2. The mean number of fruit per kg of twenty-two genotypes was 3.43.

Number of fruit/tree was counted in between 74 to 333. Significantly maximum number of fruit/tree (333) was found in AKWa2. The minimum number of fruit/tree (74) was found in AKWa12. The mean number of fruit/tree of twenty-two genotypes was 152.6.

The Yield per plant of the studied germplasm varied from 15kg to 137.6kg.The yield per plant (137.6kg) was significantly highest in genotype AKWa2, whereas the minimum yield per plant (15kg) was found in genotype AKWa12. The average yield per plant for twenty-two genotypes was 48.5kg.

**Table 4:** Mean performance of Wood apple genotypes based on skull and seed characters

| Genotype | Skull weight (g) | Skull thickness (mm) | Pulp: Skull | Number of seeds per 100g pulp | Weight of seed per 100g pulp | Seed size (mm) |
|---|---|---|---|---|---|---|
| AKWa1 | 92 | 3.17 | 2.15 | 67.27 | 4.50 | 2.47 |
| AKWa2 | 124.6 | 3.37 | 2.10 | 71 | 3.73 | 2.72 |
| AKWa4 | 106.2 | 3.45 | 1.67 | 116.2 | 5.66 | 2.77 |
| AKWa5 | 107.5 | 3.4 | 1.87 | 101.8 | 5.69 | 3.17 |
| AKWa6 | 134.05 | 3.8 | 1.61 | 114.8 | 5.45 | 3.2 |
| AKWa7 | 104.7 | 3.72 | 1.75 | 108.5 | 4.88 | 2.82 |
| AKWa9 | 121.6 | 3.8 | 1.28 | 137.4 | 7.98 | 2.82 |
| AKWa12 | 96.1 | 3.52 | 1.09 | 165.2 | 7.86 | 2.42 |
| AKWa13 | 124.2 | 3.57 | 1.7 | 125.4 | 4.37 | 2.27 |
| AKWa14 | 135 | 3.62 | 1.62 | 98.5 | 5.09 | 2.57 |
| AKWa15 | 119.1 | 3.47 | 2.14 | 83.36 | 4.43 | 2.6 |
| AKWa16 | 134.7 | 3.65 | 1.63 | 118.1 | 5.27 | 2.97 |
| AKWa17 | 135.7 | 3.5 | 1.29 | 133 | 5.96 | 2.52 |
| AKWa18 | 125.4 | 3.57 | 1.42 | 116.1 | 5.45 | 2.95 |
| AKWa19 | 138.1 | 3.87 | 1.55 | 122.1 | 5.39 | 2.95 |
| AKWa20 | 135.6 | 3.55 | 1.27 | 152.7 | 7.55 | 2.45 |
| AKWa21 | 100.9 | 3.5 | 1.34 | 119 | 5.82 | 2.65 |
| AKWa22 | 100.3 | 3.22 | 1.62 | 156.4 | 8.00 | 2.4 |
| AKWa23 | 98.6 | 3.27 | 1.03 | 214.9 | 9.9 | 2.64 |
| AKWa24 | 131.1 | 3.5 | 1.60 | 132.5 | 5.9 | 2.65 |
| AKWa25 | 124.8 | 3.6 | 1.42 | 123.1 | 5.75 | 2.57 |
| AKWa26 | 99.8 | 3.57 | 1.91 | 114.6 | 6.22 | 2.77 |
| Range | 92 - 138.1 | 3.17 - 3.87 | 1.03 - 2.15 | 67.27- 214.9 | 3.73 - 9.9 | 2.27 - 3.2 |
| Mean | 117.77 | 3.53 | 1.59 | 122.36 | 5.94 | 2.7 |
| SE(m) | 10.21 | 0.12 | 0.16 | 8.26 | 0.45 | 0.09 |
| CV | 17.33 | 7.18 | 20.74 | 7.57 | 8.61 | 6.82 |
| CD(5%) | 28.85 | 0.35 | 0.46 | 23.34 | 1.28 | 0.26 |

The skull weight of the studied genotypes was observed 92 to 138.1g. Where, significantly highest skull weight (138.1g) was recorded in AKWa19. AKWa17 and AKWa20 are at par with the AKWa19 with respect to skull weight.AKWa1 has recorded least skull weight (92g).The mean skull weight of twenty-two genotypes was found 117.77g.

Skull thickness recorded varied from 3.17mm to 3.87mm.The highest skull thickness (3.87mm) was recorded by the genotype AKWa19, AKWa7 is also at par with the AKWa19.The minimum skull thickness (3.17mm) was recorded by AKWa1. 3.53mm was the mean skull thickness of twenty-two genotypes. Pulp: skull ratio was ranged from 1.03 to 2.15.The genotype AKWa1 was recorded significantly maximum pulp: skull (2.15). The genotype AKWa23 was recorded with minimum pulp: skull ratio (1.03).The mean pulp: skull ratio was found 1.59. Number of seeds per 100g pulp was recorded in studied genotypes from 67.27 to 214.9. The genotype AKWa23 was observed with significantly maximum number of seeds per 100g pulp (214.9). The genotype AKWa1 was recorded with minimum number of seeds per 100g pulp (67.27). The average number of seeds per 100g pulp, was recorded (217.8).

Weight of seed per fruit was recorded in genotypes in between 3.73g to 9.9g. The significantly highest weight of seed per 100g pulp (9.9g) was recorded in genotype AKWa23. The minimum weight of seed per 100g pulp (3.73g) was recorded in AKWa2. The mean weight of seed per 100g pulp was recorded 10.61g.Seed size was observed in between 2.27 to 3.2mm. The highest seed size (3.2mm) was observed in AKWa6, AKWa5 is also at par with AKWa6. The minimum seed size (2.27mm) was recorded in genotype AKWa13. The average seed size was recorded 2.7mm.

**Table 5:** Mean performance of Wood apple genotypes based on fruit biochemical characters

| Genotype | Total soluble solids ($^0$Brix) | Acidity (%) | TSS: Acid | Total sugar (%) | Reducing sugars (%) | Non-reducing sugars (%) | Pectin content (%) |
|---|---|---|---|---|---|---|---|
| AKWa1 | 12.45 | 1.33 | 10.2 | 1.92 | 1.22 | 0.7 | 1.60 |
| AKWa2 | 13.42 | 1.54 | 9.62 | 2.05 | 1.28 | 0.81 | 1.79 |
| AKWa4 | 11.25 | 2.17 | 6 | 2.12 | 1.26 | 0.85 | 1.12 |
| AKWa5 | 12.12 | 2.15 | 6.55 | 2.15 | 1.24 | 0.91 | 1.26 |
| AKWa6 | 11.9 | 1.17 | 10.6 | 1.99 | 1.26 | 0.73 | 1.49 |
| AKWa7 | 12.05 | 2.07 | 7.7 | 1.98 | 1.22 | 0.75 | 1.29 |
| AKWa9 | 12.87 | 1.37 | 10.1 | 1.99 | 1.26 | 0.73 | 1.35 |
| AKWa12 | 13.35 | 2.76 | 6.04 | 1.95 | 1.23 | 0.7 | 1.08 |
| AKWa13 | 12.32 | 3.16 | 4.11 | 2.04 | 1.25 | 0.79 | 1.06 |
| AKWa14 | 12.8 | 1.12 | 12.1 | 2.03 | 1.23 | 0.80 | 1.56 |
| AKWa15 | 11.52 | 2.84 | 4.12 | 1.99 | 1.22 | 0.76 | 1.12 |
| AKWa16 | 12.32 | 2.87 | 4.5 | 1.97 | 1.15 | 0.81 | 1.19 |
| AKWa17 | 11.62 | 2.36 | 5.9 | 2.04 | 1.19 | 0.84 | 1.18 |
| AKWa18 | 11.17 | 3.12 | 4.01 | 2.09 | 1.26 | 0.76 | 1.09 |
| AKWa19 | 12.37 | 2.87 | 4.48 | 2.17 | 1.27 | 0.88 | 1.21 |
| AKWa20 | 12.32 | 1.61 | 7.90 | 1.82 | 1.25 | 0.62 | 1.49 |
| AKWa21 | 13.47 | 1.35 | 11.02 | 2.13 | 1.25 | 0.88 | 1.81 |
| AKWa22 | 12.37 | 3.69 | 3.35 | 1.96 | 1.23 | 0.73 | 1.07 |
| AKWa23 | 12.5 | 1.22 | 10.55 | 2.10 | 1.25 | 0.86 | 1.59 |
| AKWa24 | 11.37 | 2.91 | 10.55 | 1.98 | 1.19 | 0.79 | 1.26 |
| AKWa25 | 12.87 | 1.24 | 4.03 | 1.97 | 1.19 | 0.78 | 1.50 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| AKWa26 | 12.62 | 1.59 | 11.6 | 2.02 | 1.29 | 0.74 | 1.45 |
| Range | 11.17-13.47 | 1.12-3.69 | 3.35-12.19 | 1.82-2.17 | 1.15-1.29 | 0.62-0.91 | 1.06-1.81 |
| Mean | 12.32 | 2.11 | 7.51 | 2.02 | 1.23 | 0.78 | 1.34 |
| SE(m) | 0.31 | 0.14 | 0.67 | 0.047 | 0.018 | 0.054 | 0.047 |
| CV | 5.19 | 13.76 | 17.87 | 4.64 | 2.98 | 13.80 | 7.12 |
| CD(5%) | 0.90 | 0.41 | 1.89 | 0.13 | 0.052 | 0.15 | 0.13 |

The total soluble solids were analyzed and recorded in between 11.17 –13.47$^0$Brix. The AKWa21 had the highest TSS (13.47$^0$Brix) among all the genotypes. While AKWa2 and AKWa12 were at par with the AKWa21. The genotype AKWa18 had lowest TSS (11.17$^0$Brix). The average TSS for twenty-two genotypes was 12.32$^0$Brix.Acidity was recorded and has been found between 1.12 to 3.69%. Significantly highest acidity (3.69%) was noted in genotype AKWa22. While the lowest acidity was noted in genotype AKWa14. However, the average acidity of twenty-two genotypes was 2.11%.

TSS: acid ratio was recorded in between 3.35 to 12.19. Significantly highest TSS: acid ratio (12.19) was observed in genotype AKWa14. While the lowest TSS: acid ratio (3.35) was recorded in genotype AKWa22. The mean TSS: acid ratio recorded in twenty-two genotypes was 7.51. The total sugars of wood apple in different genotypes was recorded in between 1.82 to 2.17%. The highest total sugars (2.17%) was recorded in genotype AKWa19, and AKWa5, AKWa21 and AKWa4 were at par with AKWa19 and each other. The lowest total sugars (1.82%) was recorded in genotype AKWa20. However, the average total sugar was recorded in twenty-two genotypes as 2.02%.The reducing sugars of wood apple in different genotypes was recorded in between 1.15 to 1.29%. The highest reducing (1.29%) was recorded in genotype AKWa26, While AKWa2, AKWa19, AKWa18, AKWa9, AKWa6 and AKWa4 were at par with AKWa26. The lowest reducing sugars (1.15%) was recorded in AKWa16. The average reducing sugar was recorded in twenty-two genotypes of wood apple as 1.23%. The non-reducing sugars of wood apple in different genotypes was recorded in between 0.62 to 0.91%. Significantly highest non-reducing sugar (0.91%) was recorded in genotype AKWa5. While, the lowest non-reducing sugar (0.62%) was observed in genotype AKWa20. The average non-reducing sugars was recorded in twenty-two genotypes of wood apple as 0.78%.The pectin content of wood apple in different genotypes was recorded in between 1.06 to 1.81%. Significantly highest pectin content (1.81%) was recorded in genotype AKWa21 and genotype AKWa2 was at par with AKWa21. While, the genotype AKWa13 had the lowest pectin content (1.06%). The average pectin content was recorded in twenty-two genotypes of wood apple as 1.34%.

**Genotypic Coefficient of Variation (GCV)**

The data presented in the Table 6. Revealed that, the genotypic coefficient of variation (GCV) ranged from 2.08 per cent (reducing sugars) to 38.95 per cent (TSS: acid ratio) for different characters under investigation. Genotypic coefficient of variation was of low order for the characters viz., fruit diameter (8.82%), seed size (8.41%), length of fruit (7.04%), pulp % (6.31%), non-reducing sugar (5.84%), total soluble solids (4.76%) and total sugar (3.36%). Whereas the moderate order of GCV were recorded for weight of pulp (19.84%), number of seeds per 100g pulp (18.56%), pulp: skull (16.75%), pectin content (16.66%), fruit weight (15.60%), weight of seed per 100g pulp (14.26%) and skull weight (10.02%). While, high orders of GCV were recorded for acidity (37.10%).

**Phenotypic Coefficient of Variation (PCV)**

The data from the Table 6. Indicated that, the phenotypic coefficient of variation ranged from 3.64% (reducing sugar) to 42.85% (TSS: acid ratio) for the various characters studied. Low order phenotypic coefficient of variation

was recorded for the character fruit diameter (12.76%), length of fruit (11.41%), pulp % (11.24%), skull thickness (10.83%), seed size (10.83%), TSS (7.04%) and total sugar (5.73%). While, moderate order of PCV were observed for characters number of seed per 100g pulp (22.66%), weight of seed per 100g pulp (20.98%), fruit weight (20.13%), skull weight (20.03%), pectin content (18.12%) and non-reducing sugar (14.99%). While the high order of PCV were recorded for pulp: skull ratio (26.66%), weight of pulp (26.79%) and acidity (39.57%).

**Heritability Estimates in Broad Sense ($h^2$)**

Result presented in the Table 6, revealed that the higher heritability was observed for the characters acidity (87.91%), pectin content (84.54%), TSS: acid ratio (82.6%), fruit diameter (66.91%), number of seed per 100g pulp (65.39%), skull thickness (60.33%), seed size (60.33%) and fruit weight (60.1%). Whereas moderate heritability was recorded for the characters pulp weight (54.86%), weight of seed per 100g pulp (46.17%), TSS (45.62%), pulp: skull ratio (39.46%) and length of fruit (38.09%). While low heritability was found for the characters total sugar (34.36%), reducing sugar (32.68%), pulp % (31.53%), skull weight (25.03%) and non-reducing sugar (15.18%).

**Expected Genetic Advance (EGA)**

Expected genetic advance over mean was estimated for different characters and results are presented in Table 6. The findings indicated that, the expected genetic advance as percent of mean observed s in the range of 2.45% to 72.92%.High degree of genetic advance was found for the characters TSS: acid ratio (72.92%), acidity (71.66%), number of seed per 100g pulp (30.92%), weight of pulp (30.27%), pectin content (31.55%), fruit weight (24.92%), pulp: skull (21.67%) and weight of seed per 100g pulp (19.95%). Whereas moderate degree of genetic advance was found for the characters skull thickness (13.45%), seed size (13.45%), fruit diameter (12.56%), skull weight (10.32%), length of fruit (8.95%) and pulp percent (7.29%). Low degree of genetic advance was observed for total soluble solids (6.61%), non-reducing sugar (4.68%), total sugar (4.05%) and reducing sugar (2.45%).

**Table 6:** Estimates of variability, heritability, genetic advance and expected genetic advances per cent of mean

| Sr.no | Character | Range | Mean | GCV (%) | PCV (%) | Heritability ($h^2$) % | Expected genetic advance as % over mean |
|---|---|---|---|---|---|---|---|
| 1 | Fruit weight (g) | 190.5 - 389.9 | 304.6 | 15.60 | 20.13 | 60.1 | 24.92 |
| 2 | Weight of pulp (g) | 103.7 - 262.7 | 185.2 | 19.84 | 26.79 | 54.86 | 30.27 |
| 3 | Pulp (%) | 51.8 - 66.9 | 59.6 | 6.31 | 11.24 | 31.53 | 7.29 |
| 4 | Length of fruit (cm) | 9.4 -13.6 | 12.33 | 7.04 | 11.41 | 38.09 | 8.95 |
| 5 | Fruit diameter (cm) | 10.15 - 15.45 | 13.2 | 8.82 | 12.76 | 66.91 | 12.56 |
| 6 | Skull weight (g) | 92 - 138.1 | 117.77 | 10.02 | 20.03 | 25.03 | 10.32 |
| 7 | Skull thickness (mm) | 3.17 - 3.87 | 3.53 | 8.41 | 10.83 | 60.33 | 13.45 |
| 8 | Pulp : Skull | 1.03 - 2.15 | 1.59 | 16.75 | 26.66 | 39.46 | 21.67 |
| 9 | Number of seeds per 100g | 67.27- 214.9 | 122.36 | 18.56 | 22.95 | 65.39 | 30.92 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | pulp | | | | | | |
| 10 | Weight of seed per 100g pulp | 3.73 -9.9 | 5.94 | 14.26 | 20.98 | 46.17 | 19.95 |
| 11 | Seed size (mm) | 2.27 -3.2 | 2.7 | 8.41 | 10.83 | 60.33 | 13.45 |
| 12 | Total soluble solids (Brix) | 11.17-13.47 | 12.32 | 4.76 | 7.04 | 45.62 | 6.61 |
| 13 | Acidity (%) | 1.12-3.69 | 2.11 | 37.10 | 39.57 | 87.91 | 71.66 |
| 14 | TSS: Acid | 3.35-12.19 | 7.51 | 38.95 | 42.85 | 82.6 | 72.92 |
| 15 | Total sugar (%) | 1.82-2.17 | 2.02 | 3.36 | 5.73 | 34.36 | 4.05 |
| 16 | Reducing sugars (%) | 1.15-1.29 | 1.23 | 2.08 | 3.64 | 32.68 | 2.45 |
| 17 | Non-reducing sugars (%) | 0.62-0.91 | 0.78 | 5.84 | 14.99 | 15.18 | 4.68 |
| 18 | Pectin content (%) | 1.06-1.81 | 1.34 | 16.66 | 18.12 | 84.54 | 31.55 |

## Discussion

In a crop improvement programme the success of selection depends on genetic variability and correlation studies between the characters in the population. The genetic variability estimated in terms of genotypic coefficient of variation and phenotypic coefficient of variation is not adequate for the estimation of heritable variation. The heritability values, in broad sense are also helpful in selections on the basis of phenotypic performance of the quantitative characters. However, heritability estimates alone are not of any use in predicting the result of selection unless, it is accompanied by genetic advance (Johnson, *et al*., 1955[a&b]). The heritable variation among genotypes can be ascertained with greater degree of accuracy when heritability along with genetic advance is studied.

Considering these and ultimate aim exploiting all the possibilities for the improvement of the various characters studied, the results obtained in the present investigation are discussed here under.

### Analysis of Variance

Perusal of data presented in Table 1, revealed significant differences among genotypes for all the traits, suggesting presence of wide range of variation among all the genotypes for all the characters under study. This variation amongst the genotypes as regards to characters might be due to genetic variability, inherent characters and climatic adaptability in a region, which might prove an important diagnostic character for selection of genotypes for local conditions.

### Genetic Variability Studies

The study of genetic variability present in the existing genetic stock, the extent to which desirable characters are in heritable and the method and mode of selection is of prime importance in making any breeding programme success. The observed phenotypic variability is the resultant of genotypic and environmental factors. Mostly economic characters are quantities in heritance, which are influenced by genotypic and environmental interactions. Therefore, it is required to disintegrate the phenotypic variance in to genetic and environmental components. Simultaneously, the estimate of heritability that indicates the degree of transmissibility of a trait into the off springs and genetic advance, a measure of expected genetic gain in the next generation through selection is of paramount importance. Therefore, genetic parameters *viz,* genotypic and phenotypic coefficients of variation, heritability (in broad sense) and expected genetic advance (as per cent of mean) to

explore the possibilities of improvement of various traits were estimated.

Estimates of GCV, PCV and EGA as percent of means and heritability ($h^2$) are given in Table 6.

**Range**

The assessment of available germplasm for its nature and magnitude of genetic variability is a pre-requisite for developing any variety with high potential and the desired morphological and bio-chemical characters. This helps the breeder to assess and identify superior genotypes before initiating the breeding programme for improvement of any crop. In the present study involving twenty-two Wood apple genotypes, a wide range of variability observed for all the characters.

The yield of any crop is an important trait. Besides inherent genetic potential of genotypes, the yield is also influenced by environment. In Wood apple, fruit weight, weight of pulp, pulp; skull ratio, weight of seed per 100g pulp, number of seed per 100g pulp, length of fruit, diameter of fruit and number of fruits per plant were the yield contributing characters.

The range of the fruit weight was found in between 190.5 to 389.9 g, range of pulp weight was found in between 103.7 to 262.7 g, pulp percentage was ranged between 51.60 to 66.9, fruit length was ranged between 9.4 to 13.6 cm, fruit diameter was ranged between 10.15 to 15.45, skull weight was ranged between 92 to 138.1, skull thickness was ranged between 3.17 to 3.87, pulp: skull ratio was ranged between 1.03 to 2.15, number of seeds per 100g pulp was ranged between 67.27 to 214.9, weight of seeds per 100g pulp was ranged between 3.73 to 9.9 (g), seed size was ranged between 2.27 to 3.2 (mm), total soluble solids was ranged between 11.17 to 13.47 ($^0$Brix), acidity was ranged between 1.12 to 3.69 (%), TSS: acid ratio was ranged between 3.35 to 12.19, total sugar was ranged between 1.82 to 2.17 (%), reducing sugars was ranged between 1.15 to 1.29 (%), non-reducing sugars 0.62 to 0.91(%) and pectin content was ranged between 1.06 to 1.81 (%).

Hence wide range of variability for these traits was observed. This was indicative of better chance for improvement. Significant variability for various characters in Wood apple have been reported by various workers *viz*. Ghosh. *et al*. (2010),Singh. *et al*.(2016) and D. Pandey,. *et al*. (2008) in Bael. The above findings were in broad conformity with the reports of these workers.

**Genotypic and Phenotypic Coefficient of Variation**

It is essential to assess the genetic components of variability in the total variation before the variability can be utilized for further genetic improvement. The additive genetic variance will be the constant heritance portion of the total variation.

In the present investigation the phenotypic coefficient of variation (PCV) was higher than the genotypic coefficient of variation (GCV) for all the characters (Table 6), indicating the substantial modifying effect of environment in the expression of all traits studied. These results corroborate the view of Lal, (2002) in Bael and Misra. *et al.,* (2005) in Bael.

The highest genotypic coefficient of variation was observed for TSS: acid ratio, acidity (%), and pulp weight. High GCV is an indication of greater range of variability among the population and the scope of improvement of these characters through simple selection.

Similar findings pertaining to different traits including the characters like fruit weight, juice weight, seed number, rind thickness and core diameter Singh. *et al.,* (2009) in Punjab (India) in Hill lemon, Rai. *et al.,* (2002) in Bael.

Whereas, the highest phenotypic coefficient of variation was observed for TSS: acid ratio, acidity (%), pulp weight (g), pulp: skull ratio and number of seeds per 100g pulp.

The high PCV is an indication of the existence of wide scope of selection for the improvement of the traits from a considerable amount of variability present. Thus, a greater potential is expected in the selection for these characters.

Wide difference between PCV and GCV for yield implies it's susceptibility to environmental fluctuation, whereas narrow difference suggested their relative resistance to environmental alteration. This suggests the need for generation of variability either by introduction, exploration or by hybridization to get substantial gain in their improvement.

**Heritability and Expected Genetic Advance (EGA)**

The genotypic coefficient of variation is not sufficient to determine the amount of variation which is heritable. Burton (1952) also made clear that the heritable variation cannot be estimated through genetic coefficient of variation and as such the genotypic coefficient of variation together with heritability would furnish the most reliable information on the magnitude of genetic advance to be expected from selection.

High heritability indicated the effectiveness of selection based on phenotypic performance but does not necessarily mean a high genetic advance for the particular trait. The characters with high heritability when associated with high genetic gain may be attributed to the additive gene effects (Panse, 1957), which can be effectively improved by selection. On the other hand, high heritability and low genetic advance may be attributed to low phenotypic variability. These characters may be improved through hybridization, while low heritability estimates suggested that the selection for the character under consideration will not be effective.

Expected genetic advance as percent of mean observed was in the range of 2.45 to 72.92%.High degree of genetic advance was found for the characters TSS: acid ratio (72.92%), acidity (%) (71.66%), pectin content (31.55%), number of seeds per 100g pulp, pulp weight (30.27%), fruit weight (24.92%) and pulp: skull (21.67%). Whereas moderate degree of genetic advance was found for the characters weight of seeds per 100g pulp (19.95%), skull thickness (13.45%), fruit diameter (12.56%), fruit weight (10.32%) and fruit length (8.95%). Low degree of genetic advance was observed for pulp (%) (7.29%), total soluble solids (6.61%), non-reducing sugars (4.68%), total sugars (4.05%) and reducing sugars (2.45%). Similar findings with high heritability and EGA were pertaining to different traits reported for physico-chemical characteristics of Bael fruits by VP Singh and KK Mishra (2010).

Generally high heritability accompanied with high genetic advance in characters suggest that the inheritance of such character was governed mainly by additive gene effects and therefore improvement in these traits would be more effective by selection in the present material. During present study characters like TSS: acid ratio, acidity, pectin content, number of seeds per 100g pulp, weight of pulp and fruit weight had high heritability values along with the high genetic advance. Although, estimates of high heritability are useful to breeder as they provide basis of transmissible genes from parent to progeny. More reliable conclusion can be drawn when heritability is considered along with the genetic advance. Thus, the expressions of these traits were predominantly governed by additive gene effects and therefore selection based on phenotypic performance will be useful to improve these characters in future. More, over it was seen that these traits had less influence of the environment.

During present study estimates of high heritability along with moderate genetic advance were observed for the characters fruit diameter, skull thickness and seed size. These characters can be partially improved by selection, According to Panse and Sukhatme, (1954). When heritability is predominantly due to non-additive gene effects (dominance and epitasis) then the genetic gain by selection would be low, as observed in present study for these eighteen characters. Recurrent selection may be employed to carry out further improvement for these characters. The high heritability is being exhibited due to favorable influence of environment rather than genotype. The improvement in these traits would be more effective by selecting specific combinations.

## Conclusions

A wide range of variability was observed for all the characters. The estimates of genotypic coefficients of variation were lower than that of phenotypic coefficient of variation for all the characters indicating the substantial modifying effect of environment in the expression of all traits under study. The highest genotypic and phenotypic coefficient of variation was observed for the character, TSS: acid ratio (42.85 % (P), (38.95 (G)), acidity (39.57% (P), 37.10% (G)), weight of pulp (26.79% (P), 19.84% (G)), number of seeds per 100g pulp (22.95% (P), 18.56% (G)), weight of seed per 100g pulp (20.98% (P), 14.26% (G)) and pulp: skull (26.66% (P), 16.75% (G)) indicating predominance of additive gene action in the inheritance of this character revealing favorable response to selection by this character. In respect of other characters studied presence of low genotypic coefficient of variation as well as phenotypic coefficient of variation indicated predominance of non-additive type of gene action in the inheritance of these characters.

The heritability estimates (broad sense) for the characters studied showed wide range from acidity (87.91 %) to non-reducing sugars (15.18 %). This has extended the hope for reliability of selection in the present material studied. Since, it is broad sense heritability a caution has to be exercised for its direct application while making the selection. The genetic advance in the present study showed wide range reducing sugars (2.45 %) to TSS: acid ratio (72.92 %). These results observed with high values for expected genetic advance accompanied with high heritability estimates are indicative of fact that the improvement could be effectively realized through selection in these characters on phenotypic values. High heritability coupled with high genetic advanced observed for TSS: acid ratio, acidity, pectin content, number of seeds per 100g pulp, weight of pulp and fruit weight, indicated that these characters were governed largely through the additive gene effect and improvement of these characters may be achieved through phenotypic selection.

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