

**GENETIC VARIABILITY AND CORRELATION  
STUDIES IN WOOD APPLE  
(*Feronia limonia* L.)**

**THESIS**

**Submitted to  
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola  
in partial fulfilment of the requirements  
for the Degree of**

**MASTER OF SCIENCE  
IN  
HORTICULTURE  
(FRUIT SCIENCE)**

**By**

**SHINDE MAHADEV NAGANNATH**

**DEPARTMENT OF HORTICULTURE  
POST GRADUATE INSTITUTE, AKOLA**

**DR. PANJABRAO DESHMUKH KRISHI VIDYAPEETH,  
KRISHINAGAR PO, AKOLA (MS) 444104**

**Enrolment Number PP- 3400**

**2019**

## DECLARATION OF STUDENT

I hereby declare that, the experimental work and its interpretation of the thesis entitled “**GENETIC VARIABILITY AND CORRELATION STUDIES IN WOOD APPLE (*Feronia limonia* L.)**” or part thereof has neither been submitted for any other degree or diploma of any University, nor the data have been derived from any thesis / publication of any University or scientific organization. The sources of material used and all assistance received during the course of investigation have been duly acknowledged.

Place: Akola

(SHINDE MAHADEV NAGANNATH)

Date:    /    /2019

Enrolment No. PP-3400

## CERTIFICATE

This is to certify that the thesis entitled “**GENETIC VARIABILITY AND CORRELATION STUDIES IN WOOD APPLE (*Feronia limonia* L.)**” submitted in partial fulfilment of the requirement for the degree of “Master of Science in Horticulture (Fruit Science)” of Dr. Panjabrao Deshmukh Krishi Vidyapeeth; Akola is a record of bonafide research work carried out by **SHINDE MAHADEV NAGANNATH** under my guidance and supervision.

The subject of the thesis has been approved by the student’s Advisory Committee

Place: Akola  
Date: / /2019

**(Dr. U. A. Raut)**  
Chairman  
Advisory Committee

**Countersigned**

**Associate Dean,**  
Post Graduate Institute,  
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola.

THESIS APPROVED BY THE STUDENT’S ADVISORY COMMITTEE  
INCLUDING EXTERNAL EXAMINER (AFTER VIVA-VOCE)

1. Chairman Dr. U. A. Raut \_\_\_\_\_
2. Member Dr. D. M. Panchbhai \_\_\_\_\_
3. Member Dr. M. B. Nagdeve \_\_\_\_\_
4. Member Dr. S. S. Nichal \_\_\_\_\_
5. External Member ( ) \_\_\_\_\_

## ACKNOWLEDGEMENT

Every completed task has got many hands to accomplish it. At this moment of completion of my thesis, it's my immense pleasure in acknowledging my heartfelt gratitude to all those who extended help and support to me during the course of my work.

I was fortunate enough to have the guidance of **Dr. U. A. Raut**, Assistant professor, Department of Fruit Science, Dr. PDKV Akola. I express my sincere gratitude to him for the expert guidance and unfailing patience throughout my M. Sc. programme. This space is inadequate to express the extent of appreciation and thankfulness not just for his help in this work but for his understanding and benevolent nature as a person, that I have experienced in every interaction with him.

It is my privilege to record my sincere and devoted thanks to members of my advisory committee Dr. D. M. Panchbhai, Associate Dean, College of Agriculture, Nagpur, Dr. M. B. Nagdeve, Associate Dean, College of Agricultural Engineering, Dr. PDKV, Akola and Dr. S. S. Nichal, Associate Professor, Senior Research Scientist (Regional Research Unit of Soybean, Amravati) Dr. PDKV Akola for their keen interest and valuable suggestion and comments during investigation.

It is my proud privilege to record my deep sense of appreciation and sincere thanks to Dr. P. K. Nagre, Dean Faculty of Horticulture and Dr. S. G. Bharad, Head, Department of Fruit Science, Dr. PDKV, Akola for timely providing all facilities during the course of investigation.

I am grateful to Dr. Y. B. Taide, Associate Dean, Post Graduate Institute, Dr. PDKV, Akola for providing necessary facilities to carry out the research work.

I am immensely grateful to Dr. S. R. Patil, Dr. P. S. Joshi, Dr. S. V. Gholap and all the staff members of Department of Fruit Science Dr. PDKV, Akola.

I must mention my heartiest special thanks to Chief Scientist Dr. M. S. Khakare, Professor, AICRP on Dryland Agriculture and officers of Sri. G. T. Sawale for their kind co-operation during field work.

At this moment I also want to express my gratitude and appreciation to my parent's Sri. Naganath Dada Shinde and Smt. Sindhu Naganath Shinde for their love, blessings and guidance throughout my life. I also extend my gratitude to my sisters Sonali and Rupali and Brother Sagar.

I express my immense and whole hearted thanks to my seniors Akshay Sir, Sushant sir, Indranil sir and Shivaji sir and my lovely batchmates Hari, Aditya, Mangesh, Pavan, Abhay, Rajkumar, Ankit, Vishal, Amol, Niraj and Shrikant. My Friends Balaji, Prashant, Swapnil, Shivanand, Umesh, Dipak, Digambar, Ajay, Vijay, Sachin, Akshay, Mahesh, and Amar and my Junior Chetan, Dada, Vikram, Tukaram, Nilesh, Ram, Dashrath, Niketan, and Harshad.

I am very much thankful to all authors and researchers whose articles had helped me in organizing my research work on proper line and utilize proper tools for interpretation.

Lastly, I am very much thankful to Mr. Prakash Mohite (Shree graphics) for carefully and timely completion of this thesis.

Place : Akola

(Shinde Mahadev Nagannath)

Date : / / 2019

Enrolment No : PP-3400

## Table of Contents

| <b>Sr. no.</b> | <b>Particulars</b>      | <b>Page</b> |
|----------------|-------------------------|-------------|
| A              | Declaration of student  | i           |
| B              | Certificate             | ii          |
| C              | Acknowledgement         | iii         |
| D              | List of Tables          | vi          |
| E              | List of Plates          | vii         |
| F              | Abbreviations           | viii        |
| G              | Thesis Abstract         | x           |
| I              | INTRODUCTION            | 1-5         |
| II             | REVIEW OF LITERATURE    | 6-17        |
| III            | MATERIAL AND METHODS    | 18-29       |
| IV             | RESULTS AND DISCUSSION  | 30-58       |
| V              | SUMMARY AND CONCLUSIONS | 59-61       |
| VI             | LITERATURE CITED        | 62-66       |
|                | VITA                    | 67          |
|                | APPENDIX                | 68          |

**(A) List of Table**

| <b>Table</b> | <b>Title</b>  | <b>Page</b> |
|--------------|---|-------------|
| 1            | Analysis of variance of means for different characters.   | 32          |
| 2            | Mean performance of Wood apple genotypes based on tree and flowering characters.                        | 33          |
| 3            | Mean performance of Wood apple genotypes based on fruit characters.                                     | 35          |
| 4            | Mean performance of Wood apple genotypes based on shell and seed characters.                            | 38          |
| 5            | Mean performance of Wood apple genotypes based on fruit biochemical characters.                         | 40          |
| 6            | Estimates of variability, heritability, genetic advance and expected genetic advances per cent of mean. | 43          |
| 7            | Estimates of genotypic correlation coefficient for various characters.                                  | 46          |
| 8            | Estimates of phenotypic correlation coefficient for various characters.                                 | 47          |

**(B)**

**List of plates**

| <b>Plates</b> | <b>Title</b>                                  | <b>Page</b> |
|---------------|---|-------------|
| 1             | General View of experimental plot             | 29          |
| 2             | Variability in fruits of Wood apple genotypes | 58          |

## (C) Abbreviations

|                   |   |  |
|-------------------|---|--|
| (%)               | : | Percentage                             |
| <sup>0</sup> Brix | : | Degree Brix                            |
| $\sigma^2$        | : | Variance                               |
| /                 | : | per                                    |
| @                 | : | At the rate of                         |
| °C                | : | Degree Celsius                         |
| CD                | : | Critical difference                    |
| Cm                | : | Centimetre                             |
| CV                | : | Coefficient of variation               |
| d.f.              | : | Degree of freedom                      |
| ECV               | : | Environmental coefficient of variation |
| <i>et al.</i>     | : | et alia (and others)                   |
| etc.              | : | Etcetera                               |
| Fig.              | : | Figure                                 |
| g                 | : | Gram                                   |
| GCV               | : | Genotypic coefficient of variation     |
| $h^2$             | : | Heritability estimate (broad sense)    |
| Ha                | : | Hectare                                |
| i.e.              | : | That is                                |
| Kg                | : | Kilogram                               |
| M.S.S             | : | Mean sum of square                     |
| MW                | : | Meteorological Week                    |
| No.               | : | Number                                 |
| PCV               | : | Phenotypic coefficient of variation    |
| R                 | : | Residual factor                        |
| S.S.              | : | Sum of square                          |

|         |   |                                    |
|---------|---|------------------------------------|
| SE (m)+ | : | Standard error of means            |
| Sig.    | : | Significant                        |
| Viz.,   | : | Videlicet (Namely)                 |
| (PCV)   | : | Phenotypic correlation coefficient |
| (GCV)   | : | Genotypic correlation coefficient  |
| DWA     | : | Dryland Wood Apple                 |
| Mm      | : | Millimeter                         |
| ml      | : | Milliliter                         |
| Mg      | : | Milligram                          |
| Min     | : | Minute                             |
| NS      | : | North-South                        |

**(D) THESIS ABSTRACT**

- a) **Title of the thesis** : “**GENETIC VARIABILITY AND CORRELATION STUDIES IN WOOD APPLE (*Feronia limonia* L.)**”
- b) **Name of student** : **Shinde Mahadev Nagannath**
- c) **Name and Address of Major Advisor** : **Dr. U. A. Raut**  
Assistant Professor (Officer Incharge  
Main Garden)  
Department of Fruit Science,  
Dr. Panjabrao Deshmukh Krishi  
Vidyapeeth, Akola (M.S.). Pin - 444 104.
- d) **Degree to be awarded** : M.Sc. (Horticulture)
- e) **Year of award of degree** : 2019
- f) **Major subject** : Fruit Science
- g) **Total number of pages in the thesis** : 68
- h) **Total number of words in thesis abstract** : 383
- i) **Signature of the student** :
- j) **Signature, Name and Address of forwarding Authority** :

**Head,**  
Department of Fruit Science,  
Post Graduate Institute,  
Dr. Panjabrao Deshmukh Krishi  
Vidyapeeth, Akola (M.S).

---

**ABSTRACT**

The present investigation entitled “Genetic variability and correlation studies in wood apple (*Feronia limonia* L.)” was carried out on sixteen years old wood apple orchard during the year 2018-2019 at AICRP on Dryland Agriculture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola.

The flowering and duration of flowering of available germplasm varied from first week of February to first week of March and four weeks to eight 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 168.6 to 328.2 g, range of pulp weight was found in between 91.4 to 206.5 g, pulp percentage was ranged between 51.8 to 64.2, fruit length was ranged between 8.4 to 12.8 cm, fruit diameter was ranged between 9.5 to 13.6, shell weight was ranged between 74 to 127.1, shell thickness was ranged between 284 to 3.66, pulp: shell ratio was ranged between 1.13 to 2.0, number of seeds per 100g pulp was ranged between 94.3 to 208.9, weight of seeds per 100g pulp was ranged between 4.06 to 8.18 g, seed size was ranged between 2.06 to 3.23 mm, total soluble solids was ranged between 11.18 to 13.51 °Brix, acidity was ranged between 1.13 to 3.33 %, TSS: acid ratio was ranged between 3.43 to 10.30, total sugar was ranged between 1.84 to 2.15 %, reducing sugars was ranged between 1.17 to 1.28 %, non-reducing sugars 0.61 to 0.91 % and pectin content was ranged between 1.06 to 1.78 %.

The highest genotypic coefficient of variation was observed for TSS: acid ratio, acidity percentage, 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.

The correlations among the yield contributing characters weight of pulp, pulp: shell ratio, fruit length and fruit diameter was highly significant.

The genotypes DWA-27, DWA-52, DWA-76 and DWA-26 were found promising for future improvement programme. Hence, these genotypes may be given consideration while formulating selection indices for the improvement of yield and sensory qualities in Wood apple.

# CHAPTER I

## INTRODUCTION

### 1.1 Background information

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 acidissima* L., but it was ultimately changed to *Feronia limonia* (L.) Swingle. (Reuther *et al.*, 1967).

It is also popularly known as Kavath, Elephant apple, Monkey fruit, Curd fruit and Katha Bael in India. Wood apple is reported to be native of India and Sri 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 meters. It requires a monsoon climate with a distinct dry season for initial growth (Lande *et al.*, 2010).

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 and amphisarca. Seeds are compressed, oblong one celled with hard and hairy coating.

The chromosome number of the species is  $2n = 2x = 18$  which is a cross pollinated plant where pollination is mostly mediated by insects. As a result, heterozygosity is common in the species.

The exact area and annual fruit production of wood apple is not known, nor there is any report of organized cultivation of the plant, and it is mostly grown as stray plant and that too on waste land. But recently it has gained importance as a suitable Horticultural plant for soil reclamation and most hardy plant for cultivating in arid and semi-arid zones.

### **1.2 Importance and need of study**

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. 2010).

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).

Bhore (1988) recorded wood apple trees in Maharashtra flower during February-March and provide harvestable fruits during October-April. Chundawat (1999), on the other hand, noted that wood-apple trees in Rajasthan flower in February-May and provide harvestable fruits in winter.

Wood apple has high nutritional value; fruit pulp contains 2.66 per cent pectin on fruit weight bases and moisture 64.2 per cent, protein

7.1 per cent, fat 3.7 per cent, minerals 1.9 per cent, fiber 50 per cent, carbohydrates 18.1 per cent, calcium 0.13 per cent, phosphorus 0.11 per cent and iron 0.048 per cent of fruit weight. (Roy and Mazumdar, 1988)

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<sup>0</sup>Brix and filled in cans while it is still hot. Fruit has certain medicinal properties also.

Ripe fruits are sweet sour in taste and are rich sources of protein (7.1 g), riboflavin (0.17 mg),  $\beta$ -carotene (0.61 mg), niacin (0.8 mg) and minerals like calcium, phosphorus, traces of iron, magnesium, copper and zinc per 100g of pulp. (Radha *et al.*, 2000).

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 watercolors, dyes and varnishes.

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 is not exacting about its soil requirements. It can be grown on sandy as well as on clayey soils. But it never stands low lying areas, marshy soil, water stagnation or hard pan underneath. Regarding soil reaction it is seen to grow on acid, alkaline or saline soils as well. Soil fertility is not a limiting factor for growing wood apple rather it can be grown on poor soils with regard to fertility level and that is why it is suitable for reclamation of waste lands. (Chattopadhyay *et al.*, 1998).

Wood apple being a neglected and 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 Dr. VNMKV., Parbhani, Maharashtra has released a large fruited variety with an accession 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 exists 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 help to conserve valuable germplasm and could be protected from being eroded, and its utilization in further wood apple improvement programme. The wood apple genotypes are seedling originated and age of genotypes is sixteen-year-old. Out of 145 genotypes we select 25 genotypes for further investigation therefore selection of genotypes is fruit bearing trees used for investigation.

### **1.3 Objectives**

1. To estimate the extent of genotypic and phenotypic variability among wood apple genotypes.
2. To study genotypic, phenotypic and environmental correlation for yield and yield contributing characters of wood apple.

### **1.4 Scope and limitation**

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 soil.

Germplasm utilization of under cultivation is less and adopting vegetative methods of propagation 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 knowledge and evaluation studies of wood apple. Genetic variability of such a 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.

### **1.5 Hypothesis**

Diverse characters of genotypes would assist in selection of better genotypes in crop improvement programme. Evaluation of genotypes can help in identifying a better source for diverse characters. Thus, the genotype which show variability in morphological characteristics could be used directly in further improvement programme. The study of heritability and genetic advance would assist them in determining scope of further selection process. Genetic improvement in any crop depends upon variability present in that crop and there after these process helps in breeding and crop improvement programme.

Study for effective selection of genotypes for a character i.e. improvement in yield and yield contributing character is basic plan for future programme in crop improvement and Correlation study is helpful in furnishing which character should be better for selection of wood apple genotypes.

## CHAPTER II

### REVIEW OF LITERATURE

Wood apple being a neglected and no systematic work on selected genotypes has been done. Moreover, it being a minor crop and grown on stray situations, sufficient importance was not given for evaluating genotypes in crop improvement. Superior genotypes having desirable characters can be utilized for further crop improvement programme. Present investigation was carried out to find the “Genetic variability and correlation studies in wood apple (*Feronia limonia* L.)”. Very meager work has been reported on plant variability and correlation studies in Wood apple. The available, relevant literature related to various aspects of present investigation has been reviewed under the following heads and subheads.

2.1 Morphological Characters

2.2 Physical characters of fruit

2.3 Chemical parameters

2.4 Correlation

#### **2.1 Morphological Characters**

Genetic variability is determined with the help of certain genetic parameters such as coefficient of variation, heritability and genetic advance. Heritability is the heritable portion of total phenotypic variance and it is a good index of transmission of characters from parents to their offspring's.

Trimen (1893) described wood apple 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 are 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. Fruit is large (5.0-8.0 cm diameter), globose, hard, pericarp woody, rough, whitish, amphisarca.

Seeds are compressed, oblong one celled with hard and hairy coating. 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.

Genetic variability is the basis of all plant improvement programmes. Sufficient genetic variability, if present can be exploited to develop superior cultivars. Vavilov (1951) was the first to realize that a wide range of variability in any crop provided a better chance of selection of any desirable types.

The knowledge of heritability helps the plant breeder in selection for a particular character. Its estimation is important, because it determines the additive effect of genes. The heritability estimates along with genetic advance are more useful than the heritability estimates alone (Johnson *et al.*, 1955).

Bhore (1988) reported that wood apple trees in Maharashtra flower during February-March and provide harvestable fruits during October to April. Chundawat (1999), on the other hand, notes that wood-apple trees in Rajasthan flower in February-May and provide harvestable fruits in winter.

Gupta and Mishra (2002) reported that the performance of eleven-year old trees of Bael cultivars (Pant Shivani, Pant Urvashi, Pant Aparna, Pant Bael 10, Pant Bael 11, Pant Sujata, Pant Bael 13, Pant Bael 14, Pant Bael 15, Pant Bael 18, and Pant Bael Seedling) and found that Pant Bael 13 resulted into the tallest trees. Tree spread did not significantly vary among cultivars, except Pant Bael 10 and Pant Bael 18 which resulted into lesser tree spread. Pant Bael recorded a tree volume that was greater than that of Pant Aparna, Pant Urvashi, Pant Bael 10 and Pant Bael 18, but was on at par with that of the other cultivars. Pant Bael 18 and Pant Bael 10 recorded the highest leaf nitrogen content. Pant Bael 11, Pant Bael 15, Pant Aparna, and Bael Seedling registered the highest leaf magnesium concentration and Pant Urvashi the highest total leaf mineral content.

Singh *et al.*, (2006) reported that the Bael genotypes viz. CISH Bael-1, CISH Bael-2, NB-5, NB-7, NB-9, Pant Aparna, Pant Sujata, Pant Urvashi, Pant Shivani, Dhara Road and PB-1 were evaluated for their growth and flowering behavior under rainfed condition. Among the genotypes evaluated, growth (plant height and stem diameter) was recorded maximum in the genotype CISH Bael-1 while plant spread was recorded highest in NB-7. All the Genotypes exhibited significant difference for most of the growth characters.

Singh, *et al.*, (2009) in Punjab observed preponderance of Hill Lemon Seedlings, found growing at scattered/isolated areas in the various citrus growing agro climatic zones and found that the chance for the selection of elite strains are high due to wide genetic diversity in the existing germplasm. In order to reveal the genetic variability in Hill lemon (*Citrus psedolimon* Tanaka), the fruit samples from diverse area of province were collected and analyzed for various physico-chemical attributes, In present investigation wide range of variability with respect to fruit character like fruit weight, juice weight, seed number, rind thickness and core diameter have been recorded. This variability can be exploited for the selection of elite genotypes for conservation, evaluation, utilization and a source for crop improvement in future breeding programme.

Ghosh *et al.*, (2010) reported that 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-sweet with coarse texture, seediness and fibrous. Yield potential in mother plants varying from 650 to 1085 kg of fruits/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.

Singh and Mishra (2010) studied the genetic variability and correlation coefficient of eighteen Bael genotypes. Data were recorded on 24 morphological and yield contributing traits. Invariably commercially released cultivars viz., Pant Shivani, Pant Urvashi, Pant Aparna, Pant

Sujata, NB-1 along with one genotype PB-1 exhibited larger and broader leaflets with large sized flowers and floral organs. Leaf area and leaf fresh weight were also higher in these genotypes.

Singh and Singh (2016) considering the wide genetic diversity in wood apple in terms of fruit shape, size, colour and qualitative characters, an extensive survey of diversity rich area in Gujarat was made and twenty five genotypes in the form of fruits were collected from the different locations during 2015-16 to identify elite genotypes having desirable horticultural traits. All the existing trees were of seedling origin which offers a great scope for selection of suitable genotypes of high yield potentiality with good fruit quality traits having precocity in bearing, less spine Intensity and other desirable characters. Variations in morphological character were noticed in the naturally grown trees at their locations, whereas chemical analysis was done in laboratory of the station. Fruits of genotype, viz. GW-1, GW-4, GW-12, GW14, GW-16, GW-18, Gw-20 and GW-24 were observed to be round, whereas flattened round in GW-2, GW-5, GW-6, GW-8, GW-9, GW-10, GW-13, GW17, GW-21 and GW-23; triangular in GW-7 and GW-11, and oblong in GW-3, GW-15, GW-19, GW-22 and GW-25 fruit shape was observed.

## **2.2 Physical characters of fruit**

Prasad and Singh (2001) reported that the one hundred and eighty three samples of bael were collected from Uttar Pradesh and Bihar, In 1997 and 1998, and categorized into extra-large size (ELS more than 1000g), large size (LS between 750-1000g), medium size (MS between 400-750 g) and small size (SS, less than 400g). Only ELS fruits were evaluated for the different fruit quality parameters, i.e. transverse diameter, fruit weight, peel thickness, pulp content, total soluble solids, reducing sugars, non-reducing sugars and ascorbic acid content. Out of 41 strains only 8 strains (i.e. ELS 1, ELS 2, ELS 3, ELS 4, ELS 5, ELS 6, ELS 7 and ELS 8) produced excellent quality fruits.

Lal (2002) evaluated genotypes of bael collected from Jaipur (Rajasthan) in 1997-98 and 1998-99. Twelve strains were selected for further studies (JB-1 to JB -7 in the first year and BS-1 to BS -5 in the

second year). In 1997-98, the maximum fruit weight (1600g), volume (2000 ml), diameter (15.30cm), polar diameter (14.95cm) and pulp content (76.29%) were recorded in JB-1 in 1997-98, while the lowest values were recorded in JB-7 for these parameters 480g, 350 ml, 9.87cm, 10.49cm and 62.12%, respectively. In the following year, the highest values for these were found in BS-1 (around 1540g, 2090 ml, 15.53cm, 14.72cm and 76.05%) and lowest in BS-5 (around 640g, 890 ml, 10.00cm, 10.12cm and 68.70%, respectively). The peel thickness varied from 0.2cm in JB-1 to 0.27cm in JB-7 in the first year; and from 0.19cm in BS-1 to 0.27cm in BS-3 in second year. With regard to twenty (20) yield and quality parameters were studied in Pantnagar, Uttaranchal, India during 1998 and 2000. The cultivars were grouped into 3 clusters based on Mahalanobis  $D^2$  values. The cultivars included in cluster I were superior to the other cultivars in terms of fruit weight, fruit volume, fruit length, fruit diameter and fiber content. Tree spread, total soluble solid content and ascorbic acid content were highest in cluster III. Ascorbic acid content, fruit weight, fruit length, number and weight of seeds per fruit, fiber content and petiole length had the greatest contribution to genetic divergence. These characters may be used for the selection of diverse parents for hybridization.

Nath *et al.*, (2003) reported that the Bael genotypes showed variability with respect to tree morphological characters, intensity of bearing and fruit characters. The physico-chemical constituent in different genotypes also varied greatly. The fruit weight in different genotypes varied from 0.5 – 2.6kg, whereas, the fruit length was varied from 16.8 – 30.5cm. The skull thickness which is a negative character for a quality bael fruit varied from 0.17 – 0.4 cm in different genotypes collected during the exploration.

Shrivastava and Singh (2004) evaluated four commercially important cultivars viz. Narendra Bael-4, Narendra Bael-5, Narendra Bael-7 and Narendra Bael-9. The heaviest fruit weight (3.618kg), skull thickness (1.98mm), fruit length (19.50 cm), fruit breadth (21.25 cm), number of seed/fruit (112) and fiber content (335.0 g/kg Fruit) was recorded in Narendra Bael-7, whereas minimum fruit weight (0.98 kg), fruit length (14

cm) and fruit breadth (13.60cm) recorded in Narendra Bael-4. However, minimum fiber content and seed/fruit were recorded in Narendra Bael-9 and Narendra Bael5. Maximum total soluble solid (38%), ascorbic acid (15.50 mg/100g) and total sugar content recorded in Narendra Bael-5. Though, minimum total soluble solids (24%), ascorbic acid (11.05 mg/100g) and total sugars (9.12%) were recorded in Narendra Bael-7.

Nidhi and Gehlot (2007) reported that bael (*Aegle marmelos*) and guava fruits had fruit weights of 618 and 72g, pulp weights of 663 and 927 g/kg fruit, peel weights of 302 g/kg fruit, pulp: peel ratio of 2.19 and seed percentage of 3.38 and 2.76%, respectively.

Kumar and Nath (2008) reported that during survey was conducted in different parts of Orissa to assess the existing natural diversity in bael seedling trees and to identify the superior genotype with desirable horticultural traits. Observations on morphological and physico-chemical parameters of fruit were recorded in 21 promising genotypes. All the genotypes showed considerable variations with respect to physico-chemical characters assessed. The genotype CHBI-13 and CHBI-14 were found promising with respect to pulp weight (86.04 and 86.92%) and skull thickness (2.32 and 2.22mm). The CHBI-13 also had higher fruit weight (2.915 kg) and found superior over another genotype. The minimum seed number was counted in CHBI-15. The maximum Total Soluble Solids (40.43°Brix) of fruit was recorded in CHBI-20 whereas the TSS/acid ratio was maximum (107.08) in CHBI-7.

Mishra *et al.*, (2008) revealed that the wide variability exists in bael fruit size and shape, bearing habit, flesh colour, texture, fiber content, sugar content and mucilage content etc. Some types have more number of seeds, gum, locules and thick pericarp under foot-hills region of Uttar Pradesh.

Pandey, *et al.*, (2008) Surveys were conducted on bael in the districts Gonda, Basti, Gorakhpur, Deoria, Varanasi, Sultanour and Barakanki of Uttar Pradesh during the year 2008-2009. A total of 48 genotypes having desirable traits were collected and physico-chemical analysis of fruits was done. Genotypes showed considerable variations for

fruits morphological and physico-chemical traits. The number of fruits per tree varied from (110-315), fruit yield per tree (94.50-350.50 kg), fruit weight (0.55-3.10 kg) among the different genotypes collected. The fruit characteristics, viz., fruit length ranged from (7.70-17.5cm), fruit circumference (29-61cm), number of seeds per fruit (33-200), number of seed sacs per fruit (9-12), shell weight per fruit (0.10-0.73 kg), shell thickness (2.0-5.80 mm), seed weight per fruit (2.8-15.8gm), pulp percentage (50.77-73.30) among the different genotypes. With regards to biochemical parameters, TSS ranged from (26-44.4°Brix), total sugar (5.59-11.30%), non-reducing sugar (4.30-17.07%), among different genotype analyzed. On the basis of overall assessment, seven genotypes, viz., T2, T14, T15, T20, T31, T44 and T47 were found most promising.

Pandey *et al.*, (2008) survey on bael was conducted in the districts of Etawah, Manipuri, Firozabad, Agra, Mathura, Jhansi and Lucknow in Uttar Pradesh and Gwalior and Datia of Madhya Pradesh during the year 2005 and 2006. A total of forty seven genotypes having desirable traits were collected and physico-chemical analysis of fruits was done. The genotypes showed considerable variation in morphological and physicochemical traits of fruits. The number of fruits per tree varied from 56-695, fruit weight (0.38 - 2.84 kg.) and fruit yield per tree (75.74 - 450.08 kg/tree) among the different accessions collected. The other fruit characters viz., fruit length (7.93 - 18.60 cm), fruit circumference (28.20 - 61.67cm), number of seeds per fruit (33.0 - 95.0), number of seed sacs per fruit (10.0 - 19.00), skull weight per fruit (0.10 - 0.69 kg), skull thickness (1.25 - 3.32mm), seed weight (3.74 - 10.48 g), pulp weight (0.16 - 1.76kg). On the basis of overall assessment, thirteen accessions viz., T4, T5, T9, T10, T12, T15, T20, T22, T23, T27, T28, T34 and T42 were found promising and might be used as plus trees for further multiplication.

Ghosh and Nautiyal (2010) studied yield potential in wood apple 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.

Hazarika *et al.*, (2016) studied that assessment of genetic variability in available germplasm is the prerequisite for development of improved genotypes through planned breeding programme. In view of this 39 “*hatkora*” (*Citrus macroptera* Mont.) genotype collected from different locations of Mizoram, were evaluated for physico-chemical characteristics. The study reveals that there were significant variations among the collections in these particular traits. Individual fruit weight ranged from 277.78 to 617.69 (g), fruit diameter 9.32-12.52 cm, fruit length 7.74-10.19 cm, fruit volume 238.33-583.33 cc, pulp weight 153.75-320.94gm, pulp: peel ratio 1.50-3.24 and seed number 9.33-23.6.

Singh and Singh (2016) recorded that physiological analysis of wood apple fruits divulged that the fruit weight ranged between 156.45-432.93g, while fruit length and width between 5.25-9.46 cm and 5.10-9.29 cm, respectively. Shell thickness, shell weight, pulp weight, number of seeds per fruit and seed weight per fruit ranged between 0.31 to 0.47cm, 67.94-109.77g, 80.04 to 319.32g, 132.34 to 525.81 and 2.36 to 7.93g, respectively in diversity rich area of Gujarat. And twenty-five genotypes in the form of fruits were collected from the different locations during 2015-16 to identify elite genotypes having desirable horticultural traits.

### **2.3 Chemical parameters**

Roy and Mazumdar (1988) studied as wood apple has high nutritional value, fruit pulp contains 2.66 per cent pectin on fruit weight bases and moisture 64.2 per cent, protein 7.1 per cent, fat 3.7 per cent, minerals 1.9 per cent, fiber 50 per cent, carbohydrates 18.1 per cent, calcium 0.13 per cent, phosphorus 0.11 per cent and iron 0.048 per cent of fruit weight.

Radha and Mathew (2000) found ripe wood apple fruits are sweet sour in taste and are rich sources of protein (7.1 g), riboflavin (0.17 mg), b carotene (0.61 mg), niacin (0.8 mg) and minerals like calcium, phosphorus, traces of iron, magnesium, copper and zinc per 100g of pulp.

Ram and Singh (2003) revealed that the physico-chemical characteristics of bael (*Aegle marmelos*) cultivars NB-5, NB-9, NS-1 and

Kagazi. NB-9 gave the highest contents of ascorbic acid (17.25 mg/100 g), carotene (97.00 IU/100 g), non-reducing sugar (15.52%) and total sugar (19.44%). NB- 5 gave the highest reducing sugar content (4.87%). NS-1 gave the highest total soluble solids (38.50%) and acidity (0.40%). Kagazi gave the highest fibre (9.91%) contents and phenolics (2.87%).

Nidhi and Gehlot (2007) reported that the chemical constituents of bael and guava fruits such as moisture content, total soluble solids, total sugars and reducing sugar percentage were 61.76% and 83.34%, 34.50% and 13.50%, 16.93% and 8.56% and 4.57% and 3.23%, respectively, whereas acidity, ascorbic acid, crude fiber, pectin and total phenols were 0.41% and 0.47%, 4.62% and 4.46%, 17.25% and 167.50 mg/100 g, 3.27% and 2.85%, 2.38% and 0.95% and 23.71% and 2.26 mg /100 g, respectively.

Pandey *et al.*, (2008) conducted the survey in the districts of Uttar Pradesh and Gwalior and Datia of Madhya Pradesh during the year 2005 and 2006. T.S.S. content (28.67<sup>0</sup>- 46.33<sup>0</sup> Brix), acidity (0.22 - 0.56%), total sugars (16.10 - 29.78%), reducing sugars (6.94 - 11.15%), vitamin 'C' content (6.25 - 17.71 mg/100 g pulp), tannin content (1.68 - 4.68%) and total carotenoids (0.90-1.72 mg/100 g pulp) among the different accessions were evaluated.

Pandey *et al.*, (2008) conducted survey in Bihar and Jharkhand to identify superior genotypes of bael (*Aegle marmelos*). Thirty-six genotypes (designated as T1 to T36) with desirable fruit characters and bearing behavior were identified. T.S.S. was highest in T21 (48<sup>0</sup>brix). Titrable acidity was highest in T30. T2 had the highest T.S.S./acid ratio (118.57). Total sugars content was highest in T21 (32.59%). Reducing sugars was highest in T9. T25 had the highest sugar/acid ratio (104.25). Ascorbic acid was highest in T9 and lowest in T21. Tannin content was highest in T2 (5.31%). Total carotenoids ranged from 0.84 (T16) to 2.48 mg/100 g (T1). Based on the results, T1, T5, T12, T21 and T36 were considered the most promising genotypes.

Sharma (2014) recorded changes in physical and chemical properties of wood apple pulp collected from unripe, half ripe and full ripe

stages were studied. Edible portion of wood apple fruit (42.9 to 60.6 % total fruit weight) comprised 6.9% to 12.7% of seeds. Fresh pulp contained 75.16% moisture, 3% sugar, 2% protein and 1.31% ash. The total soluble solids, brix: acidity ratio, total sugar and reducing sugar of wood apple fruit increased with maturity, whereas moisture content, pectin content and ascorbic acid was decreased. The pH of the wood apple pulp increased with the advance in maturity. The ripe fruits were found significantly less acidic than unripe and half ripe.

Hazarika and Nautiyal (2016) reported that similarly of the juice content in *Citrus macroptera* varies from 13.45-32.53, acid 34.81-73.64mg/100 ml, TSS 6.15-9.10%, total sugar 5.167.97% and sugar: acid ratio 0.75-1.52. From the analysis of genetic parameters, it could be concluded that characters like fruit weight, fruit length, fruit volume, pulp weight, pulp-peel ration, juice, TSS, acidity, total sugar, sugar-acid ratio could be used as selection criteria for development of effective and productive plant types for future genetic improvement programme.

## **2.4 Correlation**

Chakrawar and Jature (1980) conducted correlation studies on Kagzi lime strain for better improvement. The fruit number, size, weight and juice percentage of fruits were determined in 89 types. There was a positive and significant relationship between fruit weight and size. The percentage of juice was positively and significantly correlated with fruit weight and size.

Chakrawar and Solunke (1981) studied correlation coefficient between all pairs of physical and chemical fruit characters of 82 ber genotypes and reported that, there was a positive and significant correlation between weight and size of fruits, between pulp percentage and weight and size of fruit and vitamin C.

Kumar (2000) studied that fruit weight components with 12 genetically diverse varieties of mango and revealed that, the character fruit weight had highly significant and positive correlations with the characters fruit length, fruit diameter.

Yadav *et al.*, (2003) studied correlation of fruit characteristics in 69 clones of Langra mango and revealed that, the correlation at the genotypic level was higher than at the phenotypic level, indicating a strong genetic correlation of characters and the lowering of effect of environmental interaction at the phenotypic level. Fruit length, fruit diameter, pulp weight and pulp percentage showed highly positive and significant genotypic and phenotypic correlation with fruit weight.

Badiyala and Sharma (2004) studied the variability in Galgal from upper Shivaliks of Himachal Pradesh, wherein they concluded that positive and significant correlation of yield was observed with fruit length (0.55), diameter (0.68), fruit weight (0.62), number of seeds (0.56) and juice content (0.8).

Josan and Kaur (2006) performed correlation analysis for various characters of mandarin germplasm from Abohar. Here they discovered that the correlation between fruit length and fruit breadth was positive and significant. On the other hand, the correlation between juice content, size and weight of the fruit was negative but non-significant. Correlation of total soluble solids with fruit weight and juice content was positive. A positive correlation of acid content with fruit weight, fruit breadth, juice content and total soluble solids was observed though it was non-significant.

Pradeepkumar *et al.*, (2006) studied variability in physicochemical characteristics of 31 mango genotypes in northern Kerala. They observed the highest significant correlation between fruit length and pulp weight.

Kishore *et al.*, (2010) studied the correlation co-efficient between physico-chemical variables of Sikkim mandarin. A perusal of data showed that fruit weight was positively correlated (0.868) with the number of seeds per fruit.

Maiti (2010) conducted an experiment to assess the correlation among fruit weight and its components to provide adequate

genetic background of jackfruit and revealed that, genotypic and phenotypic correlation were positively significant to fruit weight.

Kaur *et al.*, (2012) revealed that the fruit weight exhibited a significant positive correlation with fruit length (0.79), fruit breadth (0.96) and peel thickness (0.63). In the evaluated strains of Baramasi lemon number of articulates, total soluble solids, acidity and vitamin C content showed non-significant correlation with fruit weight.

Rabha *et al.*, (2013) reported that, fruit yield plant<sup>-1</sup> was found to be a positive and significantly correlated with, fruit length, rind weight, rind thickness and seed length; while positive correlation was found with fruit breadth, fruit weight and juice content, number of seed fruit<sup>-1</sup>, seed weight, TSS and reducing sugar in citrus.

Diwan *et al.*, (2014) conducted correlation studies on superior types of sweet oranges from Marathwada region. They reported that yield of fruits per tree was highly significant and positively correlated with the number of fruits per tree. The correlation of weight of fruit was highly significant and positive with the length of fruit and breadth of fruit. Breadth of fruit was highly significant and positively correlated with the length of fruit, weight of fruit, yield of fruit per tree.

Gaikwad *et al.*, (2015) studies that comprising 30 genotypes of pummelo, from Konkan region of Maharashtra. Correlation study revealed that the correlation of fruit yield with number of fruits tree per tree, fruit weight, fruit length, diameter, size of oil gland, diameter of axis, rind thickness, weight of pulp, rag weight and ascorbic acid was highly significant and in positive direction. The highest correlation coefficient value ( $r=0.643$ ) existed between number of fruits/ tree and yield.

## CHAPTER III

### MATERIAL AND METHODS

The present investigation entitled “Genetic variability and correlation studies in wood apple (*Feronia limonia* L.)” was carried out on Sixteen years old Wood apple orchard during the year 2018-2019 at, AICRP on Dryland Agriculture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The details of materials used and methods followed during the course of investigations are summarized below.

#### 3.1 Climate and weather conditions

Akola is situated at 307.4-meter altitude from mean sea level of 22°42'N latitude and 72°02'E longitude and has marginal tropical climate. An annual rainfall is 850 to 900 mm. The rains are received from Southwest monsoon from June– September.

Akola has got hot and dry summer and moderately cool winter. During summer, maximum temperature ranges from 40°C to 45°C and 7°C to 12°C in winter as minimum temperature. While maximum relative humidity (RH) 65.7 per cent and minimum 30.12 per cent in case of winter, December was the coolest month with 8.7°C temperature. An annual minimum rainfall was recorded 648.5 mm.

The meteorological data in respect of maximum and minimum temperature, rainfall and humidity recorded at the Meteorological Observatory Department of Agronomy during 2018-2019.

#### 3.3 Details of Experimental Design

|   |                      |   |
|---|----------------------|---|
| 1 | Name of the crop     | : Wood Apple ( <i>Feronia limonia</i> L.) |
| 2 | Family               | : Rutaceae                                |
| 3 | Number of genotypes  | : 145 genotypes (seedling originated)     |
| 4 | Year of study        | : 2018-2019                               |
| 5 | Experimental design  | : Randomized Block Design                 |
| 6 | Number of Treatments | : 25 Fruit bearing trees                  |

- 7 Treatment unit : Single plant observation  
(Plant /Treatment)
- 8 Season 1 season
- 9 Place of Research Work : AICRP On Dryland Agriculture,  
Dr. P. D. K. V. Akola.

### 3.4 Genotypes details

In the present investigation 25 genotypes were selected, which have produced flowers during February-March 2018. They were coded in the following manner.

#### Coding of genotypes:

|          |           |            |
|----------|-----------|------------|
| 1.DWA-4  | 10.DWA-39 | 19.DWA-75  |
| 2.DWA-5  | 11.DWA-43 | 20.DWA-76  |
| 3.DWA-12 | 12.DWA-44 | 21.DWA-93  |
| 4.DWA15  | 13.DWA-45 | 22.DWA-94  |
| 5.DWA-22 | 14.DWA-52 | 23.DWA-96  |
| 6.DWA-26 | 15.DWA-57 | 24.DWA-105 |
| 7.DWA-27 | 16.DWA-59 | 25.DWA-107 |
| 8.DWA-28 | 17.DWA-63 |            |
| 9.DWA-30 | 18.DWA-67 |            |

### 3.5 Cultural operations

The plot was kept free from weeds by attending timely weeding and harrowing intercultural operation. Mulching, manuring, harrowing and plant protection measures were undertaken uniformly at appropriate time.

### 3.6 Details of observations recorded

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 Kaulgud *et al.*, (1997), Rodriguez-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. The details of observation recorded as under.

### **3.7 Tree characters (Quantitative)**

#### **3.7.1 Stem girth (cm)**

The stem girth of plant was measured from 1.5 m portion of stem above ground level with the help of measuring tape and recorded in centimeter.

#### **3.7.2 Tree height (m)**

The height of observational plant was measured from ground level to the growing tip with the help of Ravi altimeter. The plant height was recorded at the time of flowering and recorded in meter.

#### **3.7.3 Number of primary branches**

Number of primary branches of observational plant was counted which originates from main trunk and recorded in number.

#### **3.7.4 Number of secondary branches**

Number of secondary branches of observational plant was counted which originates from primary branches and recorded in number.

### **3.8 Tree characters (Qualitative)**

#### **3.8.1 Bark colour**

The bark colour of observational plant was recorded by using R.H.S. colour chart given by The Royal Horticultural Society, London.

- i) Grey
- ii) Blackish grey

#### **3.8.2 Growth habit**

The nature of growth i.e. spread of plant was observed and the spread was categorized as

- i) Erect
- ii) Spreading

### **3.9 Flowering characters**

#### **3.9.1 Date of flower initiation**

Bhore (1988) recorded wood apple trees in Maharashtra flower during February-March on this basis plants were kept under observations during Feb-March and flowering was noted in weeks of each observational plant.

#### **3.9.2 Duration of Flowering**

During February-March plants were kept under observation from initial flowering to days for fruit set and days were counted in weeks as flowering duration.

### **3.10 Fruit characters (Quantitative)**

#### **3.10.1 Number of fruits/tree (kg)**

Matured fruits were harvested from each cultivar and counted per observational plant.

#### **3.10.2 Length of fruit (cm)**

The maximum length from base to apex of fruits was recorded at harvesting. Five fruits from each direction were selected and with the help of Vernier caliper length was measured and average was worked out. It was recorded in centimeter.

#### **3.10.3 Fruit diameter (cm)**

The diameter from broadest portion was recorded at the time of harvesting of twenty selected fruits with the help of Vernier caliper and average was worked out. It was recorded in centimeter.

#### **3.10.4 Fruit weight (g)**

The twenty fruits were collected from each genotype, weight of individual fruit by using weighing balance and records the mean of fruits.

#### **3.10.5 Number of fruits per kg.**

Mature fruits were collected from each genotype. Weight by using weighing balance and recorded in kilogram.

#### **3.10.6 Shell characters**

##### **i) Weight (g)**

Shell weight of selected fruit were weighed after removal of pulp and recorded in gram and average was calculated.

### **ii) Thickness (mm)**

Shell thickness of selected fruit were measured by Vernier caliper after removal of pulp and recorded in micrometer and average was calculated.

### **3.10.7 Weight of pulp (g)**

Pulp weight of each selected fruit was estimated by deducting the seed weight from the total deskulled fruit weight.

### **3.10.8 Pulp (%)**

The pulp weight obtained from each fruit was divided by respective fruit weight and expressed as percentage.

$$\text{Pulp (\%)} = \frac{\text{Pulp weight}}{\text{Fruit weight}} \times 100$$

### **3.10.9 Pulp: Shell ratio**

Pulp weights of selected twenty fruits were estimated by deducting the shell weight from the total fruit weight. Then pulp weight was divided by the shell weight to calculate pulp: shell ratio and average was calculated.

### **3.10.10 Number of seeds per 100 g pulp (g)**

Numbers of seeds were calculated per 100 gm of fruit pulp weight and recorded.

### **3.10.11 Weight of seed per 100 g pulp (g)**

Weight of extracted seeds per 100 g pulp was with the help of electronic weighing balance and recorded in grams.

### **3.10.12 Seed size (mm)**

Five Seeds of each fruit were randomly selected, and size measured by using Vernier caliper and recorded in micrometer.

### **3.10.13 Yield per plant (Kg)**

Mature fruits were harvested periodically in each genotype separately and the weight was recorded with the help of single pan balance. Then the total fruit yield (kg/ tree) was calculated.

## **3.11 Fruit characters (Qualitative)**

### **3.11.1 Pulp colour**

The pulp colour in different genotypes was recorded by using R.H.S. colour chart given by The Royal Horticultural Society, London.

- i) Light brown
- ii) Brown
- iii) Dark brown

### **3.11.2 Total Soluble Solids (<sup>o</sup>Brix)**

The TSS content in fruit pulp was determined by using digital refractometer (ATAGO, RX-7000X) by taking a drop of diluted pulp on digital refractometer and recorded.

### **3.11.3 Acidity (%)**

For the determination of acidity of fruits, the method described by Ranganna (1979) was adopted in which 1 g sample was taken and diluted with 10 ml of distilled water and filtered the solution. Then burette was filled with 0.1 N NaOH and sample was titrated against the standard NaOH solution. Add few drops of Phenolphthalein indicator. The appearance of light pink colour considered the end point of titration. This estimated value then expressed in terms of percent acid by adopting the following formula.

$$\text{Acidity (\%)} = \frac{\text{Titre value (ml)} \times \text{N NAOH} \times \text{eq.wt. Of acid} \times \text{vol. made up}}{\text{Wt. of sample} \times \text{aliquot taken for estimation} \times 100} \times 100$$

#### 3.11.4 TSS/Acid ratio

The ratio was calculated by dividing TSS (°Brix) by Acidity percentage.

#### 3.11.5 Reducing sugars (%)

The reducing sugar content was determined by the volumetric method of Lane and Eynon described by Ranganna (1986) as follow.

Ten gram of wood apple pulp was taken in 250 ml volumetric flask. To this 6-7 ml of lead acetate was added and mixed. Then necessary amount of potassium oxalate was added to precipitate excess of lead acetate. The volume was made 250 ml with distilled water and then filtered through Whatman No.1 filter paper. The filtrate was taken in burette. In a conical flask, 5 ml each of Fehling's solution A and B were taken and titrated against boiling Fehling's solution by using methylene blue as an indicator. The end point was indicated by the appearance of brick red precipitates. The reducing sugars content was calculated and expressed as per cent.

$$\text{Reducing sugars (\%)} = \frac{\text{mg of invert sugar} \times \text{Vol. made up} \times 100}{\text{Titrate} \times \text{Wt. of sample} \times 100}$$

#### 3.11.6 Non-reducing sugars (%)

Non reducing sugars content was determined by subtracting the value of reducing sugars from total sugars.

$$\text{Non - reducing sugars (\%)} = [\text{Total sugar (\%)} - \text{Reducing sugar (\%)}]$$

#### 3.11.7 Total sugars (%)

In 250 ml volumetric flask 50 g pulp was taken. To this, 5 ml concentrated HCl was added and the flask was kept in hot water bath at 70 - 80 °C for 30 min. After cooling the hydrolysate was neutralized by adding a pinch of sodium carbonate till effervescences ceased. The volume of the

neutralized hydrolysate was made to 250 ml with distilled water and the solution was filtered through Whatman No. 1 filter paper. The filtrate was taken in burette. In a conical flask, 5 ml each of Fehling's solution A and B were taken and titrated against boiling Fehling's solution by using methylene blue as an indicator. The end point was indicated by the appearance of brick red precipitates. The total sugar content was calculated and expressed as per cent.

$$\text{Total sugars (\%)} = \frac{\text{mg of invert sugar} \times \text{Dilution}}{\text{Titre} \times \text{Wt. of sample (g)}} \times 100$$

### 3.11.8 Pectin content (%)

The pectin content was estimated with using the method Srivastava and Sanjeev (2002). 20-25 g fresh weight of fruits was used for pectin test and dissolved in 10-20 ml of distilled water. 1-2 ml of 1 N NaOH was added and mixed thoroughly, the suspension was acidified by addition of 1 N HCL, 1.5 × the volume of 1N NaOH added before and mixed. To precipitate the pectin, 50 ml of 0.1 N HCL was added. The mixture was then filtered through a wide pore filter (Whatman 1). From the filtrate 10-20 ml were pipette into a 250 ml flask. The filtrate was titrated with 0.1 N NaOH using Hinton's indicator. From the result of the titration of the 10-20 ml filtrate, the HCL content of the original volume was calculated. Together with the results of the titration of pooled filtrate, residue and washings, the total amount of all pectin of original sample can be estimated.

$$\text{Pectin content (\%)} = \frac{(V_2 - V_1) \cdot 176 \cdot 0.1 \cdot K}{1000W} \times 100$$

### 3.12 Statistical and biometrical analysis

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

#### 3.12.1 Analysis of variance

The data obtained from the present investigation was analyzed as per the procedure suggested by Panse and Sukhatme (1985).

### ANOVA for RBD:

| Sources of variation | Degrees of freedom | Sum of squares | Mean of squares | F (cal.) | F (Tab.) |
|----------------------|--------------------|----------------|-----------------|----------|----------|
| Replications         | (r-1)              | RSS            | MSR             | MSR/MSE  |          |
| Genotypes            | (t-1)              | VSS            | MSV             | MSV/MST  |          |
| Error                | (r-1)(t-1)         | ESS            | MSE             |          |          |
| Total                | (rt-1)             | TSS            | MST             |          |          |

### 3.12.2 Estimation of genetic variability parameters:

#### 3.12.2.1 Genotypic, phenotypic and environmental coefficient of variation:

The genotypic (GCV), phenotypic (PCV) and environmental (ECV) coefficient of variation will be calculated by the formulae given by Burton (1952).

$$GCV = \frac{\sqrt{\text{Genotypic variance}}}{\bar{x}} \times 100$$

$$PCV = \frac{\sqrt{\text{Phenotypic variance}}}{\bar{X}} \times 100$$

$$ECV = \frac{\sqrt{\text{Environmental variance}}}{\bar{X}} \times 100$$

Where,

$\bar{x}$  = Mean of a character.

#### 3.12.2.2 Heritability ( $h^2$ ):

Heritability percentage in broad sense is calculated by the formula as suggested by Johnson *et al.*, (1955).

$$h^2 = \frac{V_g}{V_p} \times 100$$

Where,

$h^2$  = Heritability in broad sense.

$V_g$  = Genotypic variance.

$V_p$  = Phenotypic variance.

### 3.12.2.3 Genetic Advance (GA):

Improvement in the mean genotypic value of selected plants over the parental population is called Genetic Advance. It is calculated by following formula given by Johnson *et al.*, (1955).

$$\text{Genetic Advances (GA)} = h^2 \sqrt{V_p} \times K$$

Where,

$h^2$  = heritability in broad sense

$\sqrt{V_p}$  = phenotypic standard deviation

$K$  = selection differential at 5% level and value of  $K = 2.06$ .

### 3.12.2.4 Expected Genetic Advance (EGA):

Genetic advance as percentage of mean is called Expected Genetic Advance. It is calculated as follows

$$\text{Expected Genetic Advance (EGA)} = \frac{\text{GA}}{\bar{X}} \times 100$$

### 3.12.3 Correlation

The genotypic, phenotypic and environmental correlations were calculated by following formulae proposed by Miller *et al.*, (1958).

$$\text{Phenotypic correlation} = \frac{\text{PCOV}_{xy}}{\sqrt{\text{PV}_x \cdot \text{PV}_y}}$$

$$\text{Genotypic correlation} = \frac{\text{GCOV}_{xy}}{\sqrt{\text{GV}_x \cdot \text{GV}_y}}$$

$$\text{Environmental correlation} = \frac{\text{ECOV}_{xy}}{\sqrt{\text{EV}_x \cdot \text{GV}_y}}$$



**Plate 1 General View of experimental plot**

## CHAPTER IV

### RESULTS AND DISCUSSION

The experiment entitled “Genetic variability and correlation studies in wood apple (*Feronia limonia* L.)” was carried out during 2018-2019 at AICRP on Dryland Agriculture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola with following objectives.

1. To estimate the extent of genotypic and phenotypic variability among Wood apple genotypes.
2. To study genotypic, phenotypic and environmental correlation for yield and yield contributing characters of wood apple.

The experimental results obtained from the present investigation were, statistically analyzed, presented and discussed under the following subheadings.

4.1 Analysis of variance

4.2 Genetic variability studies

4.3 Correlation studies

4.4 Discussion

The quantitative morphological observations were recorded on randomly selected genotypes. In four replications viz., North, South, East, West direction. The data in respect to Stem Girth (cm), Tree Height (m), Bark colour and Growth habit were recorded as a single replication and analysed 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, Shell Weight (g), Shell 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.

## **4.1 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, Shell Weight (g), Shell 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 per cent and five per cent 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 fruit shape, size, colour and other qualitative characters were highly significant in wood apple.

## **4.2 Genetic variability studies**

With a view to understand the extent of variation 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) and heritability ( $h^2$ ), were worked out for different traits in 25 genotypes under study.

### **4.2.1 Range of mean performance**

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

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

| Sr. No. | Characters                    | Mean sum of square |           |       |
|---------|-------------------------------|--------------------|-----------|-------|
|         |                               | Replication        | Treatment | Error |
| 1       | Number of primary branches    | 0.003              | 1.25**    | 0.003 |
| 2       | Number of secondary branches  | 5.94               | 1.95**    | 2.42  |
| 3       | Number of fruits per tree     | 36.9               | 199.5**   | 26.3  |
| 4       | Length of fruit (cm)          | 3.56               | 7.29**    | 0.83  |
| 5       | Fruit diameter (cm)           | 4.24               | 6.78**    | 1.02  |
| 6       | Fruit weight (g)              | 356.3              | 9152.4**  | 205   |
| 7       | Number of fruits per kg.      | 0.26               | 2.54**    | 0.11  |
| 8       | Shell weight (g)              | 13.21              | 956**     | 38.47 |
| 9       | Shell Thickness (mm)          | 0.07               | 0.19**    | 0.04  |
| 10      | Weight of pulp (g)            | 57.04              | 4616.05** | 94.31 |
| 11      | Pulp (%)                      | 13.27              | 50.61**   | 10.01 |
| 12      | Pulp: Shell ratio             | 0.04               | 0.23**    | 0.04  |
| 13      | Number of seeds per 100g pulp | 146.03             | 3228.93** | 73.50 |
| 14      | Weight of seed per 100g pulp  | 3.18               | 5.51**    | 0.26  |
| 15      | Seed size (mm)                | 0.02               | 0.32**    | 0.02  |
| 16      | Yield per plant (Kg)          | 1.53               | 27.56**   | 2.07  |
| 17      | TSS (Brix)                    | 1.10               | 10.53**   | 0.41  |
| 18      | Acidity (%)                   | 0.004              | 1.843**   | 0.011 |
| 19      | TSS: Acid ratio               | 0.46               | 18.09**   | 0.30  |
| 20      | Reducing sugars (%)           | 0.002              | 0.003**   | 0.001 |
| 21      | Non-reducing sugars (%)       | 0.001              | 0.028**   | 0.005 |
| 22      | Total sugars (%)              | 0.004              | 0.034**   | 0.004 |
| 23      | Pectin content (%)            | 0.24               | 0.19**    | 0.01  |

\*-significant at 5% level

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

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

| Sr. no | 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 |
|--------|----------|-----------------|-----------------|----------------------------|------------------------------|---------------|--------------|-------------------------------|-----------------------|-------------|
| 1      | DWA-4    | 80              | 7.5             | 3                          | 10                           | Grey          | Spreading    | 2 <sup>nd</sup> week of Feb.  | 4 to 6 weeks          | Light brown |
| 2      | DWA-5    | 76              | 7.7             | 4                          | 12                           | Blackish grey | Erect        | 1 <sup>st</sup> week of Feb.  | 5 to 6 weeks          | Brown       |
| 3      | DWA-12   | 71              | 8.1             | 3                          | 8                            | Grey          | Erect        | 3 <sup>rd</sup> week of Feb.  | 6 to 7 weeks          | Brown       |
| 4      | DWA-15   | 75              | 7.8             | 4                          | 11                           | Blackish grey | Spreading    | 1 <sup>st</sup> week of March | 6 to 7 weeks          | Light brown |
| 5      | DWA-22   | 78              | 7.3             | 3                          | 9                            | Grey          | Erect        | 4 <sup>th</sup> week of Feb.  | 7 to 8 weeks          | Brown       |
| 6      | DWA-26   | 84              | 8.2             | 4                          | 12                           | Grey          | Erect        | 1 <sup>st</sup> week of March | 5 to 7 weeks          | Light brown |
| 7      | DWA-27   | 93              | 8.8             | 4                          | 15                           | Blackish grey | Erect        | 2 <sup>nd</sup> week of Feb.  | 5 to 6 weeks          | Dark brown  |
| 8      | DWA-28   | 79              | 7.8             | 4                          | 13                           | Grey          | Spreading    | 2 <sup>nd</sup> week of Feb.  | 4 to 7 weeks          | Brown       |
| 9      | DWA-30   | 83              | 8.2             | 3                          | 10                           | Grey          | Erect        | 1 <sup>st</sup> week of Feb.  | 5 to 6 weeks          | Brown       |
| 10     | DWA-39   | 90              | 8.4             | 4                          | 11                           | Grey          | Erect        | 1 <sup>st</sup> week of Feb.  | 4 to 7 weeks          | Light brown |
| 11     | DWA-43   | 78              | 7.1             | 3                          | 9                            | Grey          | Erect        | 3 <sup>rd</sup> week of Feb.  | 6 to 7 weeks          | Dark brown  |
| 12     | DWA-44   | 82              | 7.5             | 4                          | 13                           | Grey          | Spreading    | 1 <sup>st</sup> week of March | 5 to 7 weeks          | Brown       |
| 13     | DWA-45   | 70              | 7.7             | 3                          | 11                           | Blackish grey | Erect        | 2 <sup>nd</sup> week of Feb.  | 4 to 6 weeks          | Light brown |
| 14     | DWA-52   | 88              | 8.2             | 4                          | 14                           | Grey          | Erect        | 3 <sup>rd</sup> week of Feb.  | 5 to 7 weeks          | Brown       |
| 15     | DWA-57   | 74              | 8.7             | 2                          | 8                            | Grey          | Spreading    | 2 <sup>nd</sup> week of Feb.  | 5 to 6 weeks          | Brown       |
| 16     | DWA-59   | 87              | 7.0             | 3                          | 10                           | Blackish grey | Erect        | 4 <sup>th</sup> week of Feb.  | 4 to 6 weeks          | Light brown |
| 17     | DWA-63   | 81              | 8.4             | 3                          | 11                           | Grey          | Erect        | 1 <sup>st</sup> week of March | 5 to 6 weeks          | Light brown |
| 18     | DWA-67   | 78              | 7.5             | 3                          | 13                           | Blackish grey | Erect        | 2 <sup>nd</sup> week of Feb.  | 6 to 7 weeks          | Brown       |
| 19     | DWA-75   | 75              | 8.1             | 3                          | 11                           | Grey          | Erect        | 3 <sup>rd</sup> week of Feb.  | 7 to 8 weeks          | Light brown |
| 20     | DWA-76   | 85              | 8.5             | 5                          | 14                           | Blackish grey | Spreading    | 1 <sup>st</sup> week of Feb.  | 4 to 5 weeks          | Dark brown  |
| 21     | DWA-93   | 77              | 7.9             | 3                          | 8                            | Grey          | Erect        | 1 <sup>st</sup> week of March | 4 to 6 weeks          | Light brown |
| 22     | DWA-94   | 80              | 8.3             | 2                          | 9                            | Grey          | Erect        | 3 <sup>rd</sup> week of Feb.  | 5 to 6 weeks          | Brown       |
| 23     | DWA-96   | 82              | 7.7             | 4                          | 12                           | Grey          | Erect        | 2 <sup>nd</sup> week of Feb.  | 5 to 7 weeks          | Brown       |
| 24     | DWA-105  | 71              | 7.4             | 3                          | 10                           | Blackish grey | Erect        | 1 <sup>st</sup> week of March | 7 to 8 weeks          | Dark brown  |
| 25     | DWA-107  | 79              | 8.1             | 3                          | 11                           | Grey          | Erect        | 4 <sup>th</sup> week of Feb.  | 4 to 6 weeks          | Light brown |

The stem girth range of the studied genotypes was observed 70 cm to 93 cm. Where, significantly highest stem girth (93 cm) was recorded in DWA-27, and it was at par with DWA-39 (90 cm) respect to stem girth. DWA-45 has recorded least stem girth (70 cm). The mean stem girth of twenty-five genotypes was found 79.84 cm.

Tree height recorded varied from 7m to 8.8 m. The highest tree height (8.8 m) was recorded by the genotype DWA-27 was also at par with the DWA-57 (8.7 m). The minimum tree height (7 m) was recorded by DWA-59. 7.9m was the mean tree height of twenty-five genotypes.

Number of primary branches ranged from 2 to 5. The genotype DWA-76 has recorded significantly maximum number of primary branches (5) and genotypes DWA-5, DWA-15, DWA-26, DWA-27, DWA-28, DWA-39, DWA-44, DWA-52 and DWA-96 (4) were at par with the DWA-76. The genotypes DWA-57 and DWA-96 have recorded minimum number of primary branches (2). The mean of number of primary branches was found 3.3.

Number of secondary branches variably ranged from 7 to 15. The genotype DWA-27 recorded significantly maximum number of secondary branches (15), which were at par with genotypes DWA-52 and DWA-76 with 14 number of secondary branches each. The genotype DWA-12, DWA-57 and DWA-9 recorded minimum number of secondary branches (7). The mean of number of secondary branches was found to be 11.

The meager variation was observed with respect to trunk bark colour two types of bark colour were observed i. e. grey and blackish grey. The seventeen genotypes had shown grey bark colour, eight genotypes had shown blackish grey bark colour.

Growth habits of studied twenty-five genotypes was recorded in two types of habit i. e. erect and spreading type of growth habits. Nineteen genotypes showed erect growth habit and six genotypes showed spreading type of growth habit.

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

| Sr. no | Genotype | Fruit weight (g) | Weight of pulp (g) | Pulp (%)  | Length of fruit (cm) | Fruit diameter (cm) | Number of fruits per kg. | Number of fruits per tree | Yield per plant (kg) |
|--------|----------|------------------|--------------------|-----------|----------------------|---------------------|--------------------------|---------------------------|----------------------|
| 1      | DWA-4    | 265.0            | 153.8              | 58.3      | 10.5                 | 11.5                | 3.7                      | 87.0                      | 23.8                 |
| 2      | DWA-5    | 279.6            | 168.1              | 60.1      | 11.8                 | 12.3                | 3.5                      | 74.0                      | 22.3                 |
| 3      | DWA-12   | 224.5            | 117.8              | 52.4      | 10.0                 | 11.0                | 4.5                      | 98.0                      | 21.8                 |
| 4      | DWA-15   | 308.4            | 181.4              | 58.8      | 12.1                 | 12.4                | 3.2                      | 64.0                      | 20.9                 |
| 5      | DWA-22   | 250.7            | 146.0              | 58.2      | 9.9                  | 11.1                | 3.9                      | 79.0                      | 20.9                 |
| 6      | DWA-26   | 305.3            | 193.9              | 61.9      | 12.3                 | 12.9                | 3.2                      | 124.0                     | 39.0                 |
| 7      | DWA-27   | 328.2            | 206.5              | 64.2      | 12.8                 | 13.6                | 3.1                      | 162.0                     | 53.0                 |
| 8      | DWA-28   | 190.2            | 108.6              | 57.2      | 11.8                 | 12.7                | 5.1                      | 127.0                     | 25.1                 |
| 9      | DWA-30   | 274.6            | 166.1              | 60.5      | 11.6                 | 12.2                | 3.8                      | 96.0                      | 25.2                 |
| 10     | DWA-39   | 313.8            | 188.9              | 60.2      | 12.6                 | 13.2                | 3.1                      | 139.0                     | 45.0                 |
| 11     | DWA-43   | 301.0            | 169.9              | 56.4      | 10.7                 | 12.7                | 3.3                      | 73.0                      | 22.1                 |
| 12     | DWA-44   | 261.5            | 140.4              | 53.7      | 9.7                  | 10.1                | 3.6                      | 67.0                      | 18.8                 |
| 13     | DWA-45   | 254.8            | 149.8              | 58.8      | 8.4                  | 10.5                | 3.7                      | 99.0                      | 27.1                 |
| 14     | DWA-52   | 319.9            | 193.9              | 63.1      | 12.7                 | 13.4                | 3.1                      | 147.0                     | 48.1                 |
| 15     | DWA-57   | 284.6            | 177.3              | 62.3      | 12.5                 | 12.8                | 3.6                      | 136.0                     | 38.4                 |
| 16     | DWA-59   | 216.8            | 118.1              | 54.6      | 10.9                 | 9.8                 | 4.5                      | 107.0                     | 24.0                 |
| 17     | DWA-63   | 179.1            | 107.0              | 59.9      | 9.0                  | 9.7                 | 5.1                      | 129.0                     | 26.8                 |
| 18     | DWA-67   | 268.5            | 153.6              | 57.2      | 11.7                 | 12.4                | 3.6                      | 84.0                      | 23.0                 |
| 19     | DWA-75   | 302.6            | 191.7              | 62.1      | 12.2                 | 12.8                | 3.3                      | 105.0                     | 31.9                 |
| 20     | DWA-76   | 316.3            | 192.6              | 62.4      | 12.5                 | 13.2                | 3.2                      | 138.0                     | 43.5                 |
| 21     | DWA-93   | 254.1            | 152.7              | 60.5      | 11.1                 | 11.5                | 3.9                      | 70.0                      | 18.1                 |
| 22     | DWA-94   | 179.7            | 92.9               | 51.8      | 8.6                  | 9.5                 | 5.6                      | 81.0                      | 14.5                 |
| 23     | DWA-96   | 219.7            | 123.5              | 56.2      | 9.7                  | 12.2                | 4.5                      | 128.0                     | 28.8                 |
| 24     | DWA-105  | 280.2            | 148.3              | 52.9      | 11.5                 | 11.8                | 3.4                      | 115.0                     | 33.7                 |
| 25     | DWA-107  | 168.6            | 91.4               | 54.4      | 9.9                  | 9.6                 | 5.8                      | 86.0                      | 15.0                 |
|        | Range    | 168.6-328.2      | 91.4-206.5         | 51.8-64.2 | 8.4-12.8             | 9.5-13.6            | 3.1-5.8                  | 64-162                    | 14.5-53              |
|        | Mean     | 261.9            | 153.4              | 58.3      | 11.0                 | 11.8                | 3.9                      | 104.4                     | 28.4                 |
|        | SE(m)    | 7.16             | 4.86               | 1.58      | 0.46                 | 0.50                | 0.17                     | 2.57                      | 0.72                 |
|        | CV       | 5.47             | 6.33               | 5.43      | 8.24                 | 8.55                | 8.74                     | 19.62                     | 20.25                |
|        | CD (5%)  | 20.18            | 13.69              | 4.46      | 1.28                 | 1.42                | 0.48                     | 7.23                      | 2.03                 |

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 DWA-15, DWA-26, DWA-44, DWA-63, DWA-93 and DWA-105 produced flowers during first week of March and all other studied genotypes produced flowers in various weeks of February. In which genotypes DWA-5, DWA-30, DWA-39 and DWA-76 were observed to produce flowers in first week of February.

Duration of flowering in the studied genotypes of wood apple was observed in between four to eight weeks from date of flower initiation. In which maximum flowering duration was observed in genotypes DWA-22, DWA-75 and DWA-105 (7-8 weeks). The genotype DWA-76 showed least flowering duration i. e. 4 to 5 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-five genotypes i. e. light brown, dark brown and brown. Ten genotypes had showed light brown pulp colour, four genotypes had showed dark brown pulp colour and eleven genotypes had showed brown pulp colour.

The fruit weight in studied genotypes fall in between 168.6 to 328.2 g. The highest fruit weight (328.2 g) was found in the genotype DWA-27 which were at par with DWA-52, DWA-76, DWA-39 and DWA-15. Minimum fruit weight (168.6) was found in the genotype DWA-107. The mean fruit weight of twenty-five genotypes was 261.93 g.

Weight of pulp ranged in between 91.4 to 206.5 g. The highest weight of pulp (206.5 g) was found in the genotype DWA-27 which were at par with DWA-26 and DWA-52 to each other. Minimum weight of pulp (91.4 g) was found in the genotype DWA-107. The mean weight of pulp was 153.4 g.

Pulp per cent of studied wood apple genotypes was observed in between 51.8 to 64.2%. The genotype DWA-27 had highest pulp per cent (64.2%) and the genotypes DWA-52, DWA-76, DWA-57, DWA-75, DWA-26, DWA-30, DWA-93, DWA-39, DWA-5 and DWA-63 were at par

with DWA-27 with respect to pulp per cent. The genotype DWA-94 had minimum pulp per cent (51.8%). The mean pulp per cent of twenty-five genotypes was found 58.3%.

Length of fruit of studied wood apple genotypes was observed in between 8.4 to 12.8 cm. significantly maximum length of fruit (12.8 cm) was observed in genotype DWA-27. Genotypes DWA-52, DWA-39, DWA-57, DWA-76, DWA-26, DWA-75, DWA-15, DWA-5, DWA-28, DWA-67 and DWA-30 were at par with DWA-27 in respect to length of fruit. The genotype DWA-45 had minimum length of fruit (8.4 cm). The mean length of fruit of twenty-five genotypes was found 11.0 cm.

The fruit diameter was found in between 9.5 cm to 13.6 cm. Significantly maximum fruit diameter (13.6 cm) was observed in DWA-27 which were at par with DWA-52, DWA-39, DWA-76, DWA-26, DWA-57, DAW-75, DWA-28, DWA-43, DWA-15, DWA-67, DWA-5, DWA-30 and DWA-96. The minimum fruit diameter (9.5 cm) was observed in DWA-94. The mean fruit diameter of twenty-five genotypes was 11.8 cm.

Number of fruits per kg was counted in between 3.1 to 5.8. Significantly maximum number of fruits per kg (5.8) was counted in DWA-107. The minimum number of fruits per kg (3.1) was counted in DWA-27, DWA-39 and DWA-52 each. The mean number of fruits per kg of twenty-five genotypes was 3.9.

Number of fruits/tree was counted in between 64 to 162. Significantly maximum number of fruits/tree (162) were found in genotype DWA-27. The minimum number of fruit/tree (64) was found in DWA-15. The mean number of fruits/tree of twenty-five genotypes was 104.4.

The Yield per plant of the studied genotypes varied from 14.5 to 53 kg. The yield per plant (53 kg) was significantly highest in genotype DWA-27, whereas the minimum yield per plant (14.5 Kg) was found in genotype DWA-94. The average yield per plant for twenty-five genotypes was 28.4 kg.

**Table 4: Mean performance of wood apple genotypes based on shell and seed characters**

| Sr. no | Genotype | Shell weight (g) | Shell thickness (mm) | Pulp: Shell ratio | Number of seeds per 100g pulp | Weight of seed per 100g pulp | Seed size (mm) |
|--------|----------|------------------|----------------------|-------------------|-------------------------------|------------------------------|----------------|
| 1      | DWA-4    | 102.8            | 3.06                 | 1.50              | 94.8                          | 4.06                         | 2.36           |
| 2      | DWA-5    | 104.0            | 3.17                 | 1.67              | 100.2                         | 5.27                         | 2.88           |
| 3      | DWA-12   | 99.9             | 2.96                 | 1.22              | 108.8                         | 5.78                         | 2.71           |
| 4      | DWA-15   | 119.4            | 3.09                 | 1.52              | 128.5                         | 6.11                         | 2.52           |
| 5      | DWA-22   | 95.5             | 3.11                 | 1.53              | 94.5                          | 4.22                         | 3.14           |
| 6      | DWA-26   | 101.1            | 3.47                 | 1.92              | 119.3                         | 5.58                         | 2.63           |
| 7      | DWA-27   | 116.7            | 3.66                 | 1.77              | 130.4                         | 5.78                         | 3.23           |
| 8      | DWA-28   | 77.3             | 2.98                 | 1.40              | 108.6                         | 4.75                         | 2.53           |
| 9      | DWA-30   | 99.6             | 3.25                 | 1.67              | 120.1                         | 6.71                         | 2.69           |
| 10     | DWA-39   | 119.7            | 3.43                 | 2.00              | 128.1                         | 6.62                         | 2.93           |
| 11     | DWA-43   | 127.1            | 3.35                 | 1.34              | 99.6                          | 6.07                         | 3.05           |
| 12     | DWA-44   | 116.8            | 3.12                 | 1.20              | 129.5                         | 5.09                         | 2.83           |
| 13     | DWA-45   | 95.3             | 3.08                 | 1.58              | 131.8                         | 6.54                         | 2.73           |
| 14     | DWA-52   | 115.1            | 3.57                 | 1.69              | 96.9                          | 8.18                         | 2.37           |
| 15     | DWA-57   | 103.3            | 3.09                 | 1.72              | 150.0                         | 5.51                         | 2.51           |
| 16     | DWA-59   | 94.2             | 3.23                 | 1.25              | 155.0                         | 6.06                         | 2.17           |
| 17     | DWA-63   | 77.8             | 2.99                 | 1.38              | 166.9                         | 7.77                         | 2.82           |
| 18     | DWA-67   | 108.4            | 3.15                 | 1.42              | 122.9                         | 7.53                         | 2.63           |
| 19     | DWA-75   | 102.3            | 3.25                 | 1.88              | 116.9                         | 6.22                         | 2.48           |
| 20     | DWA-76   | 119.8            | 3.54                 | 1.62              | 130.7                         | 8.02                         | 3.11           |
| 21     | DWA-93   | 96.9             | 3.07                 | 1.56              | 141.8                         | 7.90                         | 2.26           |
| 22     | DWA-94   | 80.0             | 2.90                 | 1.16              | 190.7                         | 6.26                         | 2.69           |
| 23     | DWA-96   | 85.1             | 2.84                 | 1.45              | 136.0                         | 4.72                         | 2.06           |
| 24     | DWA-105  | 126.1            | 3.11                 | 1.13              | 117.3                         | 6.86                         | 2.76           |
| 25     | DWA-107  | 74.0             | 2.97                 | 1.24              | 208.9                         | 7.58                         | 2.36           |
|        | Range    | 74-127.1         | 2.84-3.66            | 1.13-2.0          | 94.3-208.9                    | 4.06-8.18                    | 2.06-3.23      |
|        | Mean     | 102.3            | 3.2                  | 1.5               | 129.1                         | 6.2                          | 2.7            |
|        | SE(m)    | 3.10             | 0.09                 | 0.09              | 4.29                          | 0.26                         | 0.07           |
|        | CV       | 6.06             | 5.91                 | 12.40             | 6.64                          | 8.25                         | 5.48           |
|        | CD (5%)  | 8.74             | 0.26                 | 0.26              | 12.08                         | 0.72                         | 0.21           |

The shell weight of the studied genotypes was observed 74 to 127.1g. Where, significantly highest shell weight (127.1g) was recorded in

DWA-43, which were at par with the DWA-105, DWA-76, DWA-39 and DWA-15 with respect to shell weight. DWA-107 has recorded least shell weight (74g). The mean shell weight of twenty-five genotypes was found 102.3 g.

Shell thickness recorded varied from 2.84 mm to 3.66 mm. The highest shell thickness (3.66 mm) was recorded by the genotype DWA-27, which was at par with the DWA-52, DWA-76, DWA-26 and DWA-39. The minimum shell thickness (2.84 mm) was recorded by DWA-96. 3.2 mm was the mean shell thickness of twenty-five genotypes.

Pulp: shell ratio was ranged from 1.13 to 2.0. The genotype DWA-39 was recorded significantly maximum pulp: shell ratio (2.0), which was at par with DWA-26, DWA-75 and DWA-27. The genotype DWA-105 was recorded with minimum pulp: shell ratio (1.13). The mean pulp: shell ratio was found 1.5.

Number of seeds per 100g pulp was ranged from 94.3 to 208.9. The genotype DWA-107 was observed with significantly maximum number of seeds per 100g pulp (208.9). The genotype DWA-22 was recorded with minimum number of seeds per 100g pulp (94.3). The average number of seeds per 100g pulp, was recorded 129.1.

Weight of seed per 100g pulp weight was recorded in genotypes in between 4.06 to 8.18 g. The significantly highest weight of seed per 100g pulp (8.18 g) was recorded in genotype DWA-52, which were at par with DWA-76, DWA-93, DWA-63, DWA-107 and DWA-67. The minimum weight of seed per 100g pulp (4.06 g) was recorded in DWA-4. The mean weight of seed per 100g pulp was recorded 6.20 g.

Seed size was observed in between 2.06 to 3.23 mm. The largest seed size (3.23 mm) was observed in DWA-27, which were at par with DWA-22, DWA-76 and DWA-43. The minimum seed size (2.06 mm) was recorded in genotype DWA-96. The average seed size was recorded 2.7 mm.

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

| Sr. no | Genotype | Total soluble solids (°Brix) | Acidity (%) | TSS: Acid ratio | Total sugar (%) | Reducing sugar (%) | Non-Reducing sugar (%) | Pectin content (%) |
|--------|----------|------------------------------|-------------|-----------------|-----------------|--------------------|------------------------|--------------------|
| 1      | DWA-4    | 11.83                        | 1.41        | 8.42            | 1.90            | 1.24               | 0.66                   | 1.54               |
| 2      | DWA-5    | 12.34                        | 1.33        | 9.28            | 1.93            | 1.22               | 0.71                   | 1.23               |
| 3      | DWA-12   | 11.80                        | 2.23        | 5.30            | 1.86            | 1.18               | 0.68                   | 1.13               |
| 4      | DWA-15   | 12.33                        | 2.22        | 5.55            | 1.99            | 1.23               | 0.76                   | 1.43               |
| 5      | DWA-22   | 11.79                        | 1.24        | 9.54            | 1.95            | 1.20               | 0.75                   | 1.30               |
| 6      | DWA-26   | 12.99                        | 2.36        | 5.59            | 2.10            | 1.23               | 0.88                   | 1.24               |
| 7      | DWA-27   | 13.39                        | 1.51        | 8.33            | 2.15            | 1.24               | 0.91                   | 1.71               |
| 8      | DWA-28   | 12.53                        | 2.82        | 4.45            | 2.02            | 1.26               | 0.76                   | 1.17               |
| 9      | DWA-30   | 13.24                        | 2.10        | 6.32            | 2.09            | 1.22               | 0.87                   | 1.53               |
| 10     | DWA-39   | 11.60                        | 1.13        | 10.30           | 1.87            | 1.20               | 0.67                   | 1.67               |
| 11     | DWA-43   | 11.18                        | 2.71        | 4.14            | 1.96            | 1.23               | 0.73                   | 1.78               |
| 12     | DWA-44   | 12.30                        | 2.68        | 4.58            | 1.90            | 1.24               | 0.67                   | 1.11               |
| 13     | DWA-45   | 12.35                        | 2.33        | 5.30            | 1.85            | 1.23               | 0.61                   | 1.24               |
| 14     | DWA-52   | 11.81                        | 3.24        | 3.65            | 2.07            | 1.19               | 0.88                   | 1.40               |
| 15     | DWA-57   | 13.51                        | 2.83        | 4.74            | 1.97            | 1.27               | 0.70                   | 1.32               |
| 16     | DWA-59   | 12.32                        | 1.73        | 7.14            | 2.06            | 1.23               | 0.83                   | 1.16               |
| 17     | DWA-63   | 12.43                        | 1.40        | 8.90            | 2.04            | 1.26               | 0.79                   | 1.57               |
| 18     | DWA-67   | 12.81                        | 1.30        | 9.88            | 2.12            | 1.28               | 0.84                   | 1.26               |
| 19     | DWA-75   | 12.10                        | 3.19        | 3.79            | 1.96            | 1.20               | 0.76                   | 1.66               |
| 20     | DWA-76   | 11.81                        | 1.47        | 8.06            | 2.01            | 1.17               | 0.85                   | 1.47               |
| 21     | DWA-93   | 12.71                        | 2.33        | 5.44            | 1.84            | 1.19               | 0.65                   | 1.74               |
| 22     | DWA-94   | 12.93                        | 1.62        | 8.10            | 2.05            | 1.25               | 0.80                   | 1.06               |
| 23     | DWA-96   | 13.10                        | 2.20        | 5.96            | 1.92            | 1.18               | 0.74                   | 1.27               |
| 24     | DWA-105  | 11.44                        | 3.33        | 3.43            | 2.08            | 1.24               | 0.84                   | 1.34               |
| 25     | DWA-107  | 12.22                        | 1.84        | 6.64            | 1.91            | 1.21               | 0.70                   | 1.08               |
|        | Range    | 11.18-13.51                  | 1.13-3.33   | 3.43-10.30      | 1.84-2.15       | 1.17-1.28          | 0.61-0.91              | 1.06-1.78          |
|        | Mean     | 12.4                         | 2.1         | 6.5             | 2.0             | 1.2                | 0.8                    | 1.4                |
|        | SE(m)    | 0.32                         | 0.05        | 0.27            | 0.03            | 0.01               | 0.04                   | 0.04               |
|        | CV       | 5.21                         | 4.98        | 8.43            | 3.08            | 2.17               | 9.44                   | 5.66               |
|        | CD (5%)  | 0.91                         | 0.15        | 0.77            | 0.09            | 0.04               | 0.10                   | 0.11               |

The total soluble solids were analysed and recorded in between 11.18–13.51 °Brix. The DWA-57 had the highest TSS (13.51°Brix) among all the genotypes. While DWA-27, DWA-30, DWA-96, DWA-26, DWA-94, DWA-67 and DWA-93 were at par with the genotype DWA-57. The genotype DWA-43 had lowest TSS (11.18°Brix). The average TSS for twenty-five genotypes was 12.4°Brix.

Acidity was recorded and has been found between 1.13 to 3.33%. Significantly highest acidity (3.33%) was noted in genotype DWA-105, which were at par with DWA-52 and DWA-75. While the lowest acidity was noted in genotype DWA-39. However, the average acidity of twenty-five genotypes was 2.1%.

TSS: acid ratio was recorded in between 3.43 to 10.30. Significantly highest TSS: acid ratio 10.30 was observed in genotype DWA-39, which was at par with DWA-67 and DWA-22. While the lowest TSS: acid ratio 3.4 was recorded in genotype DWA-105. The mean TSS: acid ratio recorded in twenty-five genotypes was 6.5.

The total sugars of wood apple in different genotypes were recorded in between 1.84 to 2.15%. The highest total sugars (2.15%) was recorded in genotype DWA-27 and DWA-67, DWA-26, DWA-30, DWA-105, DWA-52 and DWA-59 were at par with DWA-27 and each other. The lowest total sugars (1.84%) were recorded in genotype DWA-93. However, the average total sugars were recorded in twenty-five genotypes as 2.0%.

The reducing sugars of wood apple in different genotypes were recorded in between 1.17 to 1.28%. The highest reducing 1.28% was recorded in genotype DWA-67, while DWA-57, DWA-28, DWA-63, DWA-94, DWA-4, DWA-27, DWA-44 and DWA-105 were at par with DWA-67. The lowest reducing sugars 1.17% were recorded in DWA-76. The average reducing sugar was recorded in twenty-five genotypes of wood apple as 1.2%.

The non-reducing sugars of wood apple in different genotypes were recorded in between 0.61 to 0.91%. Significantly highest non-reducing sugar (0.91%) was recorded in genotype DWA-27, while DWA-26, DWA-52, DWA-30, DWA-76, DWA-67, DWA-105 and DWA-59

were at par with DWA-27. The lowest non-reducing sugar (0.61%) was observed in genotype DWA-45. The average non-reducing sugars were recorded in twenty-five genotypes of wood apple as 0.8%.

The pectin content of wood apple in different genotypes was recorded in between 1.06 to 1.78%. Significantly highest pectin content 1.78% was recorded in genotype DWA-43 and genotypes DWA-93, DWA-27 and DWA-39 was at par with DWA-43. While, the genotype DWA-94 had the lowest pectin content 1.06%. The average pectin content was recorded in twenty-five genotypes of wood apple as 1.4%.

#### **4.2.2 Genotypic coefficient of variation (GCV)**

The data presented in the Table 6. Revealed that, the genotypic coefficient of variation (GCV) ranged from 4.27 per cent (TSS) to 32.37 per cent (TSS: acid ratio) for different characters under investigation. Genotypic coefficient of variation was of low order for the characters viz., length of fruit (11.51%), fruit diameter (10.43%), seed size (10.23%), pulp % (5.45%) and total soluble solids (4.27%). Whereas the moderate order of GCV were recorded for number of fruit per tree (25.15%), weight of pulp (21.92%), number of seeds per 100g pulp (21.75%), weight of seed per 100g pulp (18.58%), fruit weight (18.05%), pulp: shell ratio (16.75%), pectin content (15.82%), shell weight (14.80%) and pulp: shell ratio (14.77%). While high orders of GCV were recorded for acidity (32.21%).

#### **4.2.3 Phenotypic coefficient of variation (PCV)**

The data from the Table 6, Indicated that, the phenotypic coefficient of variation ranged from 6.74% (TSS) to 33.45% (TSS: acid ratio) for the various characters studied. Low order phenotypic coefficient of variation was recorded for the character length of fruit (14.15%), fruit diameter (13.30%), seed size (11.61%), shell thickness (8.52%), pulp per cent (7.69%), TSS (6.74%). While, moderate order of PCV were observed for characters weight of pulp (26.79%), number of seed per 100g pulp (22.74%), weight of seed per 100g pulp (20.22%), pulp: shell ratio (19.28%), fruit weight (18.86%), pectin content (16.62%), shell weight (15.99%). While, the high order of PCV were recorded for acidity (32.6%) and number of fruits per tree (31.90%).

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

| Sr. no | Characters                    | Range       | Mean  | GCV (%) | PCV (%) | Heritability (h <sup>2</sup> ) % | Expected genetic advances as % over mean |
|--------|-------------------------------|-------------|-------|---------|---------|----------------------------------|--|
| 1      | Fruit weight (g)              | 168.6-328.2 | 261.9 | 18.05   | 18.86   | 91.60                            | 35.60                                    |
| 2      | Weight of pulp (g)            | 91.4-206.5  | 153.4 | 21.92   | 22.81   | 92.3                             | 43.38                                    |
| 3      | Pulp (%)                      | 51.8-64.2   | 58.3  | 5.45    | 7.69    | 50.31                            | 7.97                                     |
| 4      | Length of fruit (cm)          | 8.4-12.8    | 11    | 11.51   | 14.15   | 66.10                            | 19.27                                    |
| 5      | Fruit diameter (cm)           | 9.5-13.6    | 11.8  | 10.43   | 13.30   | 61.46                            | 16.85                                    |
| 6      | Number of fruits per tree     | 64-162      | 104.4 | 25.15   | 31.90   | 62.18                            | 40.87                                    |
| 7      | Shell Weight (g)              | 74-127.1    | 102.3 | 14.80   | 15.99   | 85.63                            | 28.22                                    |
| 8      | Shell Thickness (mm)          | 2.84-3.66   | 3.2   | 6.13    | 8.52    | 51.89                            | 9.10                                     |
| 9      | Pulp: Shell ratio             | 1.13-2.0    | 1.5   | 14.77   | 19.28   | 58.73                            | 23.32                                    |
| 10     | Number of seeds per 100g pulp | 94.3-208.9  | 129.1 | 21.75   | 22.74   | 91.47                            | 42.85                                    |
| 11     | Weight of seed per 100g pulp  | 4.06-8.18   | 6.2   | 18.58   | 20.22   | 84.41                            | 35.16                                    |
| 12     | Seed size (mm)                | 2.06-3.23   | 2.7   | 10.23   | 11.61   | 77.71                            | 18.59                                    |
| 13     | Total soluble solids (°Brix)  | 11.18-13.51 | 12.4  | 4.27    | 6.74    | 40.26                            | 5.59                                     |
| 14     | Acidity (%)                   | 1.13-3.33   | 2.1   | 32.21   | 32.6    | 97.66                            | 65.58                                    |
| 15     | TSS: Acid ratio               | 3.43-10.30  | 6.5   | 32.37   | 33.45   | 93.64                            | 64.54                                    |
| 16     | Pectin content (%)            | 1.06-1.78   | 1.4   | 15.82   | 16.62   | 90.66                            | 31.04                                    |

#### 4.2.4 Heritability estimates in broad sense (h<sup>2</sup>)

Result presented in the Table 6, revealed that the higher heritability was observed for the characters of acidity (97.66%), TSS: acid ratio (93.64%), pulp weight (92.30%), fruit weight (91.60%), number of seed per 100g pulp (91.47%) and pectin content (90.66%). Whereas moderate heritability was recorded for the characters skull weight (85.63%), weight of seed per 100g pulp (84.41%), seed size (77.71%), length of fruit

(66.10%) and fruit diameter (61.46%), While low heritability was found for the characters pulp: shell ratio (58.73%), shell thickness (51.89%), pulp % (50.31%) and TSS (40.26%).

#### **4.2.5 Expected genetic advance as per cent over mean (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 was in the range of 5.59% to 65.58%. High degree of genetic advance was found for the characters acidity (65.58%), TSS: acid ratio (64.54%), weight of pulp (43.38%) and Number of seed per 100g pulp (42.85%). Whereas moderate degree of genetic advance was found for the characters fruit weight (35.60%), weight of seed per 100g pulp (35.16%), pectin content (31.04%), shell weight (28.22%), pulp: shell (23.32%) and Low degree of genetic advance was observed for length of fruit (19.27%), seed size (18.59%), fruit diameter (16.85%), shell thickness (9.10%), pulp percent (7.97%) and total soluble solids (5.59%).

#### **4.3 Correlation studies**

In order to find out the degree of association between yield contributing traits, genotypic and phenotypic correlation coefficient were estimated are presented in Table 7 and 8.

##### **4.3.1 Genotypic correlation**

###### **4.3.1.1. Association between yield contributing characters and among themselves**

###### **a) Fruit weight (g)**

The data presented in the Table 7. showed positive and significant genotypic correlations with weight of pulp ( $r=0.986$ ), shell weight ( $r=0.900$ ), pulp : shell ratio ( $r=0.720$ ), pulp percentage ( $r=0.744$ ), length of fruits ( $r=0.781$ ), fruit diameter ( $r=0.863$ ), number of fruit per tree ( $r=0.246$ ), pectin content ( $r=0.562$ ) and yield per plant ( $r=0.703$ ), While other character showed negative and significant genotypic correlation with number of fruits per kg ( $r=-0.982$ ).

### **b) Weight of pulp (g)**

The data in respect to weight of pulp showed significant and positive genotypic correlation with shell weight ( $r=0.770$ ), pulp: shell ratio ( $r=0.860$ ), pulp percentage ( $r=0.841$ ), length of fruit ( $r=0.824$ ), fruit diameter ( $r=0.885$ ), number of fruits per tree ( $r=-0.343$ ), pectin content ( $r=0.604$ ) and yield per plant ( $r=0.754$ ). However, while one observation showed negative and significant genotypic correlation viz. number of fruits per kg ( $r=-0.967$ )

### **c) Shell weight (g)**

Shell weight showed positive and significant genotypic correlation with pulp: shell ratio ( $r=0.295$ ), pulp percentage ( $r=0.252$ ), length of fruit ( $r=0.589$ ), fruit diameter ( $r=0.630$ ), pectin content ( $r=0.459$ ) and yield per plant ( $r=0.513$ ), while it showed negative and significant correlation with number of fruits per kg ( $r=-0.909$ ).

### **d) Pulp: shell ratio**

Pulp: shell showed positive and significant genotypic correlation with the pulp percentage ( $r=0.978$ ), length of fruits ( $r=0.733$ ), fruit diameter ( $r=0.862$ ), number of fruits per tree ( $r=0.494$ ), pectin content ( $r=0.554$ ) and yield per plant ( $r=0.723$ ), while showed negative and significant correlation with number of fruits per kg ( $r=-0.671$ ).

### **e) Pulp percentage**

Pulp percentage showed was found positive and significant genotypic correlation with length of fruit ( $r=0.796$ ), fruit diameter ( $r=0.768$ ), number of fruits per tree ( $r=0.612$ ), pectin content ( $r=0.677$ ) and yield per plant ( $r=0.783$ ). While, negative and significant genotypic correlation with showed number of fruits per kg ( $r=-0.647$ ) was observed.

### **f) Length of fruit (cm)**

Length of fruit showed positive and significant genotypic correlated with diameter of fruit ( $r=0.971$ ), number of fruits per tree ( $r=0.495$ ), pectin content ( $r=0.432$ ) and yield per plant ( $r=0.747$ ), While negative and significant genotypic correlation was shown with number of fruits per kg ( $r=-0.706$ ).

**Table 7: Estimates of genotypic correlation coefficient for various characters**

|                                  | Fruit Weight (g) | Weight of Pulp (g) | Shell weight (g)    | Pulp: shell ratio | Pulp (%) | Length of fruit (cm) | Fruit diameter (cm) | Number of fruits per tree | Number of fruits per Kg | Pectin Content (%) | Yield per plant (kg) |
|----------------------------------|------------------|--------------------|---------------------|-------------------|----------|----------------------|---------------------|---------------------------|-------------------------|--------------------|----------------------|
| <b>Fruit Weight (g)</b>          | 1                |                    |                     |                   |          |                      |                     |                           |                         |                    |                      |
| <b>Weight of Pulp (g)</b>        | 0.986**          | 1                  |                     |                   |          |                      |                     |                           |                         |                    |                      |
| <b>Shell weight (g)</b>          | 0.900**          | 0.770**            | 1                   |                   |          |                      |                     |                           |                         |                    |                      |
| <b>Pulp: shell ratio</b>         | 0.720**          | 0.860**            | 0.295**             | 1                 |          |                      |                     |                           |                         |                    |                      |
| <b>Pulp (%)</b>                  | 0.744**          | 0.841**            | 0.252*              | 0.978**           | 1        |                      |                     |                           |                         |                    |                      |
| <b>Length of fruit (cm)</b>      | 0.781**          | 0.824**            | 0.589**             | 0.733**           | 0.796**  | 1                    |                     |                           |                         |                    |                      |
| <b>Fruit diameter (cm)</b>       | 0.863**          | 0.885**            | 0.630**             | 0.862**           | 0.768**  | 0.971**              | 1                   |                           |                         |                    |                      |
| <b>Number of fruits per tree</b> | 0.246*           | 0.343**            | 0.073 <sup>NS</sup> | 0.494**           | 0.612**  | 0.495**              | 0.518**             | 1                         |                         |                    |                      |
| <b>Number of fruits per Kg</b>   | -0.982**         | -0.967**           | -0.909**            | -0.671**          | -0.647** | -0.706**             | -0.820**            | -0.179 <sup>NS</sup>      | 1                       |                    |                      |
| <b>Pectin Content (%)</b>        | 0.562**          | 0.604**            | 0.459**             | 0.554**           | 0.677**  | 0.432**              | 0.534**             | 0.212*                    | -0.536**                | 1                  |                      |
| <b>Yield per plant (kg)</b>      | 0.703**          | 0.754**            | 0.513**             | 0.723**           | 0.783**  | 0.747**              | 0.796**             | 0.873**                   | -0.615**                | 0.411**            | 1                    |

\*-significant at 5% level

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

**Table 8: Estimates of phenotypic correlation coefficient for various characters**

|                                  | Fruit Weight (g) | Weight of Pulp (g) | Shell weight (g)     | Pulp: shell ratio | Pulp (%) | Length of fruit (cm) | Fruit diameter (cm) | Number of fruits per tree | Number of fruits per Kg | Pectin Content (%) | Yield per plant (kg) |
|----------------------------------|------------------|--------------------|----------------------|-------------------|----------|----------------------|---------------------|---------------------------|-------------------------|--------------------|----------------------|
| <b>Fruit Weight (g)</b>          | 1                |                    |                      |                   |          |                      |                     |                           |                         |                    |                      |
| <b>Weight of Pulp (g)</b>        | 0.951**          | 1                  |                      |                   |          |                      |                     |                           |                         |                    |                      |
| <b>Shell weight (g)</b>          | 0.783**          | 0.699**            | 1                    |                   |          |                      |                     |                           |                         |                    |                      |
| <b>Pulp: shell ratio</b>         | 0.538**          | 0.638**            | 0.140 <sup>NS</sup>  | 1                 |          |                      |                     |                           |                         |                    |                      |
| <b>Pulp (%)</b>                  | 0.436**          | 0.675**            | 0.224*               | 0.581**           | 1        |                      |                     |                           |                         |                    |                      |
| <b>Length of fruit (cm)</b>      | 0.629**          | 0.645**            | 0.465**              | 0.443**           | 0.381**  | 1                    |                     |                           |                         |                    |                      |
| <b>Fruit diameter (cm)</b>       | 0.650**          | 0.682**            | 0.472**              | 0.379**           | 0.489**  | 0.631**              | 1                   |                           |                         |                    |                      |
| <b>Number of fruits per tree</b> | 0.199*           | 0.246*             | -0.004 <sup>NS</sup> | 0.315**           | 0.302**  | 0.315**              | 0.333**             | 1                         |                         |                    |                      |
| <b>Number of fruits per Kg</b>   | -0.873**         | -0.860**           | -0.776**             | -0.492**          | -0.478** | -0.519**             | -0.519**            | -0.094 <sup>NS</sup>      | 1                       |                    |                      |
| <b>Pectin Content (%)</b>        | 0.520**          | 0.556**            | 0.400**              | 0.397**           | 0.444**  | 0.333**              | 0.393**             | 0.131 <sup>NS</sup>       | -0.456**                | 1                  |                      |
| <b>Yield per plant (kg)</b>      | 0.589**          | 0.628**            | 0.370**              | 0.506**           | 0.494**  | 0.519**              | 0.527**             | 0.862**                   | -0.547**                | 0.319**            | 1                    |

\*-significant at 5% level

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

#### **g) Fruit diameter (cm)**

Fruit diameter showed positive and significant genotypic correlation with the number of fruits per tree (0.518), pectin content ( $r=0.534$ ) and yield per plant ( $r=0.796$ ), While negative and significant genotypic correlation was with number of fruits per kg ( $r=-0.820$ ).

#### **h) Number of fruits per tree**

Number of fruits per tree showed positive and significant genotypic correlation with the pectin content ( $r=0.212$ ) and yield per plant ( $r=0.873$ ), while negative and non-significant genotypic correlation with number of fruits per kg ( $r=-0.179$ ).

#### **i) Number of fruits per kg**

Number of fruits per kg only showed the negative and significant genotypic correlation with number of pectin content ( $r=-0.536$ ) and yield per plant ( $r=-0.615$ ).

#### **j) Pectin content (%)**

Pectin content showed positive and significant genotypic correlation with the yield per plant ( $r=0.411$ ).

### **4.3.2 Phenotypic correlations**

#### **4.3.2.1 Association between yield contributing characters and among themselves**

##### **a) Fruit weight (g)**

The data presented in the Table 8 showed positive and significant phenotypic correlations with weight of pulp ( $r=0.951$ ), shell weight ( $r=0.783$ ), pulp: shell ratio ( $r=0.538$ ), pulp percentage ( $r=0.436$ ), length of fruit ( $r=0.629$ ), fruit diameter ( $r=0.650$ ), number of fruits per tree ( $r=0.199$ ), pectin content ( $r=0.520$ ) and yield per plant ( $r=0.589$ ). However, it showed negative and significant phenotypic correlations with number of fruits per kg ( $r=-0.873$ ).

### **b) Weight of pulp (g)**

The data in respect to weight of pulp showed significant and positive phenotypic correlation with shell weight ( $r=0.699$ ), pulp: shell ratio ( $r=0.638$ ), pulp percentage ( $r=0.675$ ), length of fruit ( $r=0.645$ ), fruit diameter ( $r=0.682$ ), number of fruits per tree ( $r=0.246$ ), pectin content ( $r=0.556$ ) and yield per plant ( $r=0.628$ ). However, it showed negative and significant phenotypic correlation with number of fruits per kg ( $r=-0.860$ ).

### **c) Shell weight (g)**

The data regarding shell weight showed positive and significant phenotypic correlation with pulp percentage ( $r=0.224$ ), length of fruit ( $r=0.465$ ), fruit diameter ( $r=0.472$ ), number of fruits per tree ( $r=0.199$ ), weight of shell ( $r=0.783$ ), pectin content ( $r=0.400$ ) and yield per plant ( $r=0.370$ ), while positive and non-significant phenotypic correlation with pulp: shell ( $r=0.140$ ). Whereas showed negative and non-significant phenotypic correlation with number of fruits per tree ( $r=0.004$ ).

### **d) Pulp: shell ratio**

The data regarding shell weight showed positive and significant phenotypic correlation with pulp percentage ( $r=0.581$ ), length of fruit ( $r=0.443$ ), fruit diameter ( $r=0.379$ ), number of fruits per tree ( $r=0.315$ ), pectin content ( $r=0.397$ ) and yield per plant ( $r=0.506$ ), while showed negative and significant phenotypic correlation with number of fruits per kg ( $r=-0.492$ ).

### **e) Pulp percentage**

Pulp percentage was found positive and significant phenotypic correlation with fruit length ( $r=0.381$ ), fruit diameter ( $r=0.489$ ), number of fruits per tree ( $r=0.302$ ), pectin content ( $r=0.444$ ) and yield per plant ( $r=0.494$ ). Whereas negative and significant phenotypic correlation showed with number of fruits per kg ( $r=-0.478$ ).

### **f) Length of fruit (cm)**

Length of fruit showed positively and significantly phenotypic correlated with fruit diameter ( $r=0.631$ ), number of fruits per tree ( $r=0.315$ ),

pectin content ( $r=0.333$ ) and yield per tree ( $r=0.519$ ), while negative and significant phenotypic correlated with number of fruits per kg ( $r=-0.519$ ).

#### **g) Fruit diameter (cm)**

Fruit diameter showed positive and significant phenotypic correlation with the number of fruits per tree ( $r=0.333$ ), pectin content ( $r=0.393$ ) and yield per plant ( $r=0.527$ ), While negative and significant phenotypic correlation was with number of fruits per kg ( $r=-0.519$ ).

#### **h) Number of fruits per tree**

Number of fruits per tree showed positive and significant phenotypic correlation with the yield per plant ( $r=0.862$ ), While positive and non-significant correlation with pectin content ( $r=0.131$ ), whereas showed negative and non-significant phenotypic correlation with Number of fruits per kg ( $r=-0.094$ )

#### **i) Number of fruits per kg**

Number of fruits per kg only showed the negative and significant phenotypic correlated with pectin content ( $r=-0.456$ ) and yield per plant ( $r=-0.547$ ).

#### **j) Pectin content (%)**

Pectin content showed positive and significant phenotypic correlation with yield per plant ( $r=0.319$ ).

### **4.4 Discussion**

In a crop improvement programme, the success of selection depends on genetic variability and correlations between the characters in the population. The genetic variability estimated in terms of GCV and PCV 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). The heritable variation among genotypes can be ascertained with greater degree of accuracy when heritability along with genetic advance is studied.

The correlation studies which indicate degree of relationship between yield and its components, among the components themselves is of great interest to plan and carries much practical significance.

Considering diverse characters can help to aim in exploiting the genotypes for the improvement. The various characters studied, the results obtained in the present investigation are discussed under heads and subheads.

#### **4.4.1 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 among the genotypes as regards to characters might result into genetic variability, natural characters and climatic adaptability in a region that leads to variation in characters.

#### **4.4.2 Genetic Variability Studies**

The study of genetic variability present in the existing genetic stock of Wood apple, the extent to which desirable characters are inheritable 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 quantitative in inheritance, which are influenced by genotypic and environmental interactions. Therefore, it is required to disintegrate the phenotypic variance into genetic and environmental components. Simultaneously, the estimate of heritability that indicates the degree of transmissibility of a trait into the offspring 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 per cent of means and heritability ( $h^2$ ) are given in Table 6.

#### 4.4.2.1. Range

The assessment of available Wood apple 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 biochemical 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-five 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: shell ratio, weight of seed per 100 g pulp, number of seed per 100 g 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 168.6 to 328.2 g, range of pulp weight was found in between 91.4 to 206.5 g, pulp percentage was ranged between 51.8 to 64.2, fruit length was ranged between 8.4 to 12.8 cm, fruit diameter was ranged between 9.5 to 13.6, shell weight was ranged between 74 to 127.1, shell thickness was ranged between 2.84 to 3.66, pulp: shell ratio was ranged between 1.13 to 2.0, number of seeds per 100g pulp was ranged between 94.3 to 208.9, weight of seeds per 100g pulp was ranged between 4.06 to 8.18 g, seed size was ranged between 2.06 to 3.23 mm, total soluble solids was ranged between 11.18 to 13.51 °Brix, acidity was ranged between 1.13 to 3.33 %, TSS: acid ratio was ranged between 3.43 to 10.30, total sugar was ranged between 1.84 to 2.15 %, reducing sugars was ranged between 1.17 to 1.28 %, non-reducing sugars 0.61 to 0.91 % and pectin content was ranged between 1.06 to 1.78 %.

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 and Singh (2016) and Pandey, *et al.* (2008) in Bael. The above findings were in broad conformity with the reports of these workers.

#### 4.4.2.2. 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) and Mishra, *et al.* (2005) in Bael.

The highest genotypic coefficient of variation was observed for TSS: acid ratio, acidity percentage, number of fruits per tree 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 percentage, number of fruits per tree, 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 its 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.

#### **4.4.2.3. 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 per cent of mean observed was in the range of 5.59 to 65.58%. High degree of genetic advance was found for the characters acidity (65.58%), TSS: acid ratio (64.54%), pectin content (31.04%), number of seeds per 100g pulp (42.85), pulp weight (43.38%), fruit weight (35.60%) and pulp: shell ratio (23.32%). Whereas moderate degree of genetic advance was found for the characters weight of seeds per 100g pulp (35.16%), shell thickness (9.10%), fruit diameter (16.85%), and fruit length (19.27%). Low degree of genetic advance was observed for shell thickness (9.10%), pulp per cent (7.29%) and total soluble solids (5.59 °Brix) similar findings with high heritability and EGA were pertaining to different traits reported for physico-chemical characteristics of Bael fruits by Singh and Mishra (2010).

Generally high heritability accompanied with high genetic advance in a character 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,

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 (1985). When heritability is predominantly due to non-additive gene effects (dominance and epistasis) then the genetic gain by selection would be low, as observed in present study for sixteen characters. Selection of genotypes may be employed to carry out further improvement in these characters. The high heritability is being exhibited due to natural mutation in genotypes.

#### **4.4.3 Correlation**

The interrelationship between two characters can be directly observed by the phenotypic correlations. The genotypic correlation may be interpreted as the correlation of breeding value. When two characters are invariably and linearly associated, the underlined, genetic mechanism causing such association may be due to complete linkage between the two traits or pleiotropy, some gene may increase both the traits (positive association), while one may increase and reduces the other (negative association). The present discussion is mostly concentrated on genotypic correlation because they provide an idea of association at genotypic level of inherent association between two traits and that help in carry out reliable selection in situation where phenotypic and genotypic association is closer one.

In the present investigation, the estimates of genotypic correlation were slightly higher than the corresponding phenotypic

correlation (Table 7) indicating that genotype was superior, but their expression was reduced due to the natural mutation.

The characters exhibiting significant positive genotypic correlation with fruit yields per plant were found to be fruit weight, pulp weight, pulp: shell ratio, pulp percentage, length of fruit, fruit diameter, shell weight and pectin content. These characters were also positively interlinked with among themselves. Thus, it indicated the importance of these character while selection.

Results obtained in the present study revealed that fruit weight exhibited negative and non-significant genotypic correlation with number of fruits per kg. While positive and significant correlation found with weight of pulp, pulp: shell ratio, length of fruit and pectin content. However positive and significant phenotypic correlation were found with weight of pulp, pulp percentage, number of fruits per kg, length of fruit, fruit diameter and pectin content of the fruits.

The character weight of pulp showed positive and significant genotypic correlation with pulp: shell ratio, pulp percentage, length of fruit, fruit diameter and. While it showed positive and significant phenotypic correlation with yield per plant, number of fruits per kg, pulp percentage, pulp: shell, fruit diameter and length of fruit.

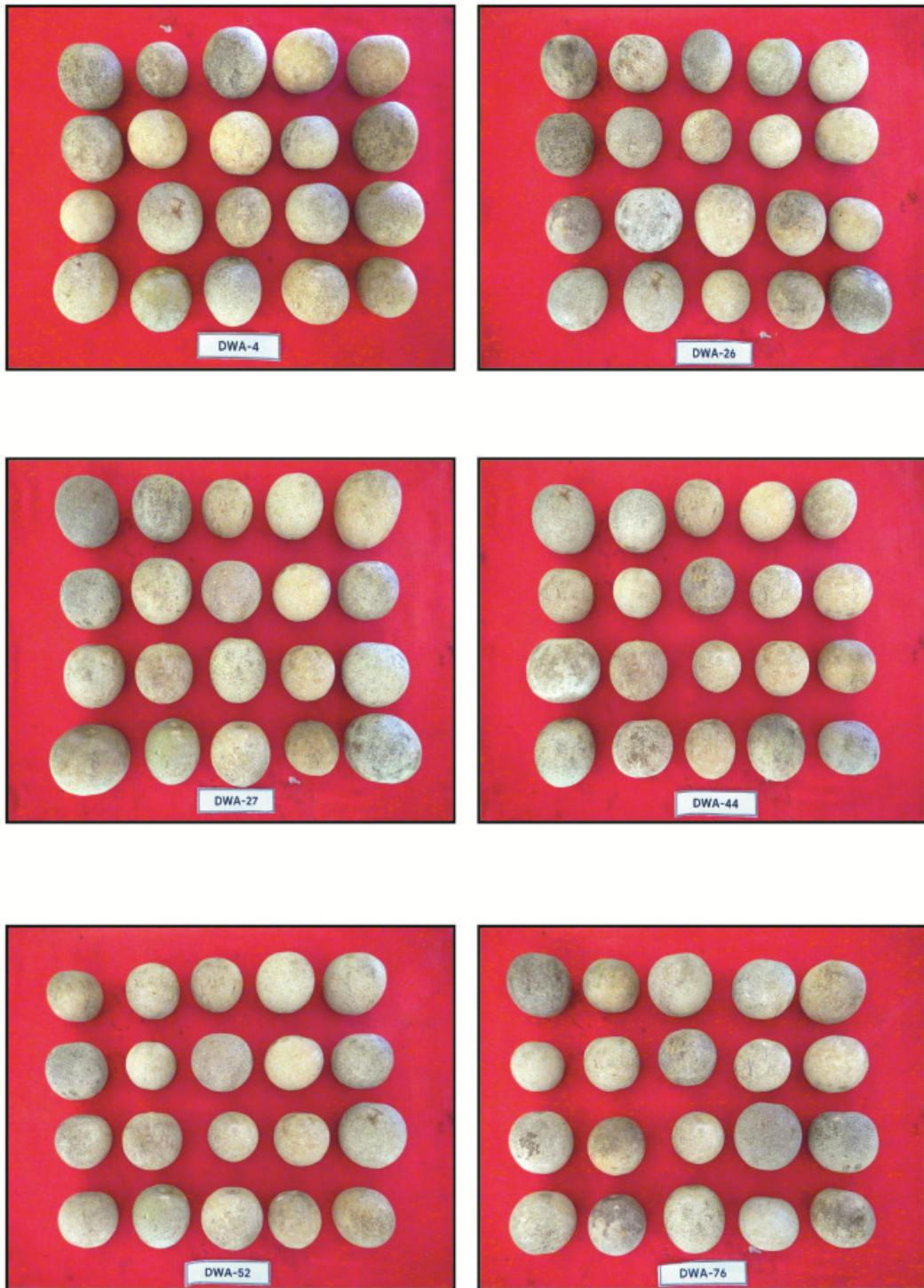
Shell weight showed positive and significant genotypic correlation with length of fruit, fruit diameter and pulp: shell ratio. Whereas it exhibits negative and significant correlation with number of fruits per kg. However positive and significant phenotypic correlation with fruit length, fruit diameter and fruit yield per tree.

Pulp: shell ratio showed positive and significant genotypic correlation with pulp percentage and number of fruits per tree. While pulp percentage, length of fruit, fruit diameter and yield per plant showed positive and significant phenotypic correlation. Pulp percentage exhibited positive and significant correlation with length of fruit and fruit diameter, while number of fruits per kg possessed negative and significant correlation at genotypic level. Yield per plant, fruit length and fruit diameter showed

positive and significant phenotypic correlation. While number of fruits per kg showed negative and significant phenotypic correlation.

Length of fruit was found positively significant with fruit diameter in case of genotypic correlation. While in case of phenotypic correlation found positive and significant with fruit diameter, number of fruits per tree and yield per plant. Fruit diameter was found positively significant with number of fruits per tree and yield per plant only in phenotypic correlation. Likewise, fruit diameter and number of fruits per tree also found positively significant with yield per plant with phenotypic correlation.

The studies indicate that the magnitude of correlation was significantly the highest between yield per plant and fruit weight. The correlation among the yield contributing characters weight of pulp, pulp: shell ratio, fruit length and fruit diameter was highly significant. Thus, an increase in number of fruits and weight of pulp accompanies increase in fruit yield per plant. Therefore, the selection for number of fruits per plant will increased automatically lead to selection for higher yield. Similar results were noticed by Mishra *et al.* (2008) in Bael, Shukla, Kumar *et al.* (2008) found somewhat similar results in Bael accessions from Bihar and Jharkhand.



**Plate 2. Variability in fruits of Wood apple genotypes**

## CHAPTER V

### SUMMARY AND CONCLUSIONS

The present study on "Genetic variability and correlation studies in Wood apple (*Feronia limonia* L.)" was undertaken on twenty-five genotypes of Wood apple. The statistical design adopted was single plant observation with four replications. This experiment was carried out during summer season of 2018-2019 at AICRP on Dry land Agriculture and analytical work was done at Analytical Laboratory, Department of Fruit Science, University Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola with the following objectives:

1. To estimate the extent of genotypic and phenotypic variability among wood apple genotypes.
2. To study genotypic, phenotypic and environmental correlation for yield and yield contributing characters of wood apple.

Salient findings of the present investigation are being summarized as below:

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 the traits under study.

The highest genotypic and phenotypic coefficient of variation was observed for the character, TSS: acid ratio (33.45 % (PCV)), (32.37 (GCV)), acidity (32.6% (PCV)), (32.21% (GCV)), weight of pulp (22.81% (PCV)), (21.92% (GCV)), number of seeds per 100g pulp (22.74% (PCV)), (21.75% (GCV)), weight of seed per 100g pulp (20.22% (PCV)), (18.58% (GCV)) and pulp: shell ratio (17.99% (PCV)), (14.80% (GCV)) indicating predominance of additive gene action in the inheritance of this character revealing favourable response to selection by these characters. 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 (97.66 %) to total soluble sugar (40.26 %). 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 for total soluble solids (5.59%) to acidity (65.58%). 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 effects and improvement of these characters may be achieved through phenotypic selection.

The correlations among the yield attributes indicate that correlation among the yield contributing characters weight of pulp, pulp: shell ratio, fruit length and fruit diameter showed positive significant direction and they are helpful and advantageous for improvement in yield.

### **Conclusion:**

On the basis of findings reported in present investigation, the following conclusions could be drawn.

The mean sum of squares for all the characters studied was found to be significant, indicating the variation for the characters under study.

High values of GCV and heritability estimates supplemented with greater genetic gains are also indicative of additive gene effects regulating the inheritance of such traits. Therefore, these characters reflect

greater selective value and offer ample scope for selection and phenotypic coefficient of variation was lessened under the influence of environment.

The correlation among the yield contributing characters weight of pulp, pulp: shell ratio, fruit length and fruit diameter indicating that the superior yielding ability was associated with these yield contributing characters.

On the basis of yield and yield contributing characters the genotypes viz., DWA-27, DWA-52, DWA-76 and DWA-26 were found promising for improvement programme. Hence, these genotypes may be given consideration for the improvement of yield and sensory qualities in wood apple.

## CHAPTER VI

### LITERATURE CITED

- Anonymous, (1980). Tropical fruit descriptor. International Plant Genetic Resources Institute (IPGRI), Rome.
- Arora, R.K. and Rao, R.V. (1995). Proceeding of expert consultation on tropical fruit species of Asia, Kuala Lumpur, Malaysia, 17–19th May 1994, pp. 116.
- Badiyala, S.D. and Sharma, S.K. (2004). Variability studies in galgal (*Citrus pseudolimon* Tanaka) in upper Shivaliks of Himachal Pradesh. *Indian Journal of Horticulture*. 61(2): 105-108.
- Bhore, D.P. (1988). Lecture on Dryland Horticulture, Advances in Arid Zone Fruits, MPAU, Rahuri, Maharashtra (Unpublished)
- Burton, G.W. (1952). Quantitative inheritance in grasses, proc. 6th International Grassland Congress. 1:277-283.
- Chakrawar, V.R. and Solunke, S.P. (1981). Correlation studies on Ber strains. *The Punjab Hort. J.*, 21(1-2): 67-69.
- Chakrawar, V.R. and Jature, S.D. (1980). Correlation studies on Kagzi lime strains. *Punjab Horticultural Journal*. 20(1/2): 39-40.
- Chattopadhyay, T.K., Choubey, L.K. and Tripathi, S.N. (1998). A Textbook on Pomology (Subtropical Fruits) Vol. 3 Kalyani Publ. New Delhi.
- Chundawat, B.S. (1999). Arid Fruit Culture, Oxford & IBH Publishing Co. Pvt. Ltd. New Delhi.
- Diwan, K., Naik, D.M., Vadak, Y., Taru, A.S. and Maholiya, B.K. (2014). Variability, correlation and path analysis studies for superior types of sweet orange (*Citrus sinensis* Osbeck). *International Journal of Agricultural Sciences*. 10(2): 649-653.
- Gaikwad, K.A., Haldavanekar, P.C. and Durgude, R.A. (2015). Correlation studies of different parameters in pummelo (*Citrus grandis* L.) with fruit yield. *Ecology, Environment and Conservation*. 21 (December Suppl.): S97-S99.
- Ghosh, S.N., Banik, A.K. and Banik, B.C. (2010). Conservation, Multiplication and Utilization of wood apple (*Feronia limonia* L.) a semi-wild fruit crop in West Bengal (India), International Symposium on Minor Fruits and Medicinal Plants, the farmer's training centre in kalyani, Nadia. Bidhan Chandra Krishi Viswavidyalaya, West Bengal, 19-22 December 2011: 1208-1214.
- Gopalan, C.B., N. Rama Shastri and Balasubramaniam (1971). Nutritive value of Indian Food, National Institute of Nutrition, ICMR, Hyderabad, India.

- Gupta, N.K., and Mishra, K.K., (2002). Growth, yield and photosynthetic efficiency of bael (*Aegle marmelos*) genotypes in foot-hills region of Uttaranchal. *Indian Journal of Agricultural Sciences*. 72 (4): 220 - 222.
- Hazarika, T.K., and Nautiyal, B.P. (2016). Variability in physico-chemical characteristics and selection of superior types among local pummelo (*Citrus grandis* L.) Osbeck) germplasms from Mizoram, North East India. *Current Science*, vol.111, 1355-1361.
- Ilango, K. and Chitra, V. (2010). Wound healing and anti-oxidant activities of the fruit pulp of (*Limonia acidissima* Linn.) in rats. *Tropical Journal of Pharmaceutical Research* 9: 223–30.
- Johnson, H.W., Robinson, H.F. and Comstock, R.E. (1955). Estimation of genetic and environmental variability in soybean. *Agron. J.* 47: 314- 318.
- Josan, J.S. and Kaur, N. (2006). Variability and character association analysis in identified mandarin germplasm. *Indian Journal of Horticulture*. 63(2): 152-154.
- Kaulgud, S.N., Supe, V.S. Karale, A.R. and Keskar, B.G. (1997). Descriptor of Pomegranate. Department of Horticulture, MPKV Rahuri. 67.
- Kishore, K., Kumar, A., Rahman, H., Monika, N. and Pandey, B. (2010). Physico-chemical and sensorial attributes of Sikkim mandarin (*Citrus reticulata*). *Indian Journal of Agricultural Sciences*. 80 (2): 164-167.
- Kumar, D. and Nath, V. (2008). Variability in Bael genotypes from Orissa. *Indian J. Plant Genet. Resour.* 23(3): 303-305.
- Kumar, R. (2000). Analysis of fruit weight components in mango. *Orissa J. Hort.* 28 (2): 70-72
- Kumar, S., Jena, S.N. and Nair, N.K. (2010). ISSR polymorphism in Indian wild orange (*Citrus indica* Tanaka, Rutaceae) and related wild species in North-east India. *Scientia Horticulturae*. 123: 350-359.
- Lal, G., (2002). Evaluation of bael (*Aegle marmelos* Correa) germplasm in semi-arid regions of Rajasthan. *Current Agriculture*. 26 (1/2): 127 – 129.
- Lande, S.B., Nirmal, V.S. and Kotecha, P.M. (2010). Studies on preparation of ready-to-serve beverages from wood apple pulp. *Beverages and Food World*, 37(4): 69-70.
- Maiti, C. S. (2010). Correlation and path coefficient analysis for some morphological and biochemical constituents of jackfruit genotypes, *Indian J. Hort.* 67(2): 169-172.

- Miller, D.A., Willians, J.C., Robinson, H.F. and Comstock K.B. (1958). Estimates of genotypic environmental variances and covariances in upland cotton their implication in selection. *Agronomy Journal*. 50:126-131
- Mishra, K.K., Singh Rajesh and Jaiswal, H.R., (2008). Performance of bael (*Aegle marmelos*) genotypes under foot-hills region of Uttar Pradesh. *Indian Journal of Agricultural Sciences*. 70 (10): 682-683.
- Mishra, K.K., Singh Rajesh and Jaiswal, H.R., (2005). Studies on leaf characters, development pattern and shoot growth in Bael genotypes. *Prog. Hort*. 31 (3/4): 144 - 150.
- Nath Vishal, Pandey Devendra and Das Bikash, (2003). Diversity of beal (*Aegle marmelos* Correa.) in east central India. *Indian Journal of Plant Genetic Resources*. 16 (3): 222 - 225.
- Nidhi and Gehlot, Rakesh (2007). Studies on physico-chemical characteristics of fresh bael and guava fruits. *Research on Crops*. 8 (1): 189 - 190.
- Pandey, D., Shukla, S.K. and Kumar, A., (2008)<sup>a</sup>. Variability in bael accessions from Bihar and Jharkhand. *Indian Journal of Horticulture*. 65 (2): 226 – 229.
- Pandey, D., Shukla S.K., and Akhilesh Kumar (2008)<sup>b</sup>. Variability in bael (*Aegle marmelos* Correa.) germplasm collected from Uttar Pradesh and Madhya Pradesh. *Journal of Tropical Forestry*. 24 (1/2): 31-36.
- Panse, V.G. (1957). Genetics of quantitative characters in relation to plant breeding. *Indian. J. genetic plant breeding*. 17 (2):318-329
- Panse, V.G. and Sukhatme, P.V. (1985). Statistical methods for agricultural workers. ICAR Publications, New Delhi. pp 155.
- Patil, R. (2014). Genetic variability and divergence studies in Guava (*Psidium guajava* L.) Ph.D. Thesis submitted to Dr. PDKV, Akola, M.S. India.
- Prasad, Y., and Singh, R.P. (2001). Evaluation of bael (*Aegle marmelos* Correa) in Uttar Pradesh and Bihar areas. *Haryana J. Hort. Sci*. 30 (1/2): 70 – 71.
- Pradeepkumar, T., Philip, J. and Johnkutty, I. (2006). Variability in physicochemical characteristics of mango genotypes in northern Kerala. *J. Trop. Agric*. 44 (1/2): 57-60.
- Rabha, A., Wangchu, L. and Singh, B. (2013). Studies on genetic diversity of citrus in east Siang district of Arunachal Pradesh. *Intl. J. Agric. Env. Biotech*. 6(1). 131-137.
- Radha, T. and Mathew L. (2000). Fruit Crops (3rd Ed.) Horticulture Science Series, New India Publishing, New Delhi, pp.357-358.

- Rai, D., Misra, K.K. and Singh, V.P. (2002). Analysis of genetic divergence in bael (*Aegle marmelos* Correa.) germplasm. *Progressive Agriculture*. 34 (1). 68.
- Rai, M., Reddy, N.N. and Prasad, V.S. (2001). Genetic variability and its relationship with yield components in mango cultivars grown under eastern Indian conditions. *Ind. J. Hort.* 58 (4): 314-320.
- Kumar, R. (2000). Analysis of fruit weight components in mango. *Orissa J. Hort.* 28 (2): 70-72.
- Ram, D. and Singh I. S., (2003). Physico-chemical studies on bael (*Aegle marmelos* Correa.) fruits. *Prog. Hort.* 35 (2): 199 - 201.
- Ranganna, S. (1986). Handbook of Analysis and Quality Control for Fruit and Vegetable Products. Tata McGraw-Hill Publishing Company Limited, New.
- Ranganna, S. (1979). Manual of Analysis of fruits and vegetables, chapters, pp.94 TATA Mac growth Hill Publishing Co. Ltd., New Delhi. *PKV Res. J.* 28 (1-2):14-21.
- Reuther, W., Webber, J.H. and Batchelor, L.D. (1967). Citrus industry, Univ. California, Div. Agril. Sciences.
- Rodriguez-Medina, N.N., Fermin, G.A., Ealdes-infante, J., Velasquez, B., Rivero, D., Martinez, F., Rodriguez, J. and Rhode, W. (2010). Illustrated descriptor for guava (*Psidium guajava* L.). *Acta Hort.* 849:103-109.
- Roy, P. and Mazumdar, B.C. (1988). Nutritional studies in wood apple. *Science and Culture*, 55: 110-111.
- Saran, P. L., Godara, A. K., Lal, G. and Yadav, I. S. (2007). Correlation and path coefficient analysis in ber genotypes for yield and yield contributing traits *Indian J. Hort.* 64(4): 459-460.
- Shanmugavelu, K.G. (1987). Production Technology of Fruit Crops. SBA Publ. Calcutta.
- Sharma, H.P. (2014). Study of Physico-Chemical Changes During Wood Apple (*Feronia limonia* L.) *Journal of Food Research and Technology*, Pg.148-152.
- Singh, A.K. and Singh S, (2016). Genetic variability in wood apple (*Feronia limonia*) from Gujarat, *Indian Journal of Agricultural Sciences* 51: 1504-08.
- Singh, A.K., Singh, S., Bagle, B.G. and Dhandar D.G., (2006). Studies on flower biology of bael (*Aegle marmelos*). Proceedings of the National symposium on production, utilization and export of fruits. West Bengal, India, 22-24: pp 65-69.

- Singh, J., Singh, R.R., Yadav, G.S. and Singh, U.K. (2004). Studies on correlation and path analysis in mango. *J. Applied Biology*, 14(2): 34- 36.
- Singh, N.P., Singh P. and Kaur S., (2009). Genetic variability in Hill Lemon strains (*Citrus pseudolimon*) Notulae Botanicae Horti Agrobotanici 37: 238-243.
- Singh, V.P. and Mishra K.K., 2010. Variability and character association analysis in Bael germplasm. *Indian J. Hort.* 67 (Special Issue): 70-74.
- Srivastava, K.K. and Singh, H.K. (2004). Physico-chemical quality of bael (*Aegle marmelos* Correa.) cultivars. *Agric. Sci. Digest.* 24 (1): 65-66.
- Srivastava, R. and Sanjeev, K. (2002). Fruit and vegetable preservation principles and Practices. Third revised and enlarged edition. International Book Distributing Company. pp.363-364
- Kaur S., Jawandha, N. P., Singh, P.P., Gill, S. and Singh, K. (2012). Evaluation of Baramasi lemon germplasm under Punjab conditions. *Hort Flora Research Spectrum.* 1(1): 46-49.
- Trimen, H. (1893). A Handbook of Flora of Ceylon. Dulae & Co. Ltd. London.
- Vavilov, N.I. (1951). The origin, variation, immunity and breeding of cultivated plants. (Trans. From Russian by Chester, K.S.). *Chronica Botanica*, 13: 1-364.
- Yadav, V.B., Wangchu, L. Singh, B., Sajeed, A. and Mitra, S.K. (2003), Correlation studies among fruit characters of different clones of mango. Cv. Langra. *Enviro and Eco.* 21 (1): 119-122.

## VITA

1. Name of student : **Shinde Mahadev Nagannath**
2. Date of Birth : 5<sup>th</sup>August 1994
3. Name of the Institute : Post Graduate Institute,  
Dr. Panjabrao Deshmukh Krishi  
Vidyapeeth, Akola.
4. Name of the Department : Department of Fruit Science,  
Dr. PDKV., Akola
5. Residential Address : At. Post- Bondle, Tal- Malshiras,  
Dist- Solapur, Pin- 413113  
Mobile No. 9552735851  
Email id:  
[1994mahadevshinde@gmail.com](mailto:1994mahadevshinde@gmail.com)

**6. Academic Qualification** :

| Sr. No. | Name of Degrees awarded | Year in which obtained | Division/ Class | Name of awarding University | Subjects                        |
|---------|-------------------------|------------------------|-----------------|-----------------------------|---------------------------------|
| 1.      | B.Sc. (Agri.)           | 2016                   | Second class    | MPKV, Rahuri                | Agriculture and Allied subjects |

7. Research papers published (if any) : Nil
8. Field of Interest (in which you desire to work) : Horticulture  
(Research and Development)

Place: Akola  
Date: / / 2019

Signature of student  
**(SHINDE MAHADEV NAGANNATH)**

**Appendix**  
**Weekly Weather data for the year 2018 recorded at Meteorological Observatory Department of Agronomy Dr. PDKV., Akola**

| Weeks | Dates    | Actual     |      | 2018       |      |           |     |            |     | Normal   |     |           |    |           |     | 1971-2000 |       |          |            |     |
|-------|----------|------------|------|------------|------|-----------|-----|------------|-----|----------|-----|-----------|----|-----------|-----|-----------|-------|----------|------------|-----|
|       |          | T MAX (°C) |      | T MIN (°C) |      | BSH (hrs) |     | WS (km/hr) |     | RH I (%) |     | RH II (%) |    | Evap (mm) |     | RF (mm)   |       | CRF (mm) | Rainy Days |     |
|       |          | N          | A    | N          | A    | N         | A   | N          | A   | N        | A   | N         | A  | N         | A   | N         | A     | N        | A          |     |
| 31    | 30-5 Aug | 31.1       | 32.2 | 23.1       | 24.2 | 3.6       | 5.8 | 11.7       | 8.1 | 88       | 81  | 66        | 56 | 4.6       | 6.0 | 49.3      | 3.2   | 561.6    | 2.5        | 1.0 |
| 32    | 6-12     | 30.2       | 30.8 | 22.9       | 24.3 | 3.5       | 1.4 | 11.6       | 9.4 | 87       | 84  | 69        | 65 | 4.2       | 5.2 | 59.9      | 4.8   | 566.4    | 2.9        | 1.0 |
| 33    | 13-19    | 30.5       | 29.4 | 22.8       | 24.0 | 4.4       | 1.2 | 11.7       | 8.5 | 86       | 89  | 66        | 74 | 4.5       | 4.1 | 40.6      | 97.8  | 664.2    | 2.2        | 3.0 |
| 34    | 20-26    | 30.5       | 27.6 | 22.6       | 22.6 | 4.3       | 1.8 | 11.0       | 9.2 | 88       | 91  | 66        | 77 | 4.3       | 4.0 | 46.7      | 106.4 | 770.6    | 2.0        | 3.0 |
| 35    | 27-2 Sep | 30.4       | 28.5 | 22.7       | 23.4 | 4.4       | 0.1 | 10.6       | 6.6 | 86       | 88  | 64        | 70 | 4.2       | 2.9 | 47.1      | 1.0   | 771.6    | 2.4        | 0.0 |
| 36    | 3-9      | 31.1       | 29.8 | 22.5       | 21.9 | 5.7       | 3.8 | 9.1        | 8.1 | 85       | 84  | 61        | 56 | 4.7       | 4.5 | 28.5      | 1.0   | 772.6    | 1.5        | 0.0 |
| 37    | 10-16    | 32.2       | 32.6 | 22.4       | 24.0 | 7.1       | 8.6 | 9.0        | 2.6 | 85       | 81  | 56        | 48 | 5.1       | 5.6 | 18.9      | 0.0   | 772.6    | 1.1        | 0.0 |
| 38    | 17-23    | 33.4       | 33.3 | 22.3       | 23.1 | 7.2       | 4.4 | 8.5        | 3.3 | 83       | 85  | 53        | 52 | 5.3       | 4.9 | 24.6      | 62.4  | 835.0    | 1.4        | 2.0 |
| 39    | 24-30    | 33.7       | 33.6 | 21.9       | 22.7 | 7.6       | 8.5 | 5.4        | 0.6 | 83       | 85  | 50        | 49 | 4.9       | 4.5 | 24.4      | 0.0   | 835.0    | 1.5        | 0.0 |
| 40    | 1-7 Oct  | 33.9       | 35.1 | 20.2       | 21.3 | 8.1       | 8.6 | 7.5        | 0.6 | 81       | 78  | 45        | 38 | 5.5       | 4.9 | 21.8      | 0.0   | 835.0    | 1.1        | 0.0 |
| 41    | 8-14     | 34.1       | 35.4 | 18.7       | 18.6 | 4.2       | 8.6 | 4.1        | 0.8 | 76       | 77  | 40        | 29 | 5.3       | 5.1 | 16.0      | 0.0   | 835.0    | 0.9        | 0.0 |
| 42    | 15-21    | 33.9       | 34.8 | 18.1       | 19.3 | 8.4       | 8.5 | 4.4        | 0.5 | 74       | 72  | 36        | 30 | 5.5       | 5.1 | 3.1       | 0.0   | 835.0    | 0.4        | 0.0 |
| 43    | 22-28    | 33.1       | 35.3 | 18.5       | 17.1 | 8.4       | 8.9 | 4.1        | 0.4 | 73       | 68  | 36        | 22 | 5.3       | 5.2 | 10.0      | 0.0   | 835.0    | 0.6        | 0.0 |
| 44    | 29-4 Nov | 33.0       | 33.4 | 15.8       | 18.1 | 8.7       | 8.9 | 4.7        | 1.3 | 72       | 68  | 31        | 32 | 5.3       | 5.9 | 2.3       | 0.0   | 835.0    | 0.3        | 0.0 |
| 45    | 5-11     | 32.4       | 33.6 | 14.8       | 16.5 | 8.6       | 7.0 | 4.5        | 0.5 | 70       | 76  | 30        | 28 | 5.2       | 4.2 | 3.7       | 0.0   | 835.0    | 0.3        | 0.0 |
| 46    | 12-18    | 31.7       | 33.3 | 13.7       | 14.0 | 8.6       | 8.9 | 4.6        | 0.4 | 70       | 66  | 30        | 20 | 4.9       | 5.0 | 1.1       | 0.0   | 835.0    | 0.2        | 0.0 |
| 47    | 19-25    | 31.0       | 32.8 | 13.1       | 17.2 | 8.6       | 7.8 | 4.4        | 0.6 | 71       | 78  | 30        | 34 | 4.6       | 4.8 | 10.1      | 4.5   | 839.5    | 0.3        | 1.0 |
| 48    | 26-2 Dec | 30.3       | 31.0 | 12.4       | 12.3 | 8.8       | 8.0 | 4.6        | 0.5 | 71       | 74  | 31        | 27 | 4.3       | 4.3 | 6.8       | 0.0   | 839.5    | 0.3        | 0.0 |
| 49    | 3-9      | 29.8       | 29.8 | 11.2       | 15.9 | 8.7       | 5.2 | 4.7        | 0.9 | 70       | 76  | 29        | 41 | 4.3       | 4.0 | 1.3       | 0.0   | 839.5    | 0.2        | 0.0 |
| 50    | 10-16    | 29.4       | 28.9 | 10.3       | 12.3 | 8.8       | 6.6 | 4.5        | 1.1 | 70       | 83  | 27        | 31 | 4.2       | 4.1 | 1.3       | 0.0   | 839.5    | 0.2        | 0.0 |
| 51    | 17-23    | 29.5       | 26.5 | 10.6       | 10.2 | 8.7       | 7.5 | 4.7        | 1.1 | 69       | 116 | 29        | 34 | 4.3       | 4.2 | 0.9       | 0.0   | 839.5    | 0.1        | 0.0 |
| s52   | 24-31    | 29.2       | 27.5 | 10.7       | 9.6  | 8.6       | 8.4 | 4.8        | 1.5 | 70       | 59  | 31        | 23 | 4.3       | 5.0 | 2.6       | 0.0   | 839.5    | 0.2        | 0.0 |

**2019**

|    |          |      |      |      |      |     |     |     |     |    |    |    |    |      |     |     |     |     |     |     |
|----|----------|------|------|------|------|-----|-----|-----|-----|----|----|----|----|------|-----|-----|-----|-----|-----|-----|
| 1  | 1-7 Jan  | 29.0 | 29.8 | 10.3 | 9.4  | 8.7 | 8.4 | 4.9 | 0.7 | 78 | 68 | 30 | 22 | 4.2  | 4.0 | 1.7 | 0.0 | 0.0 | 0.2 | 0.0 |
| 2  | 8-14     | 29.2 | 28.1 | 11.3 | 10.0 | 8.6 | 7.8 | 6.3 | 1.2 | 71 | 72 | 30 | 30 | 4.5  | 5.4 | 3.4 | 0.0 | 0.0 | 0.2 | 0.0 |
| 3  | 15-21    | 29.9 | 29.4 | 11.6 | 10.4 | 8.9 | 7.6 | 5.4 | 1.2 | 69 | 66 | 28 | 24 | 4.8  | 5.2 | 0.9 | 0.0 | 0.0 | 0.1 | 0.0 |
| 4  | 22-28    | 30.8 | 28.1 | 11.8 | 14.0 | 9.1 | 6.1 | 5.5 | 1.7 | 67 | 75 | 27 | 36 | 5.2  | 5.0 | 1.1 | 0.0 | 0.0 | 0.2 | 0.0 |
| 5  | 29-4 Feb | 31.1 | 28.1 | 12.1 | 10.7 | 9.3 | 7.9 | 5.8 | 1.5 | 61 | 61 | 25 | 22 | 5.6  | 5.3 | 2.8 | 0.0 | 0.0 | 0.2 | 0.0 |
| 6  | 5-11     | 31.3 | 29.6 | 11.9 | 13.3 | 9.1 | 8.2 | 5.6 | 3.6 | 59 | 49 | 23 | 20 | 5.9  | 6.3 | 4.9 | 0.0 | 0.0 | 0.4 | 0.0 |
| 7  | 12-18    | 32.5 | 32.2 | 13.4 | 15.9 | 9.4 | 7.9 | 6.1 | 2.3 | 56 | 54 | 22 | 24 | 6.6  | 5.9 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8  | 19-25    | 33.0 | 35.5 | 13.8 | 18.6 | 9.5 | 8.6 | 6.5 | 2.4 | 57 | 55 | 22 | 21 | 7.3  | 6.1 | 3.3 | 1.9 | 1.9 | 0.5 | 0.0 |
| 9  | 26-4 Mar | 34.7 | 33.2 | 14.8 | 17.7 | 9.6 | 8.9 | 7.0 | 4.0 | 50 | 47 | 17 | 23 | 8.1  | 7.8 | 3.4 | 0.0 | 1.9 | 0.3 | 0.0 |
| 10 | 5-11     | 36.1 | 33.7 | 16.7 | 16.2 | 9.6 | 9.1 | 6.8 | 3.2 | 44 | 48 | 18 | 21 | 9.0  | 7.5 | 2.1 | 0.0 | 1.9 | 0.3 | 0.0 |
| 11 | 12-18    | 37.3 | 36.8 | 17.5 | 16.9 | 9.6 | 8.5 | 6.9 | 3.1 | 42 | 43 | 17 | 21 | 9.5  | 8.1 | 2.5 | 0.0 | 1.9 | 0.3 | 0.0 |
| 12 | 19-25    | 38.5 | 37.9 | 18.3 | 15.9 | 9.6 | 8.9 | 6.9 | 2.2 | 37 | 47 | 13 | 18 | 10.5 | 8.4 | 0.3 | 0.0 | 1.9 | 0.1 | 0.0 |