

**GENETIC VARIABILITY STUDIES IN  
CANDIDATE PLUS TREE OF *Madhuca indica*  
Roxb. IN EASTERN VIDARBHA REGION OF  
MAHARASHTRA**

**THESIS**

**Submitted to  
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola  
in partial fulfilment of the requirements  
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**MASTER OF SCIENCE  
IN  
FORESTRY  
(FOREST GENETIC RESOURCES)**

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## DECLARATION OF STUDENT

I hereby declare that the experimental work and its interpretation of the thesis entitled “**Genetic Variability Studies in Candidate Plus Tree of *Madhuca indica* Roxb. in Eastern Vidarbha Region of Maharashtra**” 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/publications of any University or Scientific Organization. The sources of material used and all assistance received during the course of investigation have been duly acknowledged.

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Date: / /2018

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## CERTIFICATE

This is to certify that the thesis entitled “**Genetic Variability Studies in Candidate Plus Tree of *Madhuca indica* Roxb. in Eastern Vidarbha Region of Maharashtra**” submitted in partial fulfillment of the requirements for the degree of “**Master of Science in Forestry (Forest Biology And Tree Improvement)**” of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola is a record of bonafide research work carried out by **Jumnake Satish Bhaskar** under my guidance and supervision.

The subject of the thesis has been approved by the Students Advisory Committee.

Place: Akola  
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(Jumnake Satish Bhaskar)

Date:     /     /2018

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## (D) List of Abbreviation

%	- Per cent
*	- Significant at 5% level
**	- Significant at 1% level
CD	- Critical difference
SE(d)	- Standard error of deviation
CV	- Coefficient of variance
r	- Correlation co-efficient
cm	- Centimeter
°C	- Degree Celsius
CPT's	- Candidate Plus Trees
dbh	- Diameter at breast height
gbh	- Girth at breast height
Fig.	- Figure
g	- Gram
GCV	- genotypic coefficient of variation
PCV	- phenotypic coefficient of variation
GA	- Genetic Advance
$h^2$ (bs)	- Heritability (broad sense)
V <sub>g</sub>	- Genotypic variance
V <sub>p</sub>	- Phenotypic variance
V <sub>e</sub>	- Environmental variance
<i>et al.</i>	- and others
<i>Viz</i>	- namely
TSS	- Total Soluble Solid

**(E) Thesis Abstract**

- a) Title of the thesis : “GENETIC VARIABILITY STUDIES IN CANDIDATE PLUS TREE OF *Madhuca indica* Roxb. IN EASTERN VIDARBHA REGION OF MAHARASHTRA”
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**ABSTRACT**

The present investigation entitled, “Genetic Variability Studies in Candidate Plus Tree of *Madhuca indica* in eastern vidarbha region of Maharashtra” was carried out during the year 2015-2017 at Department of Forestry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The study

was carried with the objective to identify the Candidate plus tree Mahua (*Madhuca indica* Roxb.), to study the genetic variability in selected Candidate Plus Tree for morphological, physio-chemical parameter and to study the correlation of physio-chemical parameters of candidate plus tree.

The experimental material consist of forty candidate plus tree namely CPT-1 to CPT-10, CPT-11 to CPT-20, CPT-21 to CPT-30 and CPT-31 to CPT-40.

To achieve the objective identify the Candidate plus tree Mahua was done from four district of Vidarbha region namely Bhandara, Chandrapur, Gadchiroli and Gondia. The morphological observations like age of tree, canopy diameter, diameter at base, diameter at breast height, girth at base and girth at breast height were recorded along with site quality. The physio-chemical character of fruit were recorded includes weight of fruit, diameter of fruit, length of fruit, weight of fruit pulp, weight of dry fruit, moisture content of fruit, weight of 100 seed, weight of seed kernels, total soluble solid, titratable acidity, total sugar, reducing sugar, non-reducing sugar, oil content and fruit yield per tree.

Seeds contain valuable fatty oil ranging from 38% to 57%, known as mahua oil or butter of romance. Mahua oil is used as edible oil, manufacture of margarine, soap, glycerin, lubricating grease and medicine. Seed cake is used as biofertilisers, organic manure, biocide and fish meal. Due to presence of similar properties to that of diesel, Mahua oil has gained the importance as bio-diesel and is emerging as a viable alternative to fossil fuel. Importantly, the successful adoption of bio-fuels is reliant on the supply of feedstock from non-food crops with the capacity to grow on marginal land not destined to be used for the cultivation of food crops. Meeting both of these criteria and thus, can form the basis of a highly promising, profitable, and self-sustaining platform for small scale entrepreneurship and self-employment in rural areas, ensuring optimum utilization of wasteland resources and unemployed manpower. Although *Madhuca indica* is well known as oil yielding tree having wide adaptability and plethora of uses, little attempt has been directed to improve it as a crop plant because of long gestation period and slow growing nature. The wide

gap in potential and actual yield is due to the use of locally available wild material. *Madhuca indica* being open pollinated crop (Anemophillic), provide ample scope for genetic improvement through selection of superior trees with genetic variation in seed morphology and oil content along with initial progeny performance which later can be of great potential and may have greater impact than the conventional breeding. Hence, the challenging task, as of today is to screen the naturally available *Madhuca indica* genetic resources to select the best planting material with high oil content for higher productivity.

The variability in morphological characters was observed in all the CPT's. Age of tree ranged from (33 to 39 yrs.), height of tree (8.03 to 13.75 m), canopy diameter (4.09 to 9.25 m), diameter at base (26.54 to 31.45 cm), diameter at breast height (23.06 to 28.39 cm), girth at base (83.35 to 98.76 cm), girth at breast height (72.43 to 89.16 cm) were observed in May to June. CPT-37 with high estimated weight of 100 seed, fruit yield per tree and CPT-37 was also highest in oil content followed by CPT-27. There was significant variation in weight of fruit, diameter of fruit, length of fruit, weight of fruit pulp, weight of dry fruit, weight of 100 seed, weight of seed kernels, total soluble solid, titratable acidity, total sugar, reducing sugar, non-reducing sugar, oil content and fruit yield per tree. The moisture content has revealed 5% significant variation.

The highest genotypic coefficient of variation was observed for the characters diameter of fruit (28.36%), length of fruit (24.68%), weight of seed kernel (19.14%), weight of 100 seed (18.83%). The highest phenotypic coefficient of variation was observed for the character non-reducing sugar (31.92%) followed by diameter of fruit (28.99%).

The correlation amongst the value attributes indicates that weight of 100 seed, oil content and fruit yield per tree are in highly positive direction and they are helpful and advantageous for improvement in Mahua tree.

## CHAPTER I

### INTRODUCTION

#### 1.1 Background Information

Energy is the most and significant component in economic development of any nations. Energy independence is one of the vital areas to make India a development nation. The demand for oil as an energy source is increasing but the production is very low resulting in loss of exchange to imports oils. There is great need to explore plant based fuel resources as a substitute for fossil fuels, which are renewable and eco-friendly.

*Madhuca indica*, commonly known as Mahua or Mahuam, the trade name, Madhuca, is based on the Sanskrit name of the plant, Madhuca, also known as butter tree, and belongs to the family Sapotaceae. Mahua is among the most important forest trees in the country. It is an Indian tropical tree found largely in the central and north Indian plains. It is a common tree of deciduous forest in Madhya Pradesh (Haines, 1916), Maharashtra and Gujrat (Talbot, 1912), central india, Indian Peninsula, chhota Nagpur, Orisa (Troup, 1921), extending between the Ravi and Gandak (Brandis, 1906).

Mahua is ordinarily drought and frost hardy, but suffers under severe conditions. It coppices fairly well when cut in dry season, but does not coppice when cut during rains. In its natural habitat the absolute maximum shade temperature varies from 40<sup>0</sup> - 45<sup>0</sup> c with the absolute minimum temperature from 5<sup>0</sup> to 12<sup>0</sup> c.

It is deciduous in nature, thick leathery leaves and small, fleshy, pale or dull white musk-scented flowers in dusters near the end of branches. The fruits are fleshy, greenish with brown and shining seeds. They hang in close bunches from the end of the gnarled, they branches. The stalks are green or pink and furry, about 5 cm long. The plum-coloured calyx is also furry and divides into four or five lobes; within them lays the globular corolla, thick, juicy and creamy white. Through small eyelet holes

at the top, the yellow anthers can be seen. The stamens are very short and adhere to the inner surface of the corolla; the pistil is a long, protruding green tongue. It is at night that the tree blooms and at dawn each short-lived flowers fall to the ground. A couple of months after the flowering period the fruit opens. They are fleshy, green barriers, quite large and containing from one to four shiny, brown seeds.

Mahua flower is edible and is a food item of tribals. Flowers are used to prepare syrup for medicinal purposes. The flowers of Mahua tree are fermented to produce an alcoholic drink called Mahua, country liquor. Tribals of Bastar, Santhals of Santhal Paraganas (Jharkhand) and tribals of North Maharashtra, consider this tree as part of cultural heritage.

The oil which is sold at ambient temperature is used for preparation for cosmetics, soap or detergents, and as a vegetable butter. It can also be used as a fuel – oils. The product is often used in sweets and chocolates under the name “illipe”. The seed cakes obtained after extraction of oil constitute very good fertilizer.

## **1.2 Need of the Study**

Mahua are now grown almost exclusively for oil and biodiesel purpose. The fruit and seed of Mahua bear economic part. So the seed raised population of Mahua exhibits a lot of variation for all the characteristics such as various fruit and seed physiochemical properties. However, the variation is essential for the selection of desired genotypes.

Inspite of seed oil bearing tree very little improvement work has been carried out so far. In order to increase oil quantity of *Madhuca indica*, the utilization of existing genetic variability is essential.

The economics use of biofuels as alternative to diesel largely depends on the yield and recovery of oil. Hence there is an urgent need for improving the yield of tree borne oil seeds through a well defined tree improvement programme for sustainable fuel supply. Therefore research should be direct for judicious use of the genetic variability, use of suitable laboratory techniques along with appropriate official analytical practices, to obtain the desired product from a selected tree species.

With this consideration the present investigation on “Genetic variability studies in candidate plus tree of *Madhuca indica* Roxb. in eastern vidarbha region of Maharashtra study has been carried out with the following objectives-

### **1.3 Objectives**

1. To identify the candidate plus tree of *Madhuca indica* in vidarbha region of Maharashtra state.
2. To estimate the genetic variability in candidate plus tree for morphological characters of trees and physio-chemical characters of fruits.
3. To study the correlation of fruit parameters of candidate plus tree.

### **1.4 Scope and limitations**

The present investigation as “Genetic variability studies in candidate plus tree of *Madhuca indica* Roxb.in eastern vidarbha region of Maharashtra” was conducted during 2015-18 in the laboratory of department of forestry (Forest Biology and Tree Improvement) Post Graduate institute, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. (M. S.). The experimental material was fruit and seeds of candidate plus trees of *Madhuca indica*. The experiment was carried out using Randomized Block Design with five replication. The observations were recorded on twenty two different characters including various surveys and collection, morphological and physio-chemical.

This work will be helpful for the breeder to manipulate the variability in the biological population in the desired direction. The research was done by measuring the expression or phenotype of the individuals. The early production of improved planting material and further gains in subsequent generation may takes place in tree breeding programme.

Seeds contain valuable fatty oil ranging from 38 to 57%, known as mahua oil or butter of romance. Mahua oil is used as edible oil, manufacture of margarine, soap, glycerin, lubricating grease and medicine. Seed cake is used as biofertilisers, organic manure, biocide and fish meal. Its leaves are used for fodder and green manure while bark gives tannin

(CSIR, 1998). Due to presence of similar properties to that of diesel, Mahua oil has gained the importance as bio-diesel and is emerging as a viable alternative to fossil fuel. Importantly, the successful adoption of bio-fuels is reliant on the supply of feedstock from non-food crops with the capacity to grow on marginal land not destined to be used for the cultivation of food crops (Hill et al., 2006). Meeting both of these criteria and thus, can form the basis of a highly promising, profitable, and self-sustaining platform for small scale entrepreneurship and self-employment in rural areas, ensuring optimum utilization of wasteland resources and unemployed manpower. Although *Madhuca indica* is well known as oil yielding tree having wide adaptability and plethora of uses, little attempt has been directed to improve it as a crop plant because of long gestation period and slow growing nature. The wide gap in potential and actual yield is due to the use of locally available wild material. No systematic breeding program for breeding superior high yielding genotypes has been initiated. *Madhuca indica* being open pollinated crop (Anemophillic), provide ample scope for genetic improvement through selection of superior trees with genetic variation in seed morphology and oil content along with initial progeny performance which later can be of great potential and may have greater impact than the conventional breeding. Hence, the challenging task, as of today is to screen the naturally available *Madhuca indica* genetic resources to select the best planting material with high oil content for higher productivity.

The available information in literature does not provide a complete understanding of geographical variation and its influence on improvement of seed quality and quantity.

The information on the genetic structure and diversity relationship of candidate plus trees provide a basis for planning and conducting future collections and efficient utilization of genetic resources to realize the potentiality for maximum seed and oil yield.

## **1.5 Hypothesis**

The present study will be helpful in selecting the candidate plus tree with high seed yield as well as high oil content. *Madhuca indica* usually raised from seed. The fruit and seed show considerable variation in physio-chemical properties and seed yield.

## CHAPTER II

### REVIEW OF LITRATURE

The selection of Plus Tree is the important steps in any tree improvement programme. The selection of candidate plus trees (CPT's) is solely based on their phenotypic appearance and morphological characters.

However, such studies are lacking on *Madhuca indica* in India, the work on this species has not been taken up extensively. However, only few reports are available on the distribution, conservation, plus tree selection, variability studies with respect to morphological characters of trees and physio – chemical characters of fruits. Hence, the relevant literature pertaining to different aspects of present study on different tree species have also been reviewed and presented under following heads.

#### **2.1 Identification of Candidate Plus Tree of Madhuca indica.**

In response to recent suggestions in the literature that plus tree selection for yield in forest trees might in general be ineffective; the empirical information contained in 24 published reports was examined by Wright (1976). It was found that progeny of plus trees selected for yield traits tends to be faster growing than their controls. It is argued that this observed gains of up to 15 percent in height and diameter growth, and up to 35 percent in volume per unit area, can really be achieved through plus tree selection. This is consistent with theoretical expectations. However, it should be emphasized that the amount of gain from any particular plus tree selection system depends on the values of the parameters that determine the response to selection (selection intensity, genetic variance, heritability). In unfavorable situations, gain could be close to zero was also reported.

An attempt was made to identify various external characters in teak and to quantify them in selection of plus trees to raised clonal seed orchard for producing quality seeds. Looking to the increasing application

of genetics in forestry for quality improvement the quantitative characters deserve inclusion in selection work (Kotwal, 1983).

The selection of plus tree is the important step in any tree improvement programme. The selection of candidate plus trees (CPT's) is solely based on their phenotypic appearance and morphological characters. There is no any knowledge of performance of their clones, ancestors, offspring or other relatives. A superior tree is selected after thorough evaluation of the natural populations following different methods such as comparison, regression and subjective method based on type population. Comparison tree method has been widely applied in even aged or pure species stand (Brown and Goddard, 1961; Leding, 1974 and Zobel and Talbert, 1984).

Selection of phenotypically superior tree in forestry is very effective as even small genetic gain can be of immense benefit when distributed over a large plantation area annually (Schmid 1993). The selection of plus tree is first step to start any breeding programme. The selection of candidate plus tree (CPTs) is based on upon various important attributes associated with the species and their relative use of product. The superior trees should be selected through search and comparison with other individuals in the same population for given attribute. Such comparison method is used in plantations or in seed production areas and in natural forest individual tree selection (Sidhu 1996).

Dhillon *et al.* (1995) studied variability of seed character in *Dalbergia sisso*. Variability studies of thirty superior phenotypes were conducted through the estimates of range, mean, phenotypic and genotypic coefficient of variability, heritability and genetic advance as percent of mean of some seed characters. High variability was recorded for almost all seed characters.

Deviprasad *et al.* (1996) selected plus trees of *Dalbergia latifolia* in different bioregions of Karnataka. They have identified 110 plus trees from 110 provenances of Western Ghats region of Karnataka. Significant variation in morphology, growth; wood anatomy and acclimatization to different eco-systems have been reported.

Srivastava *et al.* (2001) studies the seed samples of *Dalbergia sisoo* collected from 58 CPT's representing 7 seed source, in the study all seed parameters *viz.* seed length, breadth and thickness as well as seed germination showed significant variation among various CPT's.

Bangarwa *et al.* (2002) conducted an intensive survey in Northern India and Southwestern region of Nepal to select plus trees of *Dalbergia sisoo* and selected 63 plus trees on the basis of height, diameter, clear bole (without forking), stem straightness, low branch angle, resistant to pest and diseases. Further, they mentioned that progenies showed variation for growth characteristics and stem form. Similar kind of work has been done in many tropical trees.

Surendran *et al.* (2003) reported that *Pongamia pinnata* plus trees are the individual trees of outstanding merits, initially selected on the basis of superior phenotypic characters like height, diameter, clear bole, pod and seed yield etc. In the first stage of plus tree selection, screening of the plantation was undertaken to select potential trees, to be referred as candidate plus trees such candidate plus trees were compared with surrounding trees to judge the phenotypic value to recognize good genotypes.

Yadav *et al.* (2005) undertook plus tree selection and progeny testing in Shisam (*Dalbergia sisoo*. Roxb.). A survey was conducted in Haryana and adjoining area. Plus trees were selected primarily on the basis of straightness, clear bole, apical dominance, and compact crown. In their investigation 81 trees showed wide variation in plant height, clear bole, straightness, 100 seed weight, and germination percentage among progenies of trees which showed significant variation in height, diameter at breast height, and clear bole height.

Kaushik *et al.* (2007a) have undertaken CPT studies in *Jatropha curcas* which were collected from different agroclimatic zones of Haryana. They found significant difference for seed size, 100 – seed weight and oil content among different accessions.

Kaushik *et al.* (2007b) studied the forty CPT's of *Pongamia pinnata* from Haryana to identify suitable seed sources for high oil yield as well as for production of quality seedlings for large afforestation. They reported significant differences among studies CPT's for seed size, 100 seed weight and oil content. They have reported the high genotypic correlation coefficient among pod and seed characters. Thus such traits may be genetically controlled and have potential scope for further breeding programme in this species.

Kaushik *et al.* (2007 c) studied the divergence in ninety plus trees of *Azadirachta indica* with respect to morphology, seedling growth traits, oil content and fatty acid composition of oils. It was revealed that geographical diversity is not the only factor in determining variation but on contrary selection of genotypes should be based on genetic diversity.

Pandey *et al.* (2007) conducted the phonological study of *Madhuca indica* which is among one of the most important forest tree species in the country and plays an important role in the tribal and rural economy.

Kesari *et al.* (2008) carried out the systematic study for identification of CPTs based on morphological characters both (vegetative and reproductive) and seed oil analysis in candidate plus trees of *Pongamia pinnata* across 10 locations in North Guwahati. They reported that per cent germination (46 to 95%), pod length (4.88 to 5.41 cm), seed length (2.00 to 2.35 cm), hundred pod weight (329.36 g to 440.78 g) and seed – pod ratio (0.50 to 0.58) exhibited a wide range of variation in respect to location among CPTs.

Mishra (2008) selected candidate plus trees of *Jatropha curcas* by using method of paired comparisons. The selection of candidate plus plants was done based on various important attributes associated *viz.* total height, collar diameter, crown size, seed yield, seedling cycle, oil content, tree/ seedling/ plant health, flowering and fruiting behavior and their relative ranking.

Rao *et al.* (2008) have undertaken thorough wild germplasm exploration in Andhra Pradesh and 32 high yielding candidate plus tree of *Jatropha curcas* were selected.

Narkhede *et al.* (2009) selected plus trees of *Pongamia pinnata* on the basis of morpho – metric characters, seed yield and oil content. They observed that less variation was present for number of pods per bunch, while the maximum variation was recorded for tree girth. Correlation coefficient was highest for number of pods per bunches with tree age whereas, it was observed to be negative for tree height and pods per bunch.

Ravishankar and Sakthivel (2010) reported that *Garcinia mangostana* is distributed in the humid tropical areas with very high rainfall (Sampaje, Peraje, Nalkeri villages of Karnataka). Perhaps the species were introduced. Yellow mangostana (*Garcinia xanthochymus*), was found distributed in both high rainfall zones of humid tropical areas and sub-tropical areas.

Utpala *et al.* (2010) have conducted survey work on *Garcinia* species distribution and they revealed that about 35 of *Garcinia* were reported to exist in India. Out of 35 species, seven were endemic to the Western Ghats, six in Andaman and Nicobar Island and four in North East India. North Eastern Himalayan states like parts of Meghalaya, Assam, Nagaland and Tripura were quite similar to that of Western Ghats with good diversity of *Garcinia* species, more than what was reported in the earlier floras in the region. *Garcinia* was seen occurring in the Dawki and Pynursla region at an altitude of 100-350 m above MSL, where rainfall was very high with an annual average of 2000-3000 mm.

Baruah and Borthakur (2012) reported six *Garcinia* species sporadically distributed in the Brahmaputra valley particularly to Assam *Garcinia pendunculata* Roxb, *Garcinia paniculata* Roxb, *Garcinia morella* Desr, *Garcinia cowa* Roxb, *Garcinia lanceaefolia* Roxb and *Garcinia xanthochymus* Hook.

Priya Devi *et al.* (2012) conducted field survey to know the spatial distribution and assessment of natural variability using DIVA-GIS version and reported that among the eleven talukas of Goa, Bicholim, Pernem, Ponda and Canacona were found to be promising zones of *Garcinia indica* diversity and are identified as the hotspots for its biodiversity by using various richness and diversity indices.

Divakara *et al.* (2014) evaluated 23 genotypes of *Madhuca latifolia* based on relationship of seed traits with initial progeny growth performance and divergence studies as a scope for further breeding programme. 100- Seed weight, oil content and seed length (39.1 mm) in CPT-15 genotype, seed breadth (19.2 mm) in CPT-8 and CPT-9, 100 seed weight (282.4 g) and oil content (51.2%). However, the phenotypic and genotypic coefficients of variations are close to each other for all traits. Trait oil content and 100 seed weight expressed high heritability (93.5%, 93.0%) accompanied with moderate genetic advance (17.2%, 15.6%), indicating that, heritability is due to additive gene effects and selection may be effective. At genotypic level 100 seed weight registered positive significant correlation with oil content.

Kumaran *et al.* (2015) conducted the study in Mahua (*Bassia latifolia* Roxb.) on the basis of genetic improvement, variability, tree and fruit morphological characters and oil productivity and they got the positive result in various phonological characters and they also find seed oil content expressed highly positive and significant correlation with 100 seed weight and other traits.

## **2.2 The genetic variability and correlation studies in *Madhuca indica*.**

There are different kinds of variation documented among forest trees such as variation among species, geographic sources (provenances), stands, sites, individual trees and variability as well as individual trees (Zobel *et al.* 1960b). These variations are important source for tree breeder to improve the particular species. Seed is one of the most important inputs for forest nursery production and plantation establishment. The knowledge of genetic variability and association among seed quality

traits is considered to provide considerable help in genetic improvement of species.

Population is a group of organism of the same species living within a prescribed area in which all individuals have an opportunity to mate with all other individuals existing in that area (White *et al.* 2007). There are three types of populations maintained in a breeding programmed *viz.* base, breeding and production population. A natural population is also called as a base population which consist of all available trees that could be selected, if found to be desirable (Zobel and Talbert, 1984). Hence, systematic collection and investigation of the genetic distinctness are important to maintain the eco-geographic database and is useful in providing information on conservation priorities of the germplasm.

Bagchi and Sharma (1989) carried out biometrical studies on seed characters of *Santalum album*. This observed that the genetic coefficient of variation was maximum for seed weight (11.72%) and identical for length (6.7%) of seed. More than 97% of the variations in weight were due to differences in genotypes.

Ponnammal and Gonzalez (1993) reported a positive correlation among seed size with germination and early seedling vigour in *Hardwickia binata*.

Dhillon and Khajuria (1994) studied genotypic variation in germination and potentials in *Acacia nilotica* (L.). Tree improvement programme has been conducted to improve the tree form and other desirable traits. Phenotypically superior mother plants were marked and preliminary studies with respect to the seed germination pattern and potentials were studied. Significant intergenotypic differences were recorded, offering wide scope for improvement.

Sharma *et al.* (1994) reported for *Prosopis juliflora* germplasm with reference to pod and seed traits collected from Rajasthan (November 1992) and Gujrat (January 1993). The study revealed the existence of enormous variability with respect to pod weight, number of seed/pod particularly for the collection made from Rajasthan, which lead to

identification of certain “plus trees”. Maximum intensity of correlation among all the characters was found between pod weight and pulp weight/pod (0.9619) in Rajasthan collection.

Bahadur and Hooda (1995) studied genetic variability in pod and seed of 25 trees of *Prosopis cineraria*. Mean square differs significantly for all the characters both genotypic and phenotypic co-efficient of variation were high for all the pod and seed characters except seed length. Heritability was high for all the characters except seed length. While high genetic advance was observed for pod length, pod weight, seeds per pod and seed weight per pod. Pod weight was found to be positively correlated with all other characters. Hundred seed weight had significant and positive correlation with all the pod and seed characters.

Intra –specific variation in *Irvingia gabonensis* and *Irvingia wombolu* in West and Central Africa was studied by Ladipo *et al.* (1996). They found morphological variation in vegetative and reproductive characteristics, including fruit quality attributes. They recommended that much of these intra-specific variations found in the *Irvingia* species of West and Central Africa provides opportunities for genetic improvement by genotypic selection and vegetative propagation. They also opine that this could promote the domestication process of this important wild tree as a crop for agro-forestry.

Kundu and Tigerstedt (1997) reported the existence of ecoclimal variation in seed weight, shoot: ratio, leaf number and leaflet ratio among the population of *Azadirachta indica*. Provenances having lower root ratio and lesser number of leaves were separated with their corresponding mean annual rainfall. *Azadirachta indica* employs an adaptive strategy in response to water deficit at the initial phase of seedling growth and establishment.

Sindhueverendra *et al.* (1998) evaluated seeds of *Santalum album* from various provenances in Karnataka and Kerala, which showed significant morphological variation for all the seed characteristics.

Karibasappa *et al.* (1999) evaluated Genetic variability of mango germplasm with 67 genotypes. The genetic variability observed for 40 characters, comprising tree morpho-phenology and fruit physico-chemical and quality characters revealed high phenotypic coefficient of variation (PCV) and genotypic variation (GCV) for hermaphrodite flowers, panicle number, fruit number, tree volume, bearing panicles at harvest stage, pulp content per fruit, sugar and titrable acidity and ascorbic acid content. They observed high positive correlation for fruit volume with fruit weight (0.997), pulp weight with minor width (0.875).

Sawant *et al.* (1999) evaluated 36 high yielding and early types *Garcinia indica* and studied for fruiting and quality traits. The fruit of type S8 had the highest average width (4.15cm), average circumference (13.15 cm), average weight (34.45 g) and average rind thickness (4.45 mm).

Gupta and Sehgal (2000) conducted the study on genetic variability in phenotypic characters of *Toona ciliata* for leaf characters *viz.*, leaf length, average number of leaflets per leaf, inflorescences and growth parameters *viz.* tree height, crown length, crown spread, crown area which were observed to differ significantly for attitude and zones. Wide range of variability was observed for almost all the characters. The leaf length/inflorescence, number of flowers per inflorescence had genotypic coefficient of variability, heritability and genetic advance which indicated importance of these characters for selection.

Jayashri and Rudrappa (2000) studied two types of Jambolan fruits *viz.*, the soft seed ones which is a variety and large seed type growing in Western Ghats region, Karnataka were analyzed for different chemical constituents. The titrable acidity, total and reducing sugar, ascorbic acid and mineral content were comparatively higher in the soft seed fruit. The pulp to fruit percentage is high in soft seed fruit than large seeded variety. Hence the soft seeded fruit variety was found to be better variety having maximum edible pulp over a large seeded type.

Kallaje (2000) studied variation in fruit traits of *Garcinia indica* collected from different location in Uttar Kannada district, Karnataka. Result

have shown that, fruit weight, rind weight, seed and pulp weight, fruit length was highest in Yellapur region while least in Devimani Ghat except for fruit diameter.

Leaky *et al.* (2000) have developed methods to quantify variation in the fruit, nut and kernel traits using fruits from four trees of *Irvingia gabonensis*, an indigenous fruit tree of West and Central Africa. The result revealed that there is significant variation in fruit, nut and kernel size and weight, and flesh depth, shell weight, brittleness, fruit taste, fibrosity and flesh colour. They noticed a very weak relationship between fruit size and weight with nut and kernel size and weight, indicating that it is not possible to accurately predict the traits of commercially important kernel from fruit traits.

Chopra and Hooda (2001) reported genetic variability in seed characters of 18 seed sources of *Prosopis juliflora*. Mean squares differed significantly for all the characters. High variability was observed almost in all the seed characters. While high genetic advance was observed for dehydrogenase activity. Germination percentage, root length, seedling height, vigour index-I, vigour index-II, and hundred seed weight was found to be positively correlated with other remaining characters individually.

Gera *et al.* (2001) studied the intra-population variation in *Albizia procera* for pod, seed and germination characteristics and revealed that selection of superior trees based on germination apart from tree characters like long form has been emphasized for quality seed collection.

Bisht *et al.* (2002) characteristics and seed germination among 13 seed sources of *Albizia chinensis*. A positive correlation was found between some of the seed traits among seed sources and finally they have concluded that seed characters like seed length, width, thickness, weight are important criterion for selection of seed sources and plus tree selection.

Chillar *et al.* (2002) studied seed source variation in *Acacia nilotica* and recorded the seed weight ranged from 13.06 to 15.85 g, which gives germination 69.33 to 80.66 percent, root and shoot length varied from

3.70 to 5.70 cm and 5.43 to 8.66 cm respectively. Finally they concluded that the higher seed weight, viability and low electrical conductivity gave vigorous seedlings in *Acacia nilotica*.

Jena *et al.* (2002) Hydroxy citric acid is one of the very important organic acid present in leaves and fruits rinds of some species and one such important source of hydroxycitric acid is *Garcinia* species. Other minor acids found in kokam are citric acid, malic acid and ascorbic acid. It has tendency towards factorization during purification, evaporation and concentration.

Kaushik *et al.* (2002 d) mentioned high phenotypic coefficient of variation than the genotypic coefficient of variation among studied characters. Seed weight positively correlated with seed length, breadth, thickness and oil content in *Jatropha curcas*.

Thakur *et al.* (2002) studied on variability of pod and seed characters of *Albizia chinensis* through the estimate of range, mean, phenotypic and genotypic coefficient of variation, heritability and genetic advance. The significant variations in pod length, breadth, thickness and seed weight were found. The high heritability coupled with high genetic advanced was observe for pod breadth, pod thickness, pod weight and seed weight/pod. High positive value of genotypic correlation coefficient between pod and seed characters reveal that the traits are genetically controlled and selection can be very effective in tree improvement programmed.

Bhat *et al.* (2003) monitored sixteen non-timber forest product species for yield and yield attributes for three years. They have reported that height, crown size and girth of tree influence on fruit yield among studied species. Further, they emphasized that the annual variations in fruit yield may be attributed by environmental factors. Hence, it is concluded that the predictive ability of fruit yield is difficult amongst the studied species.

Gorge *et al.* (2003) carried out experiment with a view to assess the variability in 23 families of *Madhuca latifolia* Roxb. representing

different agro climatic zones of Tamilnadu. Result indicated distinct variation among the 23 families in respect of seed characters like seed length, seed breadth ratio and 100 seed weight.

Jenner *et al.* (2003) carried out the experiment with a view to assess the variability in 23 one-parent progenies of *Madhuca indica* representing different agroclimatic zones of Tamil Nadu. The result indicated the distinct variation among the 23 one-parent progenies in respect to seed characters like seeds length, breadth, seed length: seed breadth ratio, hundred seed weight and oil content along with seedling traits like shoot length, basal diameter, root length, number of leaves and total dry weight. Out of the 23 one-parent progenies studied, TNAU and paiyur-I were found to be suitable for short rotation forestry practices.

Kumaran and Surendran (2003) observed genetic divergence among twenty eight one parent families of *Pongamia pinnata* (L.) and *Azadirachta indica* pierre to identify the promising single tree selection to be utilized in crossing programme. The twenty eight one families of both the species represented the different agro-climatic zones of Tamil Nadu. Observations on seven characters namely height, basal diameter, number of leaves, leaf length, leaf breadth, sturdiness quotient and volume index were recorded. The study also revealed that among the characters studied the maximum contribution towards the genetic divergence was made by root length (39.95%) in Neem and by height (36.24%) in Karanj.

Surendran *et al.* (2003) in natural population large amount of variability exist due to wide distribution of the species and its environmental interactions. The selection of superior parents depends on the breeding strategy formulated for characters to be improved. Reported the selection of CPTs for seed oil yields in *Pongamia pinnata*. Therefore the selections were based on pod and seed characters which exhibit direct correlation with the attribute under study.

Ginwal *et al.* (2004) undertaken study on seed source variation in growth performance and oil yield of *Jatropha curcas* in central India and also recorded significant differences among seed and oil content

from collected ten seed sources representing the states Madhya Pradesh and Maharashtra.

Hedge *et al.* (2004) studied genetic variation and inter genetic correlation of seedlings characters in *Tectona grandis*. Genetic variation in seedling characteristics was studied in 15 seed lots collected from different regions of peninsular India and selected clones planted in CSO at Walyar (Kerala). Significant variation was obtained in nested ANOVA in all six characters. They has suggested that seedling characters can be used as quantitative character defining genotype in measuring genetic distance between populations and differentiating population at early stage in variability studies.

Radhakrishnan and Vanangamudi (2004) evaluated the seed source variation for seed quality parameters in *Albizia lebbeck* (L.) Benth. by using image analyzer. Seed samples of *Albizia lebbeck* collected from 30 seed sources throughout India to evaluate seed quality parameters (seed germination, length, breadth, perimeter, roundness, aspect ratio, diameter, full ratio, weight) using image analyzer. A significant variation was observed among seed sources for seed quality parameters. On the basis of overall performance, Mettupalayam followed by Bhagwala and Gudag sources expressed superiority for seed traits. These identified seed sources could be useful to collect seeds of *Albizia lebbeck* for genetic improvement and plantation programmes.

Ginwal *et al.* (2005) recorded significant seed source variation for seed morphology (colour, size, and weight), seed germination (variability, germination percent, germination energy and germination value) and seedling growth parameters (survival percentage, seedling height, collar diameter, leave/plant and seedling biomass) in *Jatropha curcas* which showed a lot of scope for further tree selection among these seed sources.

Guylene Aurore *et al.* (2005) investigated the composition of the kernel oils of two species viz., *Calophyllumcalaba* and *Calophylluminophyllum*. The physico-chemical properties and fatty acid composition of the kernel oils were examined. Oleic acid C18:1 (39.1-

50%) is the dominating fatty acid followed by linoleic acid C18:2 (21.7-31.1%) as the second major fatty acid. Stearic acid C18:0 (13.4-14.3%) and palmitic acid C16:0 (11-13.7%) are the major saturates.

Kore *et al.* (2005) investigated the fruit character of 22 genotypes of *Garcinia indica* at Dapoli (Maharashtra). The genotypes exhibited significant variation for all the fruit character and the environment co-efficient of variation recorded for all the fruit character was very low. The higher magnitude of phenotypic and genotypic co-efficient of variation indicated good amount of variation among the genotypes. Estimates of heritability and genetic advance were relatively higher for length, weight and volume of fruit, fresh rind weight, pulp weight, dry seed weight.

Maheshwari and Reddy (2005) investigated that *Garcinia indica* seed butter has been successfully used in chocolate and cocoa industry. It helps in improving texture of chocolate without affecting the flavor. Kokam fat has been reported to be used in chocolate and confectionary preparation. It is also used in manufacture of soap, candle and ointments.

Pant *et al.* (2006) studied seed oil content variation in *Jatropha curcas* Linn. in different altitudinal ranges and site conditions in H.P. (India). The highest oil (43.19%) was recorded in T2 E2 (non-arable site with low altitude), similarly various morphological and yield attribute like number of fruits/branches, number of fruits/tree, number of seed/tree were recorded highest in Arable site with high altitude (T1E3).

Bhahar *et al.* (2007) observed significant variations for morphological features of population, seed characteristics, germination percent and seedlings characteristics in *Sapindus mukorossi* from thirteen seed sources of Himachal Pradesh.

Deena (2007) studied fatty acid of forty five genotypes of *Perilla frutescens*, which indicated considerable genetic differences for five fatty acids namely palmitic, stearic, oleic, linoleic and linolenic acid. Oil content in the seeds and protein in the de-fatted cake also showed large

variation from one genotype to another. The correlation co-efficient amongst different fatty acid revealed significant positive correlation of oleic, lineolic and linolenic acid with palmitic acid. Genotypes with desirable traits have been identified.

Dhillon *et al.* (2007) reported a sustainable variability for morphological traits among natural populations of *Azadirachta indica* and a lot of variation with respect to fruiting intensity and time of ripening among progenies of selected CPTs.

Kaushik *et al.* (2002d) mentioned high phenotypic coefficient of variation than the genotypic coefficient of variation among studied characters. Seed weight positively correlated with seed length, breadth, thickness and oil content in *Jatropha curcas*.

Manjunatha *et al.* (2007) reported that the seed oil content differed significantly among different germplasm of *Garcinia indica*. The maximum seed oil content (23.73%) and minimum seed oil content (12.25%) were observed in CPTDK-31 and CPTUK-5 respectively.

Nawabhar and Singh (2007) studied seed of *Sapindus mukorossi* (S.) collected from 30 different locations in Himachal Pradesh. Significant variation was observed for the fruit character *viz.* fruit diameter, fruit weight, pericarp weight, seed diameter, seed weight and seed coat. The significantly varying locations with maximum of desirable traits were selected as plus tree, for seed collection.

Shivanna *et al.* (2007) have evaluated the extent of variation among the sources with respect to different seed and seedling traits in *Pongamia pinnata*. They have reported that the seed length amongst the different seed sources varied from 7.70 to 11.13 mm and seed width ranged from 6.95 to 9.22 mm, 100 seed weight varied from 19.90 to 32.20 g and germination per cent from 69.61 to 89.20.

Vyas and Bansal (2007) studied selection of superior (plus) tree phenotype in a multipurpose tree species Semul (*Bombax cieba*, L.). The growth and survival characteristics of *Bombax cieba* were studied to select outstanding plus trees from 568 trees surveyed in and around

Jabalpur. In their study, 9 genotypes were identified and marked as plus trees. The plus trees were found resistant to the attack of defoliator, termites and other parasites and also varied significantly in other physical parameters.

White *et al.* (2007) reported that the overall goal of population selection is to choose species and seed sources that are well adapted to the planting conditions and produce maximum quantities of the desired products in the least amount of time.

Dhillon *et al.* (2008) conducted study on variation in seed parameters, germination behavior and seedling traits among different seed sources of *Jatropha curcas* and elucidated the pattern of variation in the seed weight, germination behavior and seedling traits. They also stated that the seed weight was significantly correlated with all germination indices, plant height and collar diameter. The coefficients of variation, heritability and genetic advance were relatively high for germination and medium for growth traits.

Divakaran (2008) studied variation and character association for various pod traits in *Tamarindus indica* (L). Pod traits like shell weight, pod weight, pulp weight and vein weight recorded higher estimates of heritability coupled with higher genetic advance. Correlation coefficient studies indicated that pulp weight per pod expressed highest positive genotypic and phenotypic association with pod weight, vein weight, shell weight, pod width and pod length. Path coefficient analysis revealed that, pod weight, pulp per cent, seed per cent and shell per cent exhibited positive direct effect on pulp weight.

Kotwal (2008) made an attempt to identify various external characters in teak and to quantify them in selection of plus trees to raise clonal seed orchards for producing quality seeds. Twenty characters have been identified and allotted five marks each. The grading system and its applicability is useful in unbiased selection of plus trees and to maintain a minimum standard and their selection.

Luna *et al.* (2008) found a significant variation among seed sources for height, girth and number of branches in *Jatropha curcas*. They reported that maximum variation was observed for 100 seed kernels followed by oil content and weight of 100 seeds. Maximum genetic gain was found for girth, followed by weight of 100 seed kernel, number of branches and weight of 100 seeds.

Kesari *et al.* (2008) carried out systematic characterization and seed oil analysis in candidate plus trees of *Pongamia pinnata* occurring across 10 locations in North Guwahati, were identified based on morphological markers (vegetative and reproductive) using combined analyses over locations. Identified CPTs were then multiplied using seed propagation technique in a nursery bed. The performance of the candidate trees with respect to seed and pod traits, the two most important characters with regard to oil. When the seed to solvent ratio varied, no significant difference was noticed on the total oil yield for an individual tree, although the recovery of solvent and the time taken for oil extraction were significantly reduced at higher ratios of solvent used.

Mishra (2008) had undertaken work for selection of candidate plus trees on basis of phenotypes in *Jatropha curcas* (L.) using method of paired comparisons, dealing with the method of selecting plus phenotypes for exploiting genetic variability for further improvement. The selection of candidate plus plants (CPTs) was based upon various important attributes associated with the species and their relative ranking. The most important ones observed in seed and oil yields.

Mukta and Murthy (2008) worked on variability assessment in *Jatropha curcas* seed and oil quality for biodiesel suitability. The study was conducted during 2005-06 in Hyderabad, Andhra Pradesh, India, to assess the variability in seed parameters of 63 *Jatropha curcas* accessions. Various biometric and biochemical parameters of the seed were evaluated. Fatty acid profiles of seed oil of *Jatropha curcas* accessions having varying oil content in their seed/kernel were examined.

Narkhede *et al.* (2008) studied seed source variability in *Jatropha curcas* and observed a high correlation coefficient for number of

branches per plant, where as it was minimum for male ; female flower ratio. They reported that maximum variation was recorded for the plant girth, followed by number of bunches per plant. However, a minimum variability was recorded for 100 seed weight. The plant growth parameters like height and girth do not have any effect on seed yield.

Sunil *et al.* (2008) also carried out a systematic collection of *Jatropha curcas* germplasm from four district ecogeographic zones of peninsular India. They reported that oil content of 162 collected accessions was done by Soxhlet method and it ranged from 22 to 42 percent. Further, they mentioned that plant height (1.5 to 3 m), collar diameter (20 to 50 cm), primary branches (3 to 6) and fruits per cluster (5 to 10) have recorded significant variation amongst superior individuals.

Rao *et al.* (2008) reported a significant difference among progenies of *Jatropha curcas* for seed yield, seed morphology, oil content and few growth characters. Highest broad sense heritability has observed for seed yield and plant height.

Readdy *at al.* (2008) reported significant variation in *Pongamia pinnata* for seedling traits viz. shoot length, root length, root and shoot dry weight of seedlings and concluded that seed sources with higher biomass and seedling vigour index test weight, germination and seedling had proven to be important selection criteria for breeding.

Shrivastava *et al.* (2008) studied variation of seed traits, germination and oil content of *Jatropha curcas* collected from 24 locations in Karnataka. Significant variation in seed length, seed width, kernel weight, 100 seed weight, seed germination and oil content was reported among 24 seed sources. They have also mentioned that the oil content varied from 25.9 to 44.23 per cent and provenances of drier region had lower values for seed traits, but it was highest for oil content.

Singh *et al.* (2008) studied variation in pod and seed characteristics and germination amongst seed sources of *Albizia procera*. Significant ( $p < 0.05$ ) variation in pod and seed characters was recorded in

between seed source. The germination per cent in general decreased with increasing altitude of seed collection source.

Thakur and Rana (2008) worked on physico chemical evaluation of *Terminalia chebula* fruits. The study showed variation in the fruits shape, colour, physical dimension and chemical characteristics. The high fresh fruit weight, fresh pulp and kernel ratio in the fruits from Paragpur -1 suggested this plant sources as a better genetic material for raising plantation on large scale.

Thakur *et al.* (2008) studied assessing natural variation in fruits and seeds of Harar (*Terminalia chebula* Retz). Significant variation was observed in fruit size, weight and seed/pulp ratio. Significant and positive correlation recorded in fruit diameter with green fruit weight.

Ukey *et al.* (2008) studied genetic parameters for seed traits in *Pongamia pinnata*. The genetic parameters for 4 seed characters and per cent germination were worked out in 40 accessions of *Pongamia pinnata* collected from the state of Madhya Pradesh, India. Values for variability and expected genetic gain were calculated for all individual characters such as seed weight exhibited high genetic variability, heritability, genetic gain and genetic gain. Correlation study was undertaken to know the variability patterns.

Luna *et al.* (2009) studied the seed source variation in *Albizia lebbek* with respect to different pod and seed characteristics among 20 seed sources from Punjab, Haryana, and Uttaranchal. The correlation matrix revealed that statistically significant correlation exists between seed weight, seed width and seed length. Germination percentage was positively correlated with number of seeds per pod. Finally they suggested that seeds of *Albezia lebbeck* to be collected from healthy trees and fresh pods to be collected to obtain maximum germination.

Mukta *et al.* (2009) found a wide variability in oil content among 75 accessions of *Pongamia pinnata* that collected from various districts of Telengana region of Andhra Pradesh, in India.

Neelannavar and Chavan (2009) reported high variability for germination percent, 100 seed weight and seed volume index among the different sources of *Albezia lebbeck*. They have recorded the highest genetic advance for germination (59.94%) followed by 100 seed weight (39.74%), while highest heritability was recorded for 100 seed weight (0.94), followed by germination (0.93).

Sahoo *et al.* (2009) reported that *Pongamia pinnata* is an oil-producing tree species with multiple uses and considerable potential as a bioenergy crop. The investigation was carried out to assess the extent of genetic structure in a representative set of 226 individuals of encompassing seven populations, as a prelude to utilization of promising and genetically divergent material in breeding programmes. The data obtained indicate an immediate need to widen the genetic base of germplasm for proper characterization, and for extensive plantations of elite varieties to meet the demands for biodiesel.

Sunil *et al.* (2009) reported variability and divergence in *Pongamia pinnata* (L.) Pierre. Germplasm – a candidate tree for biodiesel. Three explorations were undertaken in South East Coastal zone of India covering parts of Andhra Pradesh and Orissa states to collect germplasm. A total of 123 accessions were collected and seed data recorded were analyzed for morphometric traits. Based on the observed diversity, Chittoor, Srikakulam and Adilabad districts of AP were most suitable for collecting diverse germplasm lines and also for in situ conservation.

Ukey and Koshta (2009) studied on genetic variability of pod and seed characters of *Pongamia pinnata* through the estimates of range, mean, phenotypic and genotypic co-efficient of variation, heritability and genetic advance as percent of mean. High variability was observed almost in all the seed and pod characters. Significant variations were observed in pod length, pod breadth, 100-pod weight, seed length, seed breadth, 100-seed weight and oil content. High heritability coupled with high genetic advance was observed pod breadth, 100-pod weight, seed length.

Abraham *et al.* (2010) observed a wide variability in seed traits and oil content in *Madhuca longifolia*. A significant positive correlation

was observed between 100 seed weight with seed length, seed breadth and seed thickness, seed thickness and hilum breadth and kernel oil content (%) while kernel oil content recorded negatively correlation with seed characters except 100 seed weight.

Divakaran *et al.* (2010) elucidated the genetic variation and relationship of pod and seed traits on germination capacity in *Pongamia pinnata* to select the best planting material for higher productivity. The variability studies revealed that maximum values for pod length (65.64 mm), pod thickness (12.72 mm), 100-pod weight (542.35 g), seed length (27.93 mm), 100-seed weight (202.89 g), pod-seed ratio (2.89) and total oil content (44.33%) and germination capacity (94.67%). The phenotypic and genotypic coefficients of variations were also close to each other for all these traits, but 100-pod weight and 100-seed weight exhibited higher phenotypic and genotypic coefficients of variation than the other traits. Estimate of broad sense heritability ranged from 0.82 (for seed length) to 0.98 (for 100-pod weight), genetic advance ranged between 12.30 and 46.04 per cent.

Hareesh and Vasudeva (2010) worked on variation for fruit and seed traits of *Garcinia indica* Choisy and observed variation for fruit colour, shape and taste. They identified eight variants which vary in terms of colour, shape and taste.

Hegde *et al.* (2010) worked on evaluation of morphological and chemical variation in two endangered medicinal tree species of *Garcinia*. They observed wide morphological variation for shape, colour and size. Varied shape like round, flat, pear shaped with or without prominent navel fruits were seen. Fruit colour varied from dark red to crimson red and also pure yellow. The study revealed that the HCA content ranged from 7.0 to 13.0% among higher fruit yielding trees. The lactone content was 4.9 to 10.5 %, citric acid content ranged from < 0.1 to 2.8 %. In case of white fruit rind type HCA content ranged from 9.0 to 11.9%.

Kumaran *et al.* (2010) carried out correlation and path coefficient studies in 15 seed sources of *Simarouba glauca* collected from

Tamil Nadu, Karnataka, Maharashtra and Orissa. Genotypic correlation coefficients in all the cases. Height and basal diameter had positive and highly significant correlation with volume index at both phenotypic and genotypic levels, in all the three location viz. Mettupalayam, Tindivanam and Coimbatore. Heights exhibited positively and highly significant inter correlation with basal diameter at both level in all three locations. Path analysis revealed that height and basal diameter exhibited positive direct effect, while number of branches showed negative direct effect on volume index in all three locations except at Mettupalayam. Height basal diameter could serve as reliable selection index.

Mirgal *et al.* (2010) worked on characterization of fruit and seed traits of *Garcinia indica* Choisy: implication to tree selection. They revealed that there was a significant variation for fruit character among the selected individual trees. The fruit weight ranged from 14.7 to 71.82 gm and had an average weight of 25.49 gm. among the sampled trees. Similarly, the rind thickness of the fruits ranged from 0.20 to 0.38 cm and an average weight of 0.26 g dry weight. Fruit shape of the identified genotypes varied from round, round flat, onion and pyriform shaped.

Nagwekar *et al.* (2010) reported that the fruits of 'Konkan Hatis', a released variety of *Garcinia indica*, are bolder than Konkan Amrutha with a maximum fruit length (4.22cm), maximum width (6.29cm), average weight of the fruit (91.50g), average weight of rind (5.60g), the fruit was apple shaped. The rind of Konkan Hatis fruits recorded 9.20% total soluble solids, 4.10% reducing sugar.

Ravishankar and Sakthivel (2010) reported wide variation in canopy architecture of trees (dome, round, conical and pyramidal) and branching patterns (erect, spreading and drooping) in Malabar tamarind (*Garcinia gummi-gutta*), *Garcinia xanthochymus* trees were erect with dome shaped canopy. Wide variability in morphological and fruit characters within and between the *Garcinia* species such as *Garcinia indica*, *Garcinia gummi-gutta*, *Garcinia xanthochymus*, *Garcinia morella* and *Garcinia mangostana* has also been reported.

Baliga *et al.* (2011) have reported general chemical composition of *Garcinia indica* and shown that the rind contains protein, tannin, pectin, sugar, fat, organic acids like (-) hydroxy citric acid, hydroxy citric acid lactone, anthocyanin, cyanidin-3-glucoside and cyanidin-3-sambubioside.

Navhale *et al.* (2011) conducted variability study in 40 genotypes of *Chebulic myrobalan* (*Terminalia chebula* Retz.) were selected from the nearby area of Dapoli, Burondi, Wakawali, Murud and Anjarla during January to December 2008. These genotypes were studied for six morphological characters of trees and twelve physical parameters of fruits. The analysis of variance revealed significant variation among the genotypes for all the characters. On the basis of different characters, WR-4, CR-1, VR-2 and BR-12 were selected as CPTs in *Chebulic myrobalan*. These CPTs performed well for at least two characters.

## CHAPTER III

### MATERIAL AND METHODS

The present study entitled “**Genetic variability studies in candidate plus tree of *Madhuca indica* Roxb. in eastern vidarbha region of Maharashtra**” was conducted during 2015-17 at Department of Forestry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, with a view for selection of candidate plus trees in mahua their morphological characters of trees and physiochemical characters of fruits from different district in eastern vidarbha region of Maharashtra State.

#### **Survey and collection of candidate plus trees of *Madhuca indica***

Selection of plus trees was done by using subjective grading system proposed by Zobel and Talbart (1984). The following observations was recorded for selected candidate plus tree.

#### **3.1 Experimental site**

The observations were taken from four districts namely Bhandara, Chandrapur, Gadchiroli and Gondia of eastern vidarbha region of Maharashtra. The observations of CPT's were taken at five locations from each District and two trees were selected from each location.

**Table 1. Details of CPT's selected**

<b>CPT Code</b>	<b>Location</b>	<b>Tehsil</b>	<b>Latitude N</b>	<b>Longitude E</b>
<b>BHANDARA</b>				
CPT 1	Mohagaon	Tumasar	21 <sup>0</sup> 15'30.6"	79 <sup>0</sup> 39'40.1"
CPT 2	Mohagaon	Tumasar	21 <sup>0</sup> 15'31.6"	79 <sup>0</sup> 39'35.7"
CPT 3	Walmazari	Sakoli	21 <sup>0</sup> 08'35.7"	79 <sup>0</sup> 59'27.5"
CPT 4	Walmazari	Sakoli	21 <sup>0</sup> 08'36.4"	79 <sup>0</sup> 59'30.7"
CPT 5	Pimpalgaon	Lakhani	20 <sup>0</sup> 53'15.2"	79 <sup>0</sup> 43'50.5"
CPT 6	Pimpalgaon	Lakhani	20 <sup>0</sup> 53'14.7"	79 <sup>0</sup> 43'53.5"
CPT 7	Parsodi	Lakhandur	21 <sup>0</sup> 08'28.6"	79 <sup>0</sup> 32'06.4"
CPT 8	Parsodi	Lakhandur	21 <sup>0</sup> 08'26.8"	79 <sup>0</sup> 32'07.2"
CPT 9	Kodurli	Pauni	20 <sup>0</sup> 46'47.5"	79 <sup>0</sup> 39'47.6"
CPT 10	Kodurli	Pauni	20 <sup>0</sup> 46'46.1"	79 <sup>0</sup> 39'44.1"

<b>CHANDRAPUR</b>				
CPT 11	Sonapur	Nagbhid	20°21'53.9"	79°40'06.4"
CPT 12	Sonapur	Nagbhid	20°21'56.7"	79°40'07.6"
CPT 13	Sirkada	Sindewahi	20°18'38.4"	79°31'28.1"
CPT 14	Sirkada	Sindewahi	20°18'38.0"	79°31'27.4"
CPT 15	RajoliChak	Savali	20°06'56.7"	79°51'38.9"
CPT 16	RajoliChak	Savali	20°06'57.2"	79°51'29.2"
CPT 17	Borgaon	Gondpipri	20°36'27.8"	79°53'57.8"
CPT 18	Borgaon	Gondpipri	20°36'30.8"	79°53'42.6"
CPT 19	Khatora	Warora	20°16'49.6"	79°20'44.2"
CPT 20	Khatora	Warora	20°16'47.6"	79°20'46.2"
<b>GADCHIROLI</b>				
CPT 21	Kadholi	Kurkheda	20°30'40.4"	80°09'42.9"
CPT 22	Kadholi	Kurkheda	20°30'47.7"	80°09'34.4"
CPT 23	Vairagad	Armorli	20°26'18.0"	80°05'09.6"
CPT 24	Vairagad	Armorli	20°26'18.2"	80°05'18.8"
CPT 25	Ghot	Chamorshi	19°48'45.0"	79°59'07.6"
CPT 26	Ghot	Chamorshi	19°48'54.4"	79°59'07.8"
CPT 27	Indala	Gadchiroli	20°09'19.6"	79°56'32.3"
CPT 28	Indala	Gadchiroli	20°09'20.2"	79°56'37.2"
CPT 29	Visora	Wadsa	20°37'56.2"	79°59'43.5"
CPT 30	Visora	Wadsa	20°37'58.0"	79°59'34.1"
<b>GONDIA</b>				
CPT 31	Lohara	Salekasa	21°14'17.2"	80°28'12.8"
CPT 32	Lohara	Salekasa	21°14'08.1"	80°28'11.0"
CPT 33	Amgaon	Amgaon	21°22'03.2"	80°22'49.8"
CPT 34	Amgaon	Amgaon	21°21'58.6"	80°23'04.6"
CPT 35	Koylari	SadakArjuni	21°05'49.6"	80°16'28.4"
CPT 36	Koylari	SadakArjuni	21°05'43.2"	80°16'18.3"
CPT 37	Kaneri	Arjuni	20°45'17.6"	80°07'18.2"
CPT 38	Kaneri	Arjuni	20°45'11.1"	80°07'22.5"
CPT 39	Silezari	Arjuni	20°55'27.4"	79°58'10.7"
CPT 40	Silezari	Arjuni	20°55'23.8"	79°57'59.3"

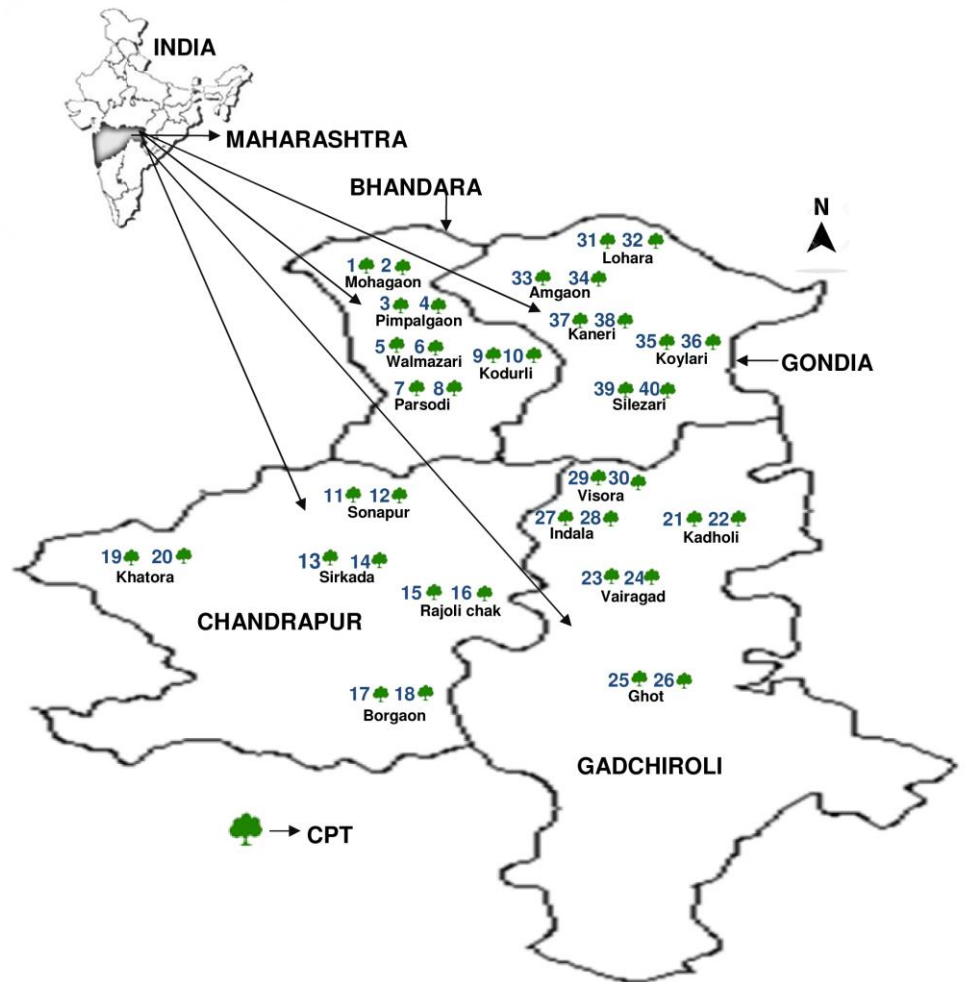


Plate 1. Location map of selected CPTs in *Madhuca indica* from eastern vidarbha region of Maharashtra



**CPT-27**  
Indala,  
Gadchiroli



**CPT-37**  
Kaneri  
Gondia



**CPT-39**  
Silezari  
Gondia



**CPT-5**  
Pimpalgaon  
Bhandara



**CPT-12**  
Sonapur  
Chandrapur

**Plate 2. A Candidate Plus Tree (CPT) of *Madhuca indica***

### 3.2 Soil

The soil of experimental site belongs to alluvial in Bhandara, very dark grey, clay loam in Chandrapur, hard and compact, shallow coarse, medium and deep black Gadchiroli and granite in Gondia gneiss of Achaeans origin located at an elevation of 244 m, 188 m, 217 m and 300 m above mean sea level respectively.

### 3.3 Climate and weather conditions

The Mahua plants are situated in a village of Bhandara, Chandrapur, Gadchiroli and Gondia district respectively. The CPT's of Mahua comes under the agro-climatic zone number VI, VII, VIII and IX at latitude 21.17<sup>0</sup>, 19.950<sup>0</sup>, 20.10<sup>0</sup> and 21.4598<sup>0</sup>N respectively and longitude 79.65<sup>0</sup>, 79.297<sup>0</sup>, 80.0<sup>0</sup> and 80.195<sup>0</sup> E respectively. The average range of temperature is 35.6<sup>0</sup>C to 47.9<sup>0</sup>C with mean annual rainfall of 1327 mm, 1249 mm, 1704 mm and 1325 mm respectively.

### 3.4 Details of Experiment

- 1) Experimental design : Randomise Block Design (RBD)
- 2) Number of replications : 05 (Five)
- 3) Number of treatments : 40 (forty) (Genotypes)

The materials used and methods followed during the course of present investigation are as follows.

**Species Botanical name:** *Madhuca indica* Common name: Mahua tree.

**Location:** The candidate plus trees (CPT's) were selected from eastern vidarbha region of Maharashtra state.

**Provincance:** The locations of trees were taken with the help of Global Positioning System (GPS) instrument in the form of Longitude and Latitude.

#### **Identification of Candidate Plus Trees (CPT's)**

The CPT's were examined for various morphological characters *viz.* height, girth, form, bole straightness, vigour etc.

**Marking of trees:** Yellow colour paints band of 3 cm was used to mark the CPT's.

**Tree Measurement:** For the measurement of tree diameter and canopy diameter of the tree standard measuring tape was used. While the measurement of tree diameter was taken at diameter breast height i.e. at 1.37 m from ground level and canopy diameter was recorded in N – S and E – W direction.

**Instruments:** Following Measurement tools and Laboratory instruments were used during the course of genetic variability study.

Morphological character: Wooden and Digital caliper, Tape

Physiochemical character: Standard and sensitive laboratory equipment's like seed sampler, grinder, hot air oven and soxhlet oil extraction apparatus, electronic balance, etc.

### **3.5 OBSERVATIONS**

The identification of CPT's was done on the basis of following parameters

#### **3.5.1 Variability in Morphological characters of trees from different genotypes of *Madhuca indica***

The observations on seven morphological characters of selected trees were taken.

**3.5.1.1 Age** - The age of trees was determined by using Swedish increment borer instrument.

**3.5.1.2 Height** - The height of trees was measured by using altimeters and recorded in meters.

**3.5.1.3 Canopy diameter** - The canopy diameter of the tree was determined by shadow method and calculated by given formula  $A+B=C$ ,  $C/2$  and recorded in meter.

**3.5.1.4 Diameter at base** - The diameter at base was measured at ground level using measuring tape and recorded in centimetre.

**3.5.1.5 Diameter at breast height** – The diameter at breast height of trees was measured at 1.37 m above ground level using measuring tape and recorded in centimetre.



**Plate 3. The fruits of *Madhuca indica***



**Plate 4. Variation in seeds among CPT's of *Madhuca indica***



**Plate 5. Variation in kernels among CPT's of *Madhuca indica***



**Plate 6. Estimation of titratable acidity**

**3.5.1.6 Girth at base** - The girth at base was measured in ground level using measuring tape and recorded in centimetre.

**3.5.1.7 Girth at breast height** - The girth of the trees was measured at 1.37 m above ground level using measuring tape recorded in meters.

### **3.5.2 Variability in physio-chemical parameters of fruit**

The observations on physio-chemical parameters of five fruits from the selected trees were taken.

**3.5.2.1 Weight of fruit** – The weight of fruit was measured with the help of electronic balance and weight of fruits was calculated and recorded as fruits weight in gram.

**3.5.2.2 Diameter of fruit** – The diameter of selected fruit was measured with the help of Vernier caliper and after computing mean, it was recorded as average diameter of fruit in centimeter.

**3.5.2.3 Fruit yield per tree** – The fruits harvested from each observational plant during each harvesting weighed on electronic balance. The total weight of fruit from all harvesting was calculated and recorded as fruits yield per plant in kilogram.

**3.5.2.4 Length of fruit** – The length of each fruit was measured with the help of vernier caliper and after computing mean, it was recorded as average length of fruit in centimeter.

**3.5.2.5 Weight of fruit pulp** – The weight of fruit pulp was extracted from fruit with the help of fruit pulp machine and recorded by using electronic balance in milligram.

**3.5.2.6 Weight of dry fruit** – The fruit of each location was dried in hot air oven at 70°C for 4 hrs. The dry weight per fruit was computed on average basis.

**3.5.2.7 Weight of 100 seed** – The weight of 100 seeds from each individual candidate plus tree was measured in gram.

**3.5.2.8 Weight of kernels** - The weight of kernel was measured with the help of electronic balance and weight of kernel was calculated and recorded as kernel weight in gram.

**3.5.2.9 Moisture content** – Moisture content was determined by taking seed in brown paper bags kept in hot air oven at 70°C for 4 hrs. The reduction in seed weight indicated the loss of moisture. The percent seed moisture was calculated on the basis of dry weight with following formula.

$$\text{Moisture Content (\%)} = \frac{\text{Fresh weight (g)} - \text{Dry weight (g)}}{\text{Fresh weight (g)}} \times 100$$

**3.5.2.10 TSS** – Pulp was extracted from fruits and total fruits and total soluble solids (TSS) was determined using Atago make RX 1000 refractometer. A drop of juice was extracted and placed on clean prism of refractometer and the lid was closed. Reading was taken directly from the scale at 20°C temperatures and recorded as total solids in °Brix.

**3.5.2.11 Titratable acidity** – It was determined by titrating the sample against 0.1 N sodium hydroxide (NaOH) solution from colourless to faint pink. A few drops of 1 percent phenolphthalein were used as an indicator and the percentage of total acidity was calculated by using following formula.

$$\text{Titrateable acidity (\%)} = \frac{\text{Titrate} \times \text{normality of alkali} \times \text{equivalent weight of acid}}{\text{Volume of sample taken for estimation} \times 1000} \times 100$$

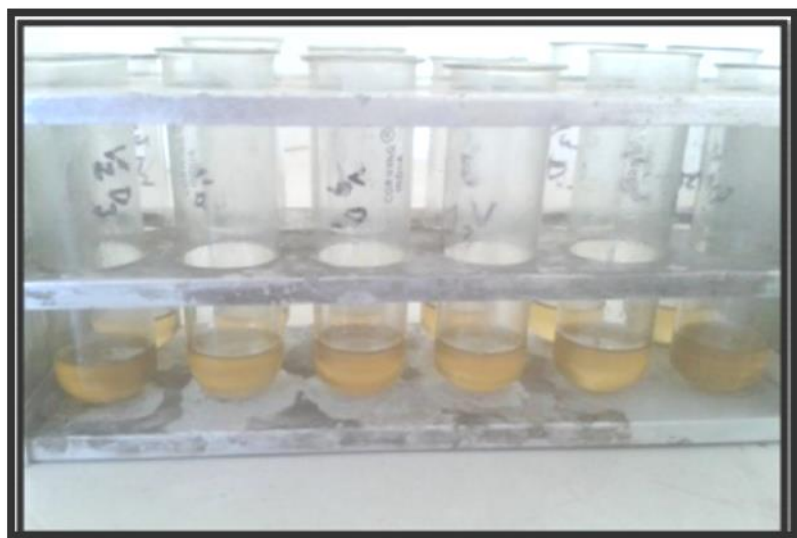
**3.5.2.12 Total sugar** – Total sugars estimation was done by extract prepared from selected fruit pulp. Total sugars were determined by “Dubois method” (Sadasivam and Manickam, 1996), in this method 5 per cent phenol and 96 per cent concentrated H<sub>2</sub>SO<sub>4</sub> was used to carry out the analysis. Absorbance of the samples was noted at 490 nm on spectrophotometer and graph values were put in the following formula.

$$\% \text{Total sugar} = \text{Reading from graph } (\mu\text{gm}^{-1}) \times \frac{1}{1000000} \times \frac{100 \times 50}{1} \times \frac{100}{\text{wt of sample of sample taken}} \times 100$$

**3.5.2.13 Reducing sugar** – For estimation of reducing sugars, extract prepared from selected fruit pulp. Reducing sugars was determined by method suggested by Sadasivam and Manickam, 1996. In this method 1g



**Plate 7. Estimation of sugars in spectrophotometer**



**Plate 8. Oil extraction from *Madhuca indica* seeds**

Dinitrosalicylic acid, 4g of sodium hydroxide (NaOH), 30g of potassium sodium tartarate (Rochait's salt) was used to carry out the analysis. Absorbance of the samples was noted at 540 nm on spectrophotometer and graph values were put in the following formula.

$$\% \text{Reducing sugar} = \text{Reading from graph } (\mu\text{gm}^{-1}) \times \frac{1}{1000000} \times \frac{100 \times 50}{1} \times \frac{100}{1} \times \frac{100}{\text{wt of 1 ml juice}}$$

### 3.5.2.14 Non- reducing sugar –

Non reducing sugars= Total sugars –Reducing sugars

One gram of the fruit pulp was ground well and blended with 3 percent Metamorphic acid ( $\text{HPO}_3$ ) and volume was made to 100 ml with  $\text{HPO}_3$ . The contents after shaking well was filtered with Whatman No. 1 filter paper. 10 ml of the filtrate wastitrate against dye solution of 2, 6-dichlorophenols indophenols till light pink colour persisted for at least 15 seconds. The titration values was put in the following formula to calculated acid content.

$$\text{Vitamin C } \left( \frac{\text{Mg}}{100\text{g}} \right) = \frac{e \times d \times c}{c \times a} \times 100$$

$$\text{Dye factor (d)} = \frac{0.5}{\text{Avarage burette reading for standardization of dye solution}}$$

Where,

a = weight of sample

b = volume made with metamorphic acid

c = volume of aliquot taken for estimation

d = dye factor

e = average burette reading for sample

### 3.5.2.15 Oil content (%) –

Buttercup fruit-seeds, after removal of fruit shell, was crushed with a hammer on a cardboard, communicated in a high-speed mixer and milled into a fine particle sized (ca. 2mm) meal, which was sticky in

consistency, then soxhlet extracted with n-hexane for 8 hours. The oil yield was calculated as follows.

$$\% \text{oil content in the sample} = \frac{X - F}{W} \times 100$$

Where,

X = weight of the flask with oil and chips

F = weight of the flask and the chips

W = weight of the kernels

### 3.6 Statistical Analysis

The arithmetic mean, standard deviation, coefficient of variation per genotype was computed for morphological observations on trees and used for further statistical analysis.

#### 3.6.1 Analysis of variance for various characters

The analysis of variance was carried out to test difference between the genotype for the characters under study as per the standard method given by Panse and Sukhatme (1954) and Singh and Chaudhary (1977).

The statistical model for Randomized Block Design is given below.

$$X_{ij} = \mu + t_i + r_j + e_{ij}$$

Where,

$X_{ij}$  = observation of the  $i^{\text{th}}$  treatment in  $j^{\text{th}}$  replication

$\mu$  = general mean

$t_i$  = the effect of  $i^{\text{th}}$  treatment

$r_j$  = the effect of  $j^{\text{th}}$  replication

$e_{ij}$  = the random error

Based on above model, the table of analysis of variance (ANOVA) was set up as below.

## Analysis of variance

Source of variation	d.f.	S.S.	M.S.S.
Replications	(r-1)	SSr	MSr
Treatments (genotype)	(g-1)	SSg	MSg
Error	(r-1)(g-1)	SSe	MSe

Where,

r = Number of replications

g = Number of genotypes of treatment

d.f. = degrees of freedom

F' test was used to measure the significance of the differences among the clones. The standard error of differences S.E. (d) and critical difference (C.D.) between two means were calculated for treatment comparison as below

$$SE(d) = \frac{\sqrt{2EMSS}}{r}$$

C.D. = S.E. (D)  $\times$  tab t.

At 5 % and 1 % level of significance at error degrees of freedom.

### 3.6.2 Analysis of covariance

The covariance analysis was done for all possible combinations of quantitative characters and the analysis of variance was done on the similar pattern of variance with the exception that the words 'sum of products' was substituted for 'sum of square' for various parameters of fruit. The statistical analyses of fruit parameters were using Randomized Block Design with five replications.

### 3.6.3 Partitioning of the variances and co-variances into genotypic, phenotypic and environmental components

Fisher and Yates (1958) suggested a method for partitioning the variance and covariance into its heritable and non-heritable components as per below.

i) Genotypic variance

$$\sigma^2_g = \frac{MSg - MSe}{r}$$

ii) Phenotypic variance

$$\sigma^2_p = \sigma^2_g + MSe$$

iii) Environmental variance

$$\sigma^2_e = MSe$$

The genotypic, phenotypic and environmental covariance were estimated on similar lines.

### 3.6.4 Variability parameters studies

The variability parameters *viz.* genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability estimates ( $h^2$ ) and expected genetic advance (EGA) were computed as follows.

#### 3.6.3.1 Genotypic co-efficient of variation

It was estimated by the formula given by Burton (1952).

$$G.C.V. = \frac{\sqrt{\text{Genotypic variance}}}{\bar{X}} \times 100$$

Where,

$\bar{X}$  = Mean of the character

G.C.V. = Genotypic coefficient of variation

#### 3.6.3.2 Phenotypic coefficient of variation

It was estimated by the formula,

$$P.C.V. = \frac{\sqrt{\text{Phenotypic variance}}}{\bar{X}} \times 100$$

Where,

$\bar{X}$  = Mean of the character

P.C.V. = Phenotypic coefficient of variation

### 3.6.3.3 Heritability estimates

Heritability estimates in broad sense was calculated by the following formula given by Hanson, Robinson and Comstock, (1956).

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

Where,

$h^2$  = Heritability in broad sense

$V_g$  = Genotypic variance

$V_p$  = Phenotypic variance

### 3.6.3.4 Genetic Advance (GA)

The expected genetic improvement at five per cent selection intensity was calculated by the formula suggested by Lush (1940) and further used by Burton and De Vane (1953).

$$\text{Genetic advance (GA)} = \left( \frac{V_g}{V_p} \right) \times \sqrt{V_p} \times K$$

Where,

$V_p$  = Phenotypic variance

$V_g$  = Genotypic variance

$K$  = Selection differential at 5% selection intensity. The value of  $K$  = 2.06 (Allard, 1960).

## 3.7 Simple Correlation

The variance and co-variance components, the genotypic correlation were calculated by the method suggested by Hayes, Immer and Smith (1955). The following formula was used for computing the correlation coefficient.

1) Genotypic correlation

$$r_{ij}(g) = \frac{\text{Genotypic covariance of characters 'i' \& 'j'}}{\sqrt{\text{Genotypic variance of 'i' X genotypic variance of 'j'}}$$

2) Phenotypic correlation

$$r_{ij}(p) = \frac{\text{Phenotypic covariance of characters 'i' \& 'j'}}{\sqrt{\text{Phenotypic variance of 'i' X phenotypic variance of 'j'}}$$

3) Environmental correlation

$$r_{ij}(e) = \frac{\text{Environmental covariance of characters 'i' \& 'j'}}{\sqrt{\text{Environmental variance of 'i' X Environmental variance of 'j'}}$$

Where,

$r_{ij}$  = Correlation coefficient between characters ' i ' & ' j '

' i ' & ' j ' = Characters under study

### **3.7.1 Test of significance of simple correlation coefficients**

The estimated values of correlation coefficient were tested with table values of at (g-2) degrees of freedom at 5 percent and 1 percent level of significance respectively where 'g' is the number of genotypes.

## CHAPTER IV

### RESULT AND DISCUSSION

The study was undertaken to identify and evaluate the candidate plus tree of *Madhuca indica* in the eastern vidarbha region of Maharashtra during the period 2015-2017. The results of the present investigation are presented in this chapter.

#### A. Result

The experimental findings of the investigation entitled “Genetic variability studies in candidate plus tree of *Madhuca indica* Roxb. in eastern vidarbha region of Maharashtra” were presented under following subheads.

4.1 Morphological variation in candidate plus tree.

4.2 physio-chemical characters

4.3 Top five identified candidate plus tree

4.4 Variability parameter studies

4.5 Analysis of variance

4.6 Simple correlation

#### 4.1 Morphological variation in candidate plus tree

The observation recorded for age of tree, height of tree, canopy diameter, diameter at base, girth at base, diameter at breast height and girth at breast height are presented for all 40 trees marked as CPT's among the individuals in the natural population distributed in five locations each from four districts. (Table No. 2).

This CPT's showed a great degree of variation within and among locations. The tree heights of 20 CPT's were above population mean.

##### 4.1.1 Age of tree (yrs.)

The CPT-7, CPT-30 and CPT-32 recorded a maximum age of tree (39.00 yrs.). CPT-5, CPT-10, CPT-16, CPT-24, CPT-25, CPT-26, CPT-36 (37.00 yrs.) followed by

**Table No. 2: Variation in morphological characters of trees from different genotypes**

<b>CPT Code</b>	<b>Age of tree</b>	<b>Height of tree (m)</b>	<b>Canopy Diameter (m)</b>	<b>Diameter at base (cm)</b>	<b>Diameter at breast height (cm)</b>	<b>Girth at base (cm)</b>	<b>Girth at breast height (cm)</b>
CPT 1	35	9.00	8.03	28.10	24.87	88.25	78.12
CPT 2	34	8.25	8.03	27.54	24.33	86.48	76.42
CPT 3	36	10.03	7.25	29.40	26.22	92.34	82.34
CPT 4	34	9.04	7.04	27.84	24.66	87.43	77.45
CPT 5	37	11.00	6.75	29.76	26.25	93.47	82.43
CPT 6	38	10.04	8.03	30.41	26.88	95.51	84.42
CPT 7	39	11.25	7.09	31.45	27.56	98.76	86.56
CPT 8	35	8.07	6.05	28.12	24.59	88.32	77.23
CPT 9	36	9.05	7.65	29.11	26.19	91.42	82.24
CPT 10	37	12.25	6.55	29.97	26.48	94.12	83.15
CPT 11	38	10.05	6.07	30.32	26.78	95.23	84.12
CPT 12	33	8.06	4.09	26.85	23.06	84.34	72.43
CPT 13	38	11.00	5.05	30.68	27.21	96.35	85.47
CPT 14	35	9.04	6.09	28.47	25.03	89.42	78.62
CPT 15	34	10.25	5.35	27.74	24.28	87.12	76.24
CPT 16	37	10.04	6.05	29.97	26.26	94.11	82.46
CPT 17	38	8.05	7.35	30.61	26.48	96.14	83.17
CPT 18	35	12.25	7.05	28.46	24.63	89.38	77.36
CPT 19	36	9.45	6.85	29.34	27.84	92.15	87.42
CPT 20	33	11.25	7.45	26.54	23.96	83.35	75.24
CPT 21	34	12.05	6.01	27.46	23.99	86.25	75.35
CPT 22	38	10.25	8.35	30.36	28.10	95.35	88.26
CPT 23	35	8.03	6.09	28.14	24.65	88.36	77.42
CPT 24	37	11.25	7.05	30.08	27.53	94.46	86.47
CPT 25	37	12.05	7.55	29.70	27.78	93.27	87.25
CPT 26	37	9.75	5.35	29.99	27.18	94.18	85.35
CPT 27	38	13.00	8.15	30.92	28.14	97.12	88.38

CPT 28	35	12.15	7.02	28.42	25.90	89.26	81.34
CPT 29	34	10.05	8.08	27.79	24.92	87.29	78.26
CPT 30	39	13.25	8.35	31.31	27.81	98.32	87.34
CPT 31	38	10.25	6.65	30.68	27.78	96.35	87.23
CPT 32	39	13.05	8.25	31.33	28.39	98.38	89.16
CPT 33	38	11.35	7.25	30.40	27.52	95.46	86.43
CPT 34	35	11.75	8.05	28.45	24.95	89.34	78.37
CPT 35	38	12.05	7.08	30.72	27.81	96.47	87.34
CPT 36	37	9.03	9.25	30.07	27.50	94.43	86.36
CPT 37	35	13.00	8.85	28.13	25.23	88.33	79.23
CPT 38	38	11.05	8.05	31.02	28.14	97.42	88.38
CPT 39	35	13.75	9.25	28.49	24.98	89.48	78.46
CPT 40	36	12.25	8.35	29.40	25.95	92.34	81.49
Mean	36.27	10.85	7.38	29.33	26.19	92.13	82.26
SD	1.73	1.55	1.06	1.33	1.47	4.19	4.62
CV (%)	4.79	14.27	14.43	4.55	5.61	4.54	5.61

CPT-7, CPT-30, CPT-32 age of (39.00 yrs.) and CPT-6, CPT-11, CPT-13, CPT-17, CPT-22, CPT-27, CPT-31, CPT-33, CPT-35, CPT-38 (38.00 yrs.) at par with CPT-3, CPT-9, CPT-19, CPT-40 (36.00 yrs.). Where CPT-12 and CPT-20 recorded a minimum age of (33.00 yrs.) show in (Table No. 2)

#### 4.1.2 Tree height (m)

The CPT-39 recorded a maximum tree height of (13.75 m). CPT-10, CPT-18, CPT-40 (12.25 m) followed by CPT-39 (13.75 m) and CPT-30 (13.25 m) at par with CPT-28 (12.15 m). Where CPT-23 recorded a minimum height of (8.03 m).

#### 4.1.3 Canopy diameter (m)

The CPT-36, CPT-39 recorded a maximum canopy diameter of (9.25 m). CPT-22, CPT-30, CPT-40 (8.35 m) followed by CPT-36, CPT-39 (9.25 m) and CPT-37 (8.85 m) at par with CPT-32 (8.25 m). Where CPT-12 recorded a minimum canopy diameter of (4.09 m).

#### **4.1.4 Diameter at base (cm)**

The CPT-7 recorded a maximum diameter at base of (31.45 cm). CPT-30 (31.31 cm) followed by CPT-7 (31.45 cm) and CPT-32 (31.33 cm) at par with CPT-38 (31.02 cm). Where CPT-21 recorded a minimum diameter at base of (27.46 cm).

#### **4.1.5 Diameter at breast height (cm)**

The CPT-32 recorded a maximum diameter at breast height of (28.39 cm). CPT-22 (28.10 cm) followed by CPT-32 (28.39 cm) and CPT-27, CPT-38 (28.14 cm) at par with CPT-19 (27.84 cm). Where CPT-12 recorded a minimum diameter at breast height of (23.06 cm).

#### **4.1.6 Girth at base (cm)**

The CPT-7 recorded a maximum girth at base (98.76 cm). CPT-30 (98.32 cm) followed by CPT-7 (98.76 cm) and CPT-32 (98.38 cm) at par with CPT-38 (97.42 cm). Where CPT-20 recorded a minimum girth at base of (83.35 cm).

#### **4.1.7 Girth at breast height (cm)**

The CPT-32 recorded a maximum girth at breast height of (89.16 cm). CPT-22 (88.26 cm) followed by CPT-32 (89.16 cm) and CPT-27, CPT-38 (88.38 cm) at par with CPT-19 (87.42 cm). Where CPT-12 recorded a minimum girth at breast height of (72.43 cm).

There was no major pest and disease infestation recorded on selected CPT's of *Madhuca indica*, where infected tree were not selected as CPT's.

### **4.2 Physio-chemical characters**

The data on physio-chemical parameters were presented and tabulated in Table (3) and data trends shown in the figure from figure (1) to figure (15).

#### **4.2.1 Weight of fruit (g)**

The highest fruit weight was recorded in CPT-27 with value (19.01 g). CPT-12 (18.94 g) followed by CPT-27 with value (19.01 g)

and CPT-37 (18.99 g) was at par with CPT-5 (18.71 g). However, the lowest fruit weight was recorded in CPT-1 with value (10.02 g) show in (Table No. 3).

#### **4.2.2 Diameter of fruit (cm)**

Among 40 CPT's fruit diameter of CPT-4, CPT-15 (4.95 cm) was superior over other CPT's. CPT-5 (4.80 cm) followed by CPT-4 (4.95 cm) and CPT-19 (4.93 cm) was at par with CPT-8 (4.71 cm). However, CPT-10 was reported the lowest fruit diameter of (2.02 cm).

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

The fruit length were found in higher magnitude same in CPT's like (6.52 cm) was reported in CPT-27 and CPT-37. CPT – 38 (6.13 cm) was followed by CPT-27, CPT-37 (6.52 cm) and CPT-39 (6.37 cm) was at par with CPT-4, CPT-15 (5.95 cm) The lowest fruit length was recorded in CPT-10 (3.02 cm).

#### **4.2.4 Weight of fruit pulp (mg)**

Highest weight of fruit pulp was observed in CPT-27 (16.85 mg). CPT-12 (16.08 mg) was followed by CPT-27 (16.85 mg) and CPT-37 (16.45 mg) was at par with CPT-5 (16.06 mg). However the lowest weight of fruit pulp was observed in CPT-1, CPT-21 and CPT-31 (9.14 mg).

#### **4.2.5 Weight of dry fruit (g)**

Highest dry fruit weight was observed in CPT-39 (7.15 g). CPT-19 was followed by CPT-39 and CPT-12 was at par with CPT-27 (6.99 g). However the lowest dry fruit weight was observed in CPT-15 (3.52 g).

#### **4.2.6 Moisture content (%)**

Initially CPT-40 recorded the maximum moisture content (65.61 %). CPT-15 (64.95 %) was followed by CPT-40 (65.61 %) and CPT-30 (65.47 %) was at par with CPT-35 (64.87 %). However, CPT-19 recorded the minimum moisture content (57.66 %).

#### **4.2.7 Weight of 100 seed (g)**

Highest seed weight was observed in CPT-37 (270.26 g). CPT-27 (266.05 g) was followed by CPT-37 (270.26 g) and CPT-5 (270.00 g).

g) was at par with CPT-12 (265.66 g). However the lowest 100 seed weight was observed in CPT-40 (155.62 g).

#### **4.2.8 Weight of seed kernel (g)**

The highest seed kernel weight was recorded by CPT-15 of (6.29 g). CPT-5 (5.90 g) was followed by CPT-15 (6.29 g) and CPT-36 (6.00 g) was at par with CPT-27 (5.84 g). However, the lowest seed kernel weight of (3.15 g) was recorded in CPT-21.

#### **4.2.9 Total soluble solid (%)**

The highest total soluble solid was found in CPT-27 with value of (27.50 %). CPT-12, CPT-37 (27.10 %) was followed by CPT-27 (27.50 %) and CPT-5 (27.42 %) was at par with CPT-13 (26.60 %). However, the lowest total soluble solid was found in CPT-1 with value of (24.01 %).

**Table No. 3: Mean performance of forty CPT's Selected from four districts in five locations each for fifteen physio-chemical parameters of fruit**

CPT	Weight of fruit (g)	Diameter of fruit (cm)	Length of fruit (cm)	Weight of fruit pulp (mg)	Weight of dry fruit (g)	Moisture content (%)	Weight of 100 seed (g)	Weight of seeds kernels (g)	TSS (%)	Acidity (%)	Total sugar (%)	Reducing sugar (%)	Non reducing sugar (%)	Oil content (%)	Fruit yield per tree (kg)
CPT 1	10.02	2.31	3.31	9.14	3.83	61.71	160.00	4.70	24.01	12.00	10.108	7.60	2.50	30.00	35.00
CPT 2	11.89	2.55	3.55	10.92	4.32	63.69	162.83	4.47	25.77	12.22	11.136	7.71	3.42	34.73	36.04
CPT 3	12.83	2.66	3.66	10.63	4.51	64.75	164.64	3.42	25.96	13.00	10.936	7.37	3.56	35.47	36.47
CPT 4	16.32	4.95	5.95	12.05	6.44	60.54	252.94	5.08	26.16	15.02	12.942	8.06	4.87	40.32	41.31
CPT 5	18.71	4.80	5.80	16.06	6.96	62.77	270.00	5.90	27.42	16.30	13.608	8.52	5.08	44.80	46.00
CPT 6	15.85	4.71	5.71	11.15	5.62	64.38	167.21	3.81	25.67	12.60	11.336	7.47	3.86	30.19	36.99
CPT 7	13.48	2.66	3.66	10.45	4.95	63.26	165.14	5.07	25.79	12.42	10.744	7.59	3.15	31.22	36.22
CPT 8	17.57	4.77	5.77	12.64	6.85	61.07	243.36	5.35	26.20	14.37	12.742	8.08	4.65	41.11	42.91
CPT 9	13.35	2.25	3.25	9.55	4.86	63.82	174.55	3.92	24.56	12.02	11.336	7.83	3.50	36.05	37.25
CPT 10	16.06	2.02	3.02	9.57	5.93	64.15	167.84	3.97	24.39	13.60	11.144	7.75	3.38	31.69	37.69
CPT 11	17.85	3.45	4.45	14.94	6.66	62.84	236.02	4.15	26.27	14.01	12.142	7.93	4.20	39.42	35.22
CPT 12	18.94	4.46	5.46	16.08	7.13	62.338	265.66	5.75	27.10	16.10	13.808	8.74	5.06	43.88	44.88
CPT 13	15.46	3.13	4.13	11.64	6.02	61.00	246.52	4.35	26.60	14.16	12.942	8.53	4.40	40.83	42.42
CPT 14	16.00	3.37	4.37	12.05	5.82	63.60	248.46	5.36	26.36	14.07	12.742	8.13	4.60	39.20	38.00
CPT 15	10.03	4.95	5.95	9.86	3.52	64.95	196.22	6.29	25.01	12.40	10.324	7.65	2.67	34.13	35.53
CPT 16	15.72	2.93	3.93	10.95	5.85	62.62	194.54	3.71	25.51	12.82	11.336	7.68	3.65	37.86	39.83
CPT 17	14.89	2.54	3.54	9.85	5.21	64.66	176.04	3.79	24.36	13.20	11.136	7.24	3.89	30.36	36.16
CPT 18	13.59	2.66	3.66	10.24	5.06	62.57	177.86	3.63	25.01	13.02	10.736	7.66	3.07	37.52	39.32
CPT 19	17.00	4.93	5.93	13.75	7.11	57.66	239.56	5.16	24.96	14.47	12.942	8.34	4.60	40.10	42.50

CPT 20	14.98	2.94	3.94	12.39	5.63	62.21	172.85	3.46	25.06	13.02	10.524	7.28	3.24	36.32	38.32
CPT 21	10.23	2.65	3.65	9.14	3.83	62.43	168.62	3.15	24.56	13.80	11.136	7.24	3.89	39.26	40.66
CPT 22	15.09	2.66	3.66	9.92	6.04	60.43	170.75	3.25	24.16	13.22	10.536	7.63	2.90	36.28	38.68
CPT 23	16.69	2.84	4.24	12.64	5.86	64.83	233.36	4.24	25.16	14.48	12.742	8.33	4.41	40.16	41.76
CPT 24	14.95	2.25	3.25	9.65	5.42	63.49	168.55	5.24	24.56	13.60	11.336	7.87	3.46	38.90	40.70
CPT 25	15.79	2.04	3.04	9.86	5.76	63.42	164.84	3.86	24.36	13.22	10.576	7.35	3.22	38.00	39.20
CPT 26	16.70	3.45	4.45	12.35	6.45	61.24	250.03	5.51	25.56	14.47	12.742	8.14	4.60	42.15	43.15
CPT 27	19.01	4.52	6.52	16.85	6.99	63.20	266.05	5.84	27.50	16.02	13.544	8.36	5.18	44.85	45.85
CPT 28	17.59	3.14	4.14	12.64	6.41	63.48	234.54	5.59	26.37	14.76	12.966	8.32	4.63	39.82	42.39
CPT 29	17.11	3.37	4.37	11.95	6.39	62.44	247.66	4.22	25.36	14.47	12.632	8.04	4.58	40.71	41.71
CPT 30	15.68	2.94	3.94	9.57	5.41	65.47	214.42	5.75	25.26	12.46	10.552	7.41	3.13	36.49	37.49
CPT 31	15.93	2.66	3.66	9.14	5.65	64.38	179.41	3.75	24.36	12.62	11.136	7.82	3.31	38.09	39.09
CPT 32	15.08	2.66	3.66	10.32	6.26	60.22	177.75	3.93	24.16	13.23	10.536	7.13	3.40	37.45	38.85
CPT 33	11.80	2.84	3.84	10.63	4.33	63.26	183.93	3.42	24.66	12.82	11.124	7.70	3.42	34.97	38.33
CPT 34	12.61	2.25	3.25	12.45	4.71	62.62	168.55	3.90	24.96	13.02	10.936	7.43	3.50	39.45	40.85
CPT 35	10.29	2.38	3.38	10.86	3.62	64.87	170.24	5.82	24.76	14.40	11.336	7.60	3.73	36.74	39.88
CPT 36	17.07	3.65	4.85	12.15	6.75	62.24	252.03	6.00	26.57	15.07	12.832	8.01	4.82	41.99	42.98
CPT 37	18.99	4.52	6.52	16.45	6.75	64.42	270.26	5.74	27.10	16.22	13.344	8.32	5.01	45.00	46.03
CPT 38	16.97	4.13	6.13	12.64	6.81	59.79	248.55	5.52	25.97	15.47	12.834	8.32	4.51	40.40	42.89
CPT 39	18.08	4.37	6.37	10.95	7.15	60.42	163.05	5.24	26.16	15.27	12.432	8.05	4.37	40.89	42.09
CPT 40	16.70	2.94	3.94	9.57	5.68	65.61	155.62	4.29	25.16	13.24	10.324	7.58	2.74	38.63	40.23
S.E. (d)	0.98	0.13	0.16	0.94	0.44	1.95	15.95	0.37	0.82	0.88	0.86	0.61	0.52	2.59	2.55
C.D.	2.94	0.39	0.48	2.82	1.32	5.85	47.85	1.11	2.46	2.64	2.58	1.83	1.56	7.77	7.65

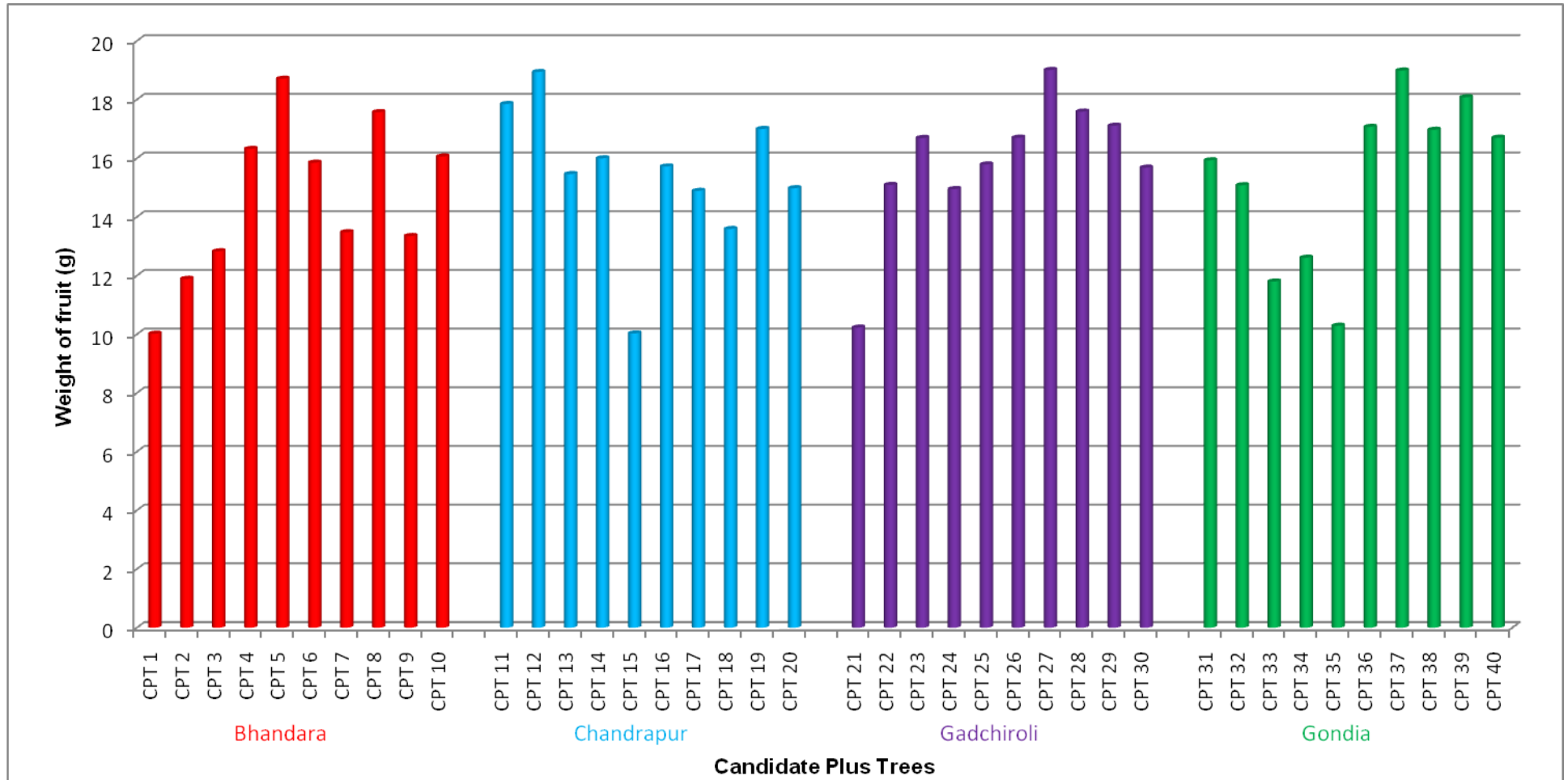
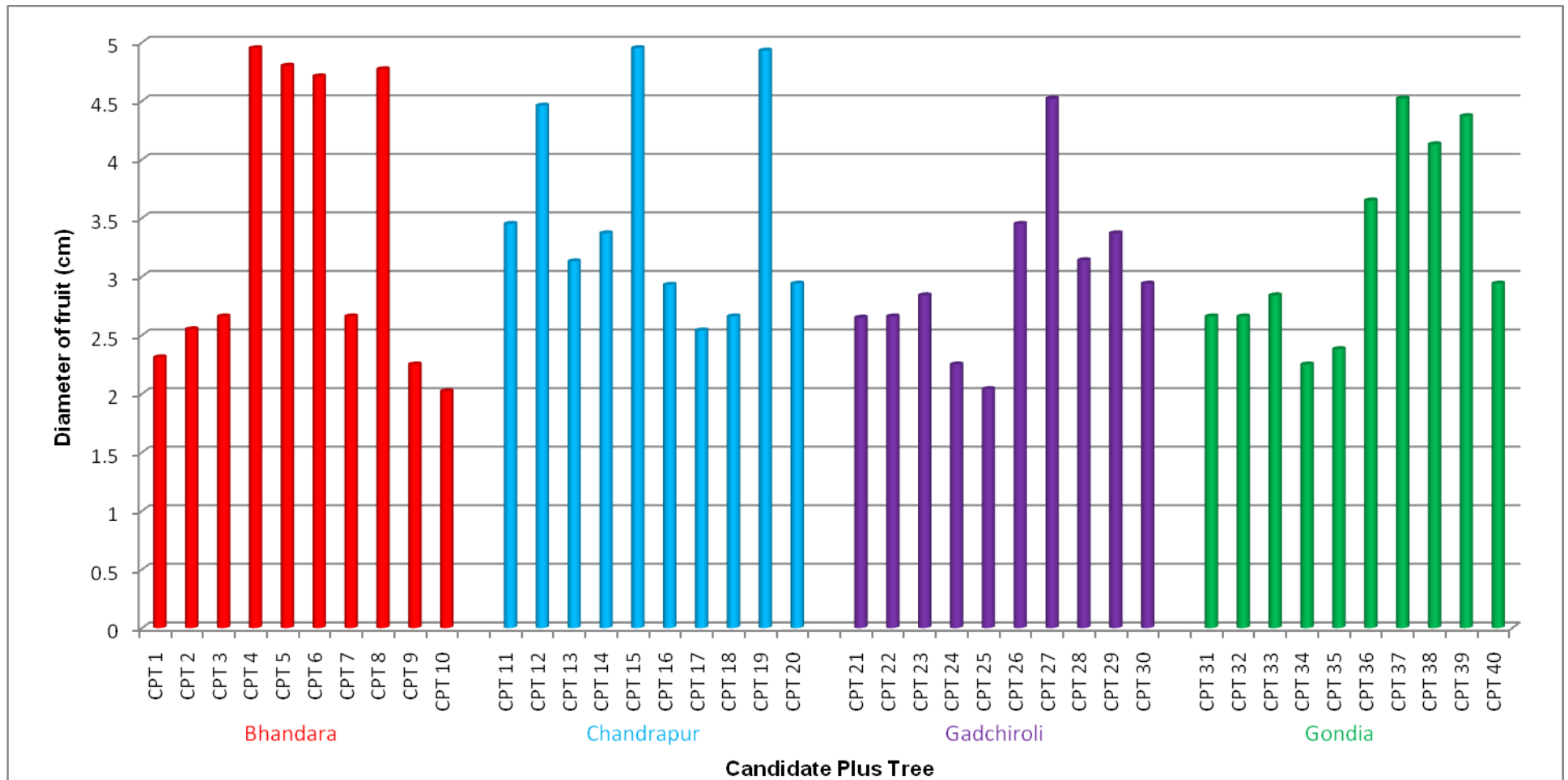
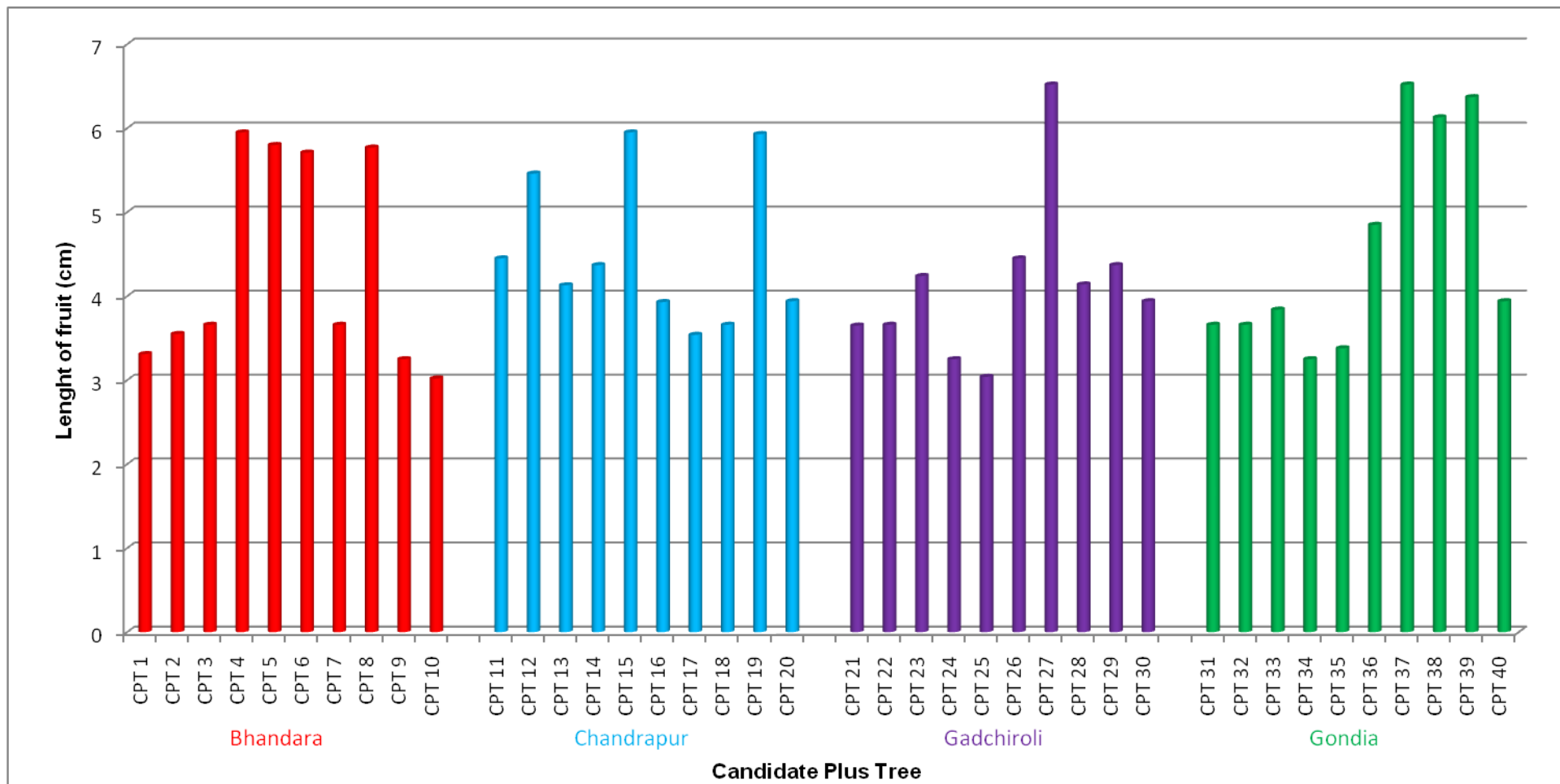


Fig. 1 Variation in weight of fruit (g) among 40 CPT's of *Madhuca indica*



**Fig. 2** Variation in diameter of fruit (cm) among 40 CPT's of *Madhuca indica*



**Fig. 3** Variation in length of fruit (cm) among 40 CPT's of *Madhuca indica*

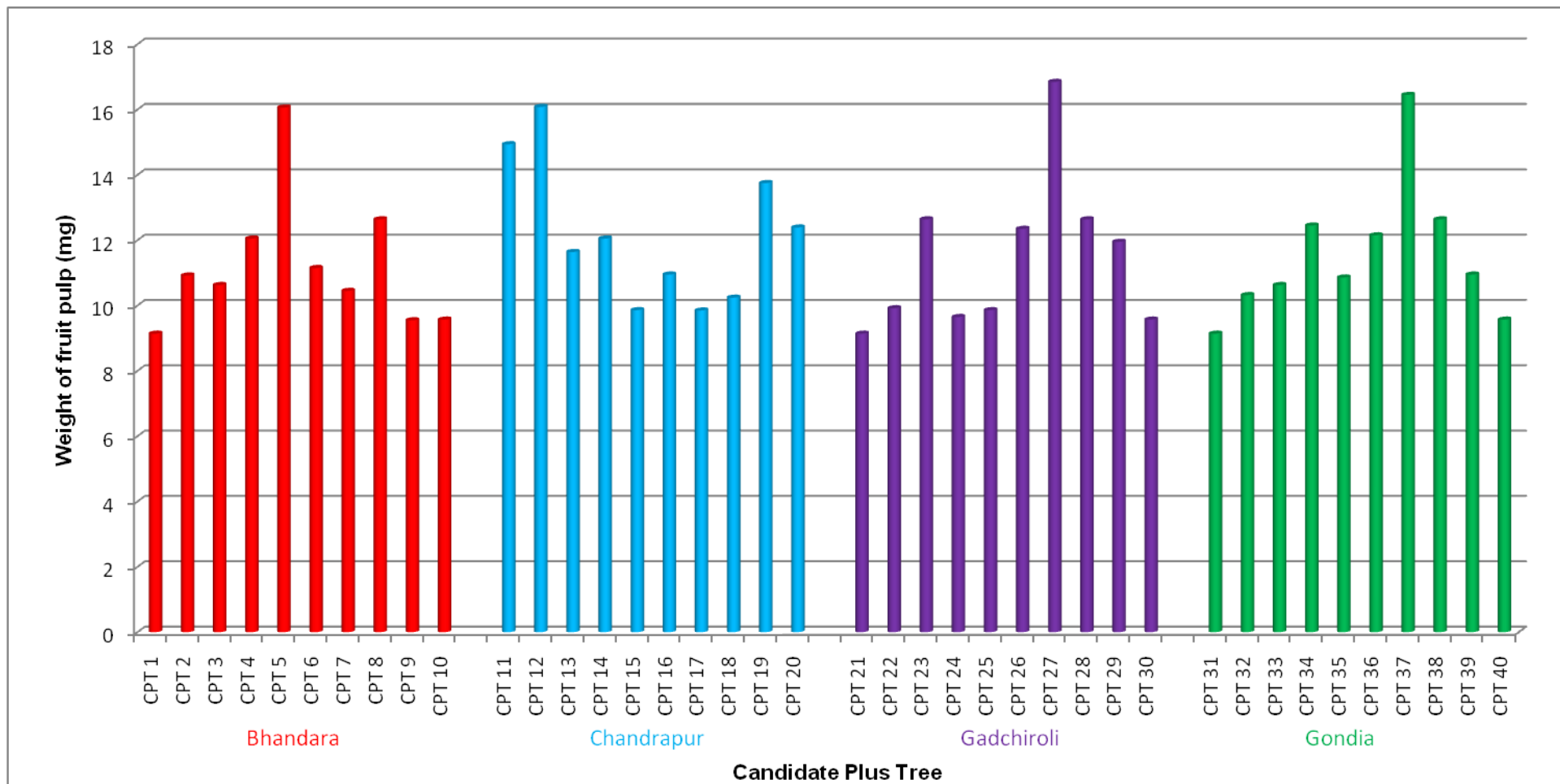
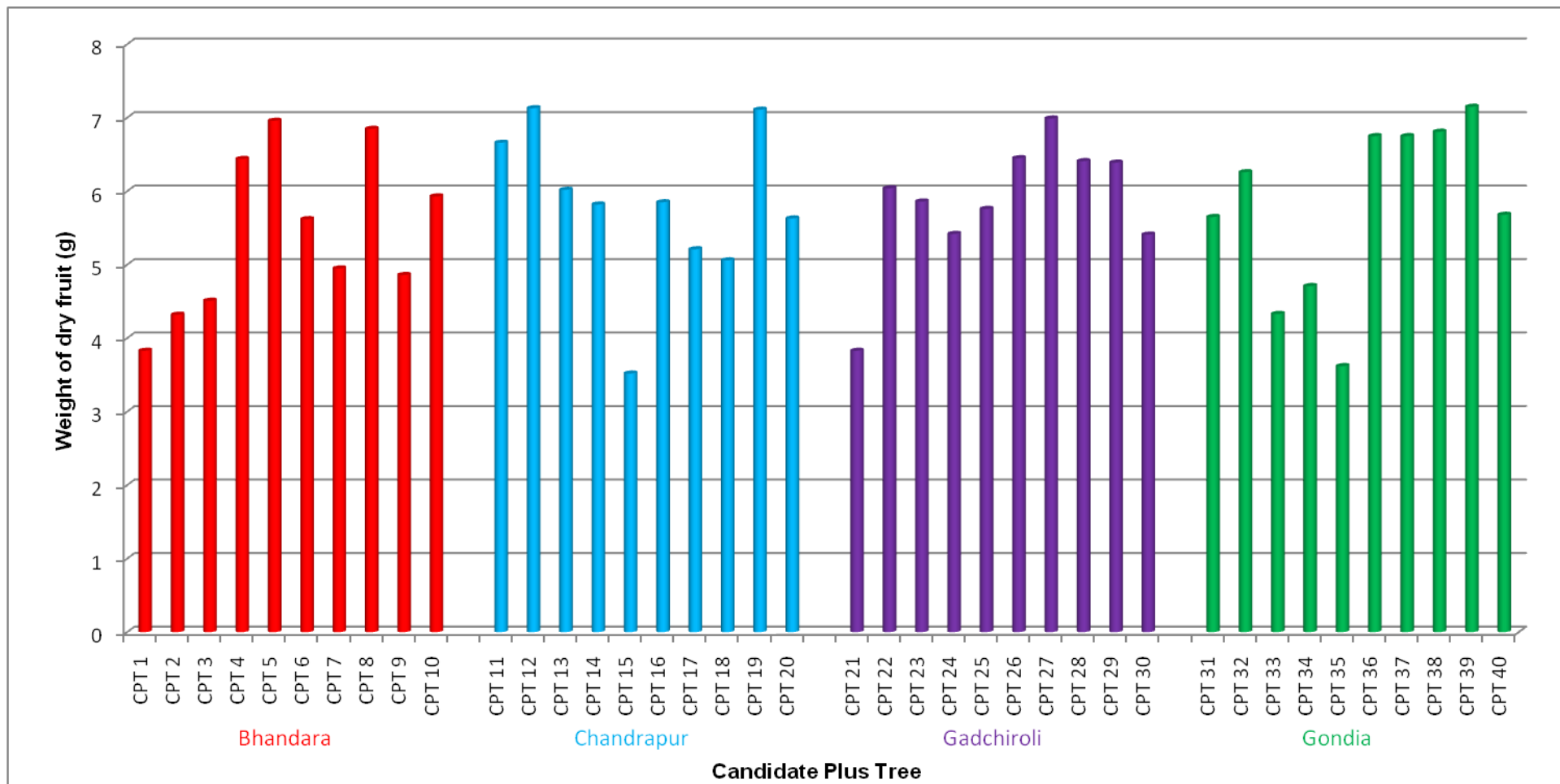
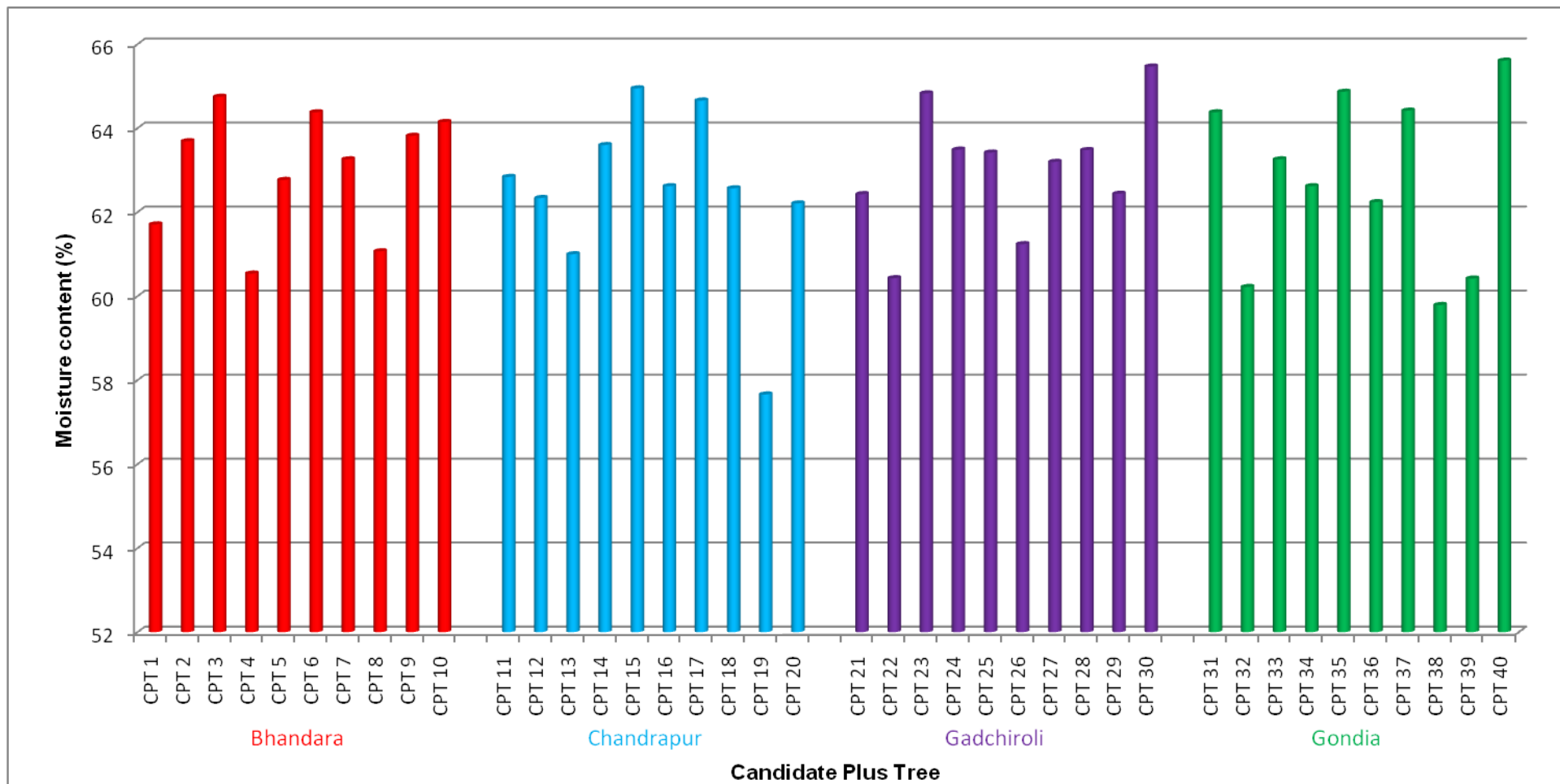


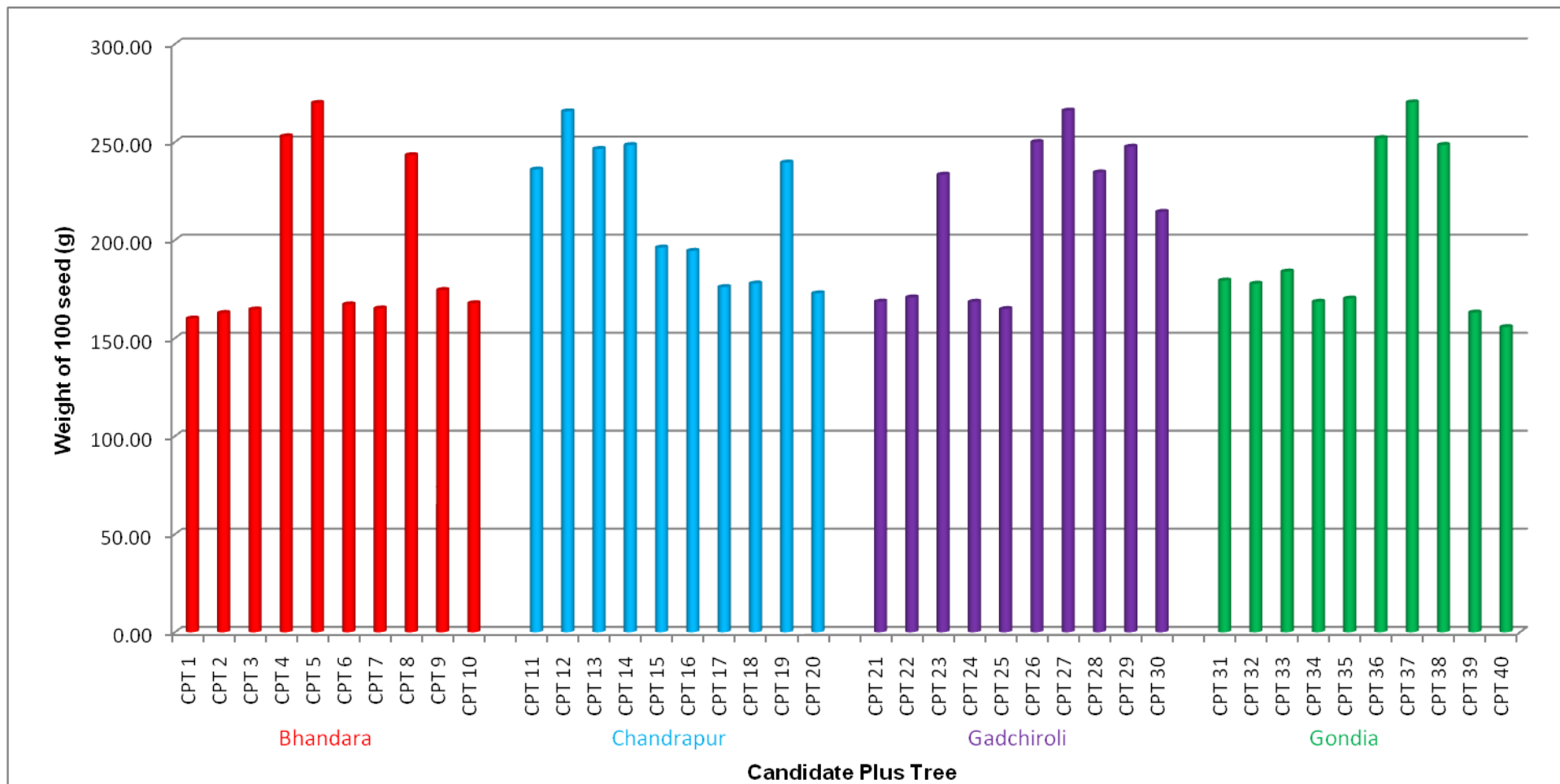
Fig. 4 Variation in weight of fruit pulp (mg) among 40 CPT's of *Madhuca indica*



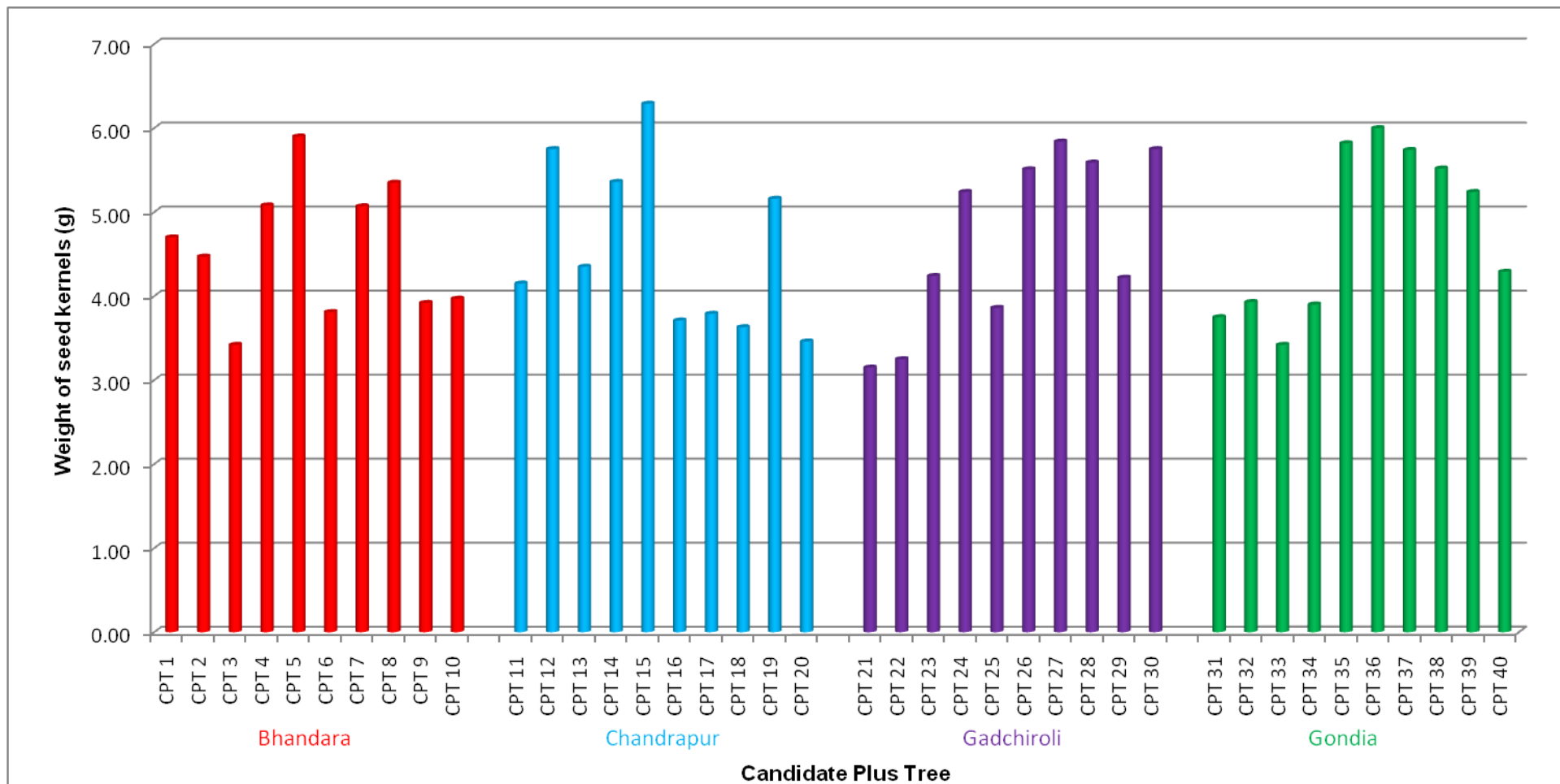
**Fig. 5 Variation in weight of dry fruit (g) among 40 CPT's of *Madhuca indica***



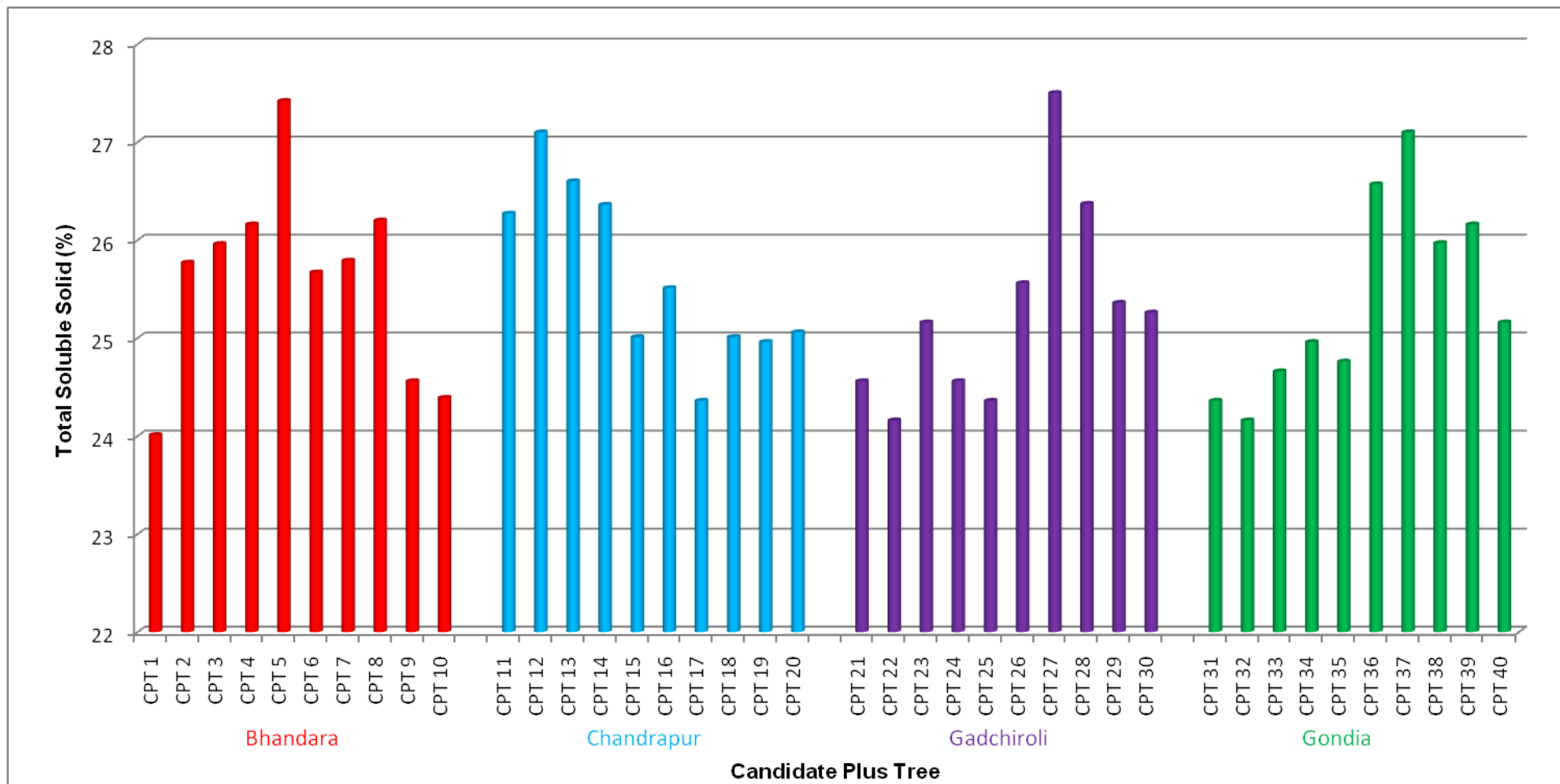
**Fig. 6 Variation in moisture content of fruit (%) among 40 CPT's of *Madhuca indica***



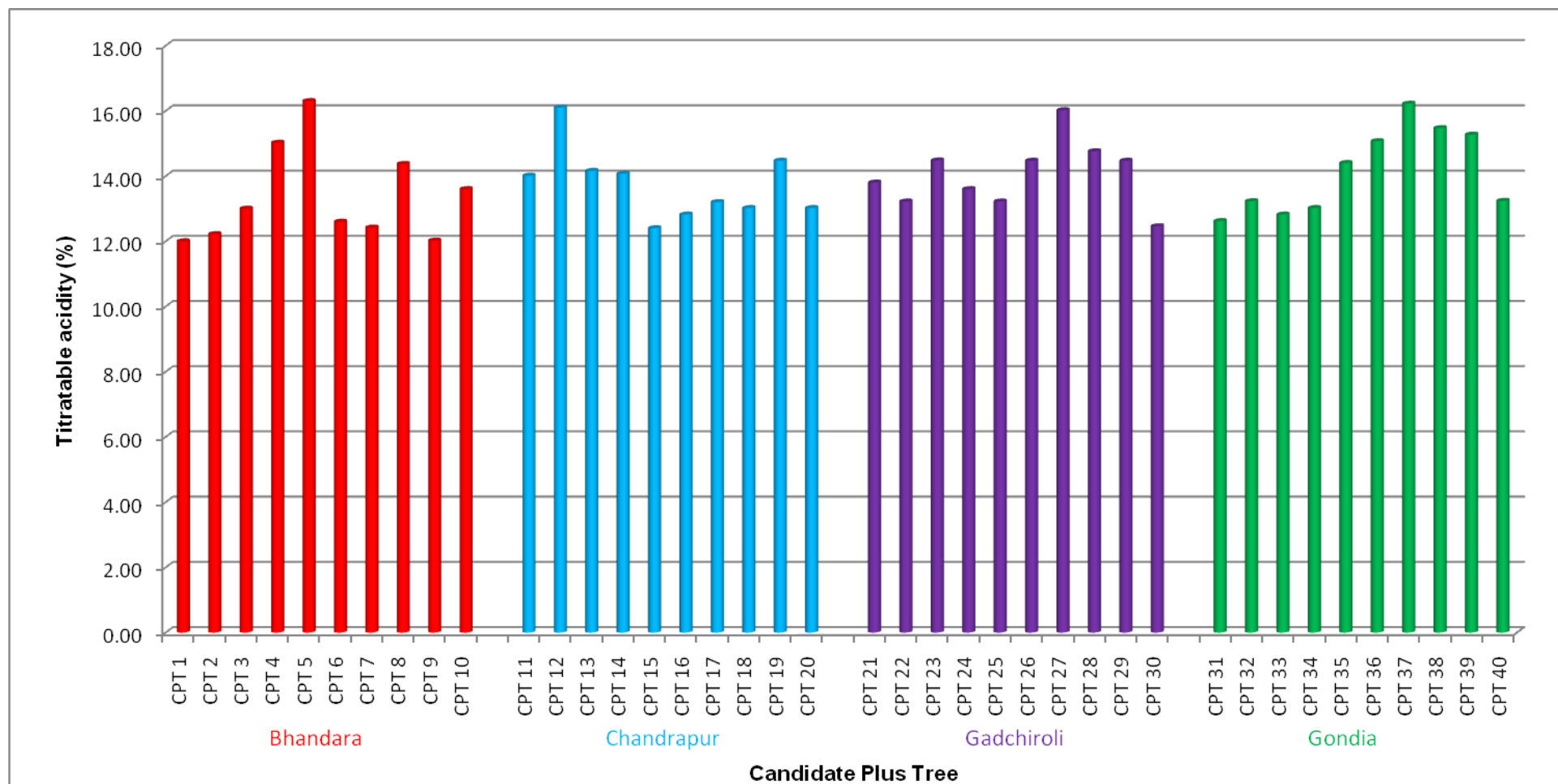
**Fig. 7 Variation in weight of 100 seed (g) among 40 CPT's of *Madhuca indica***



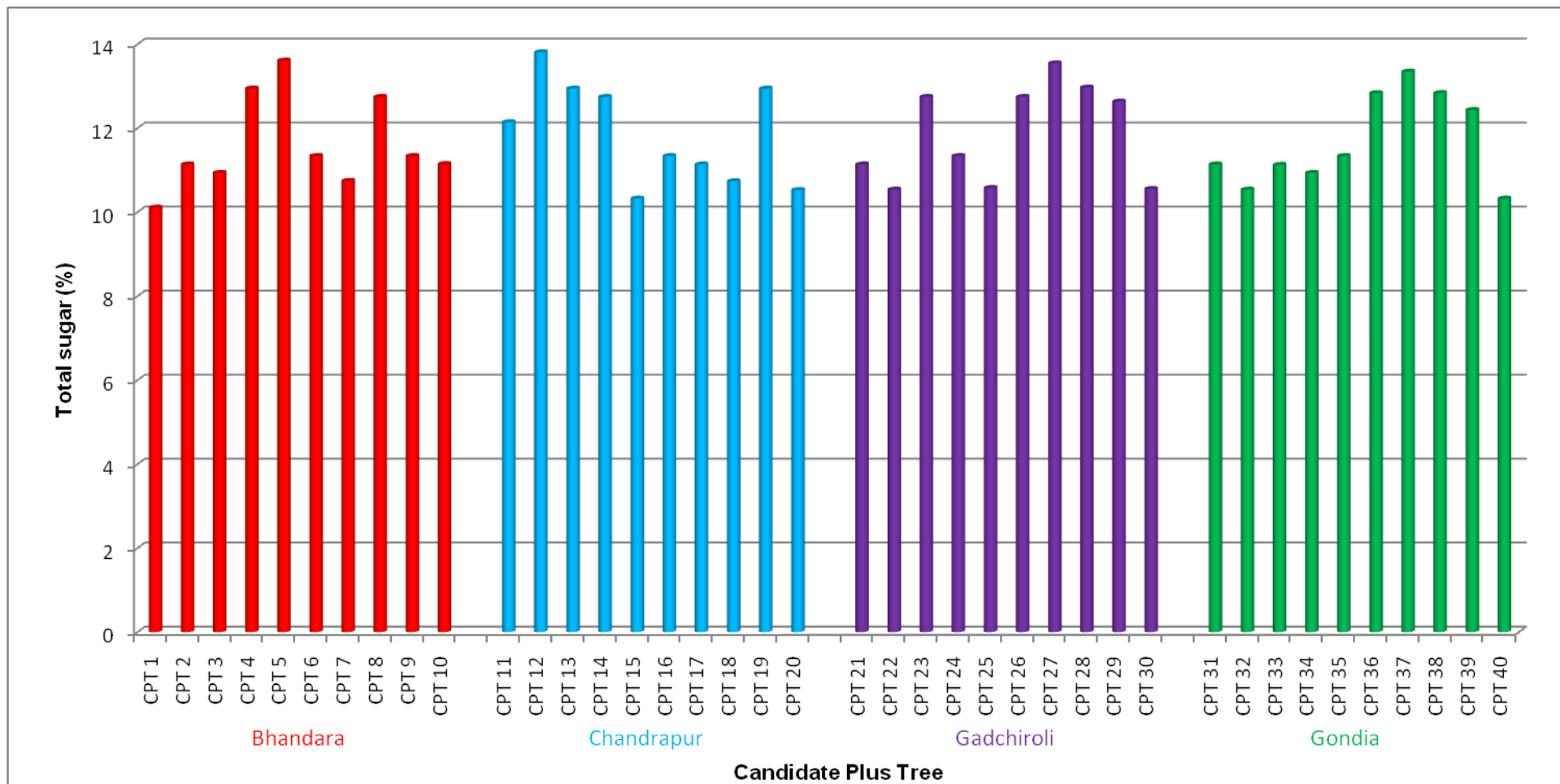
**Fig. 8 Variation in weight of seed kernels (g) among 40 CPT's of *Madhuca indica***



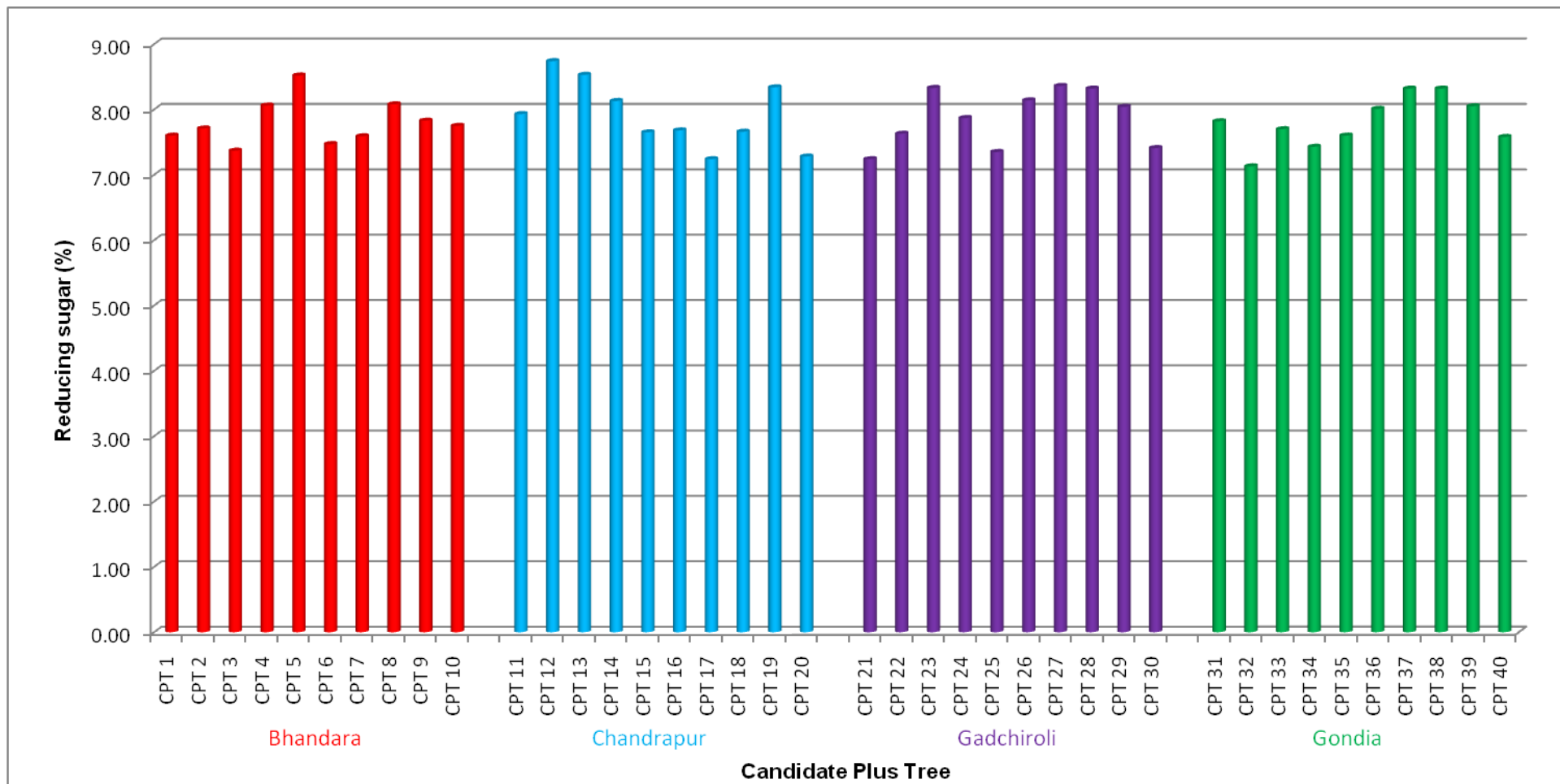
**Fig. 9 Variation in total soluble solid (%) among 40 CPT's of *Madhuca indica***



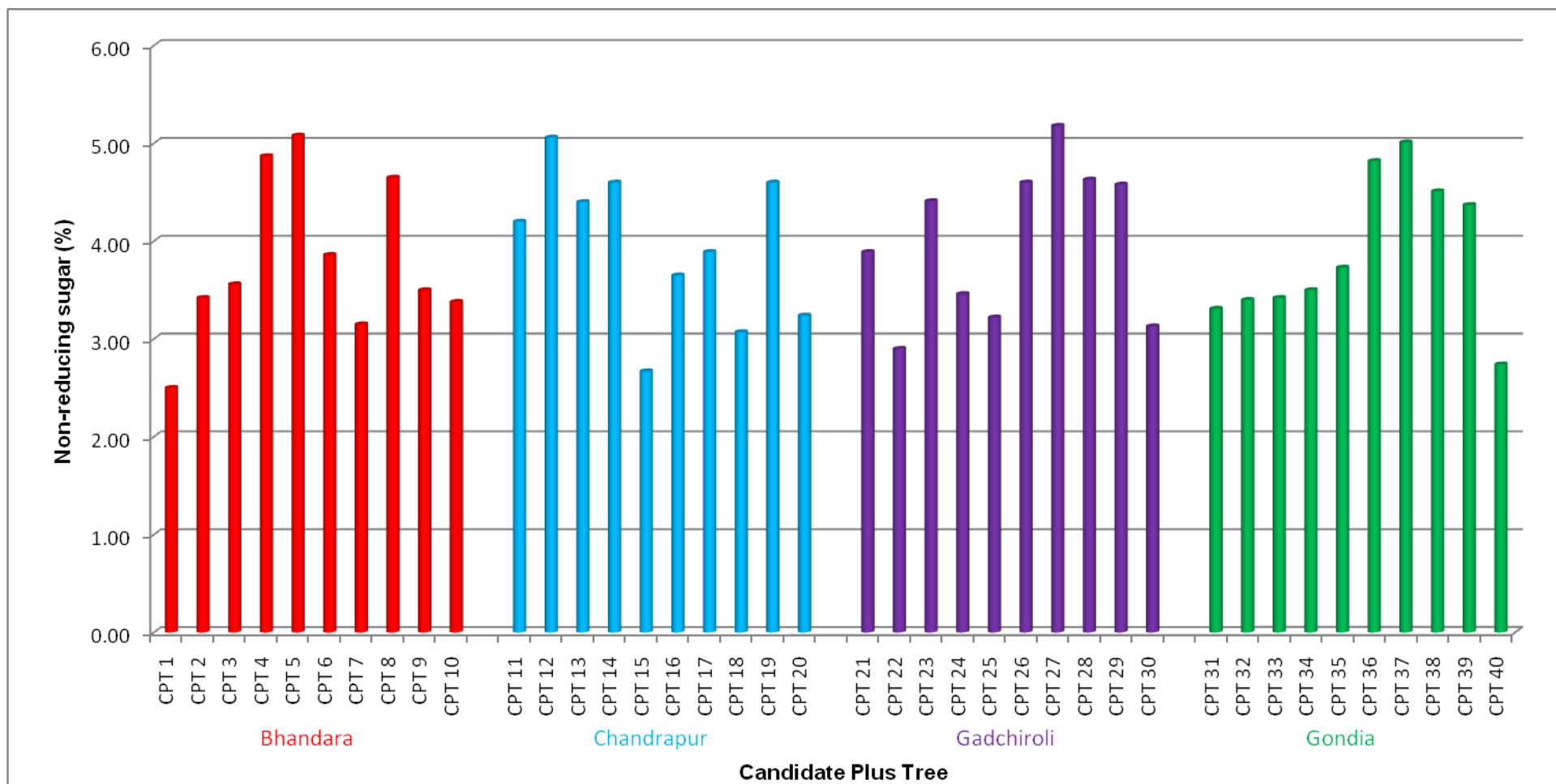
**Fig. 10** Variation in titratable acidity (%) among 40 CPT's of *Madhuca indica*



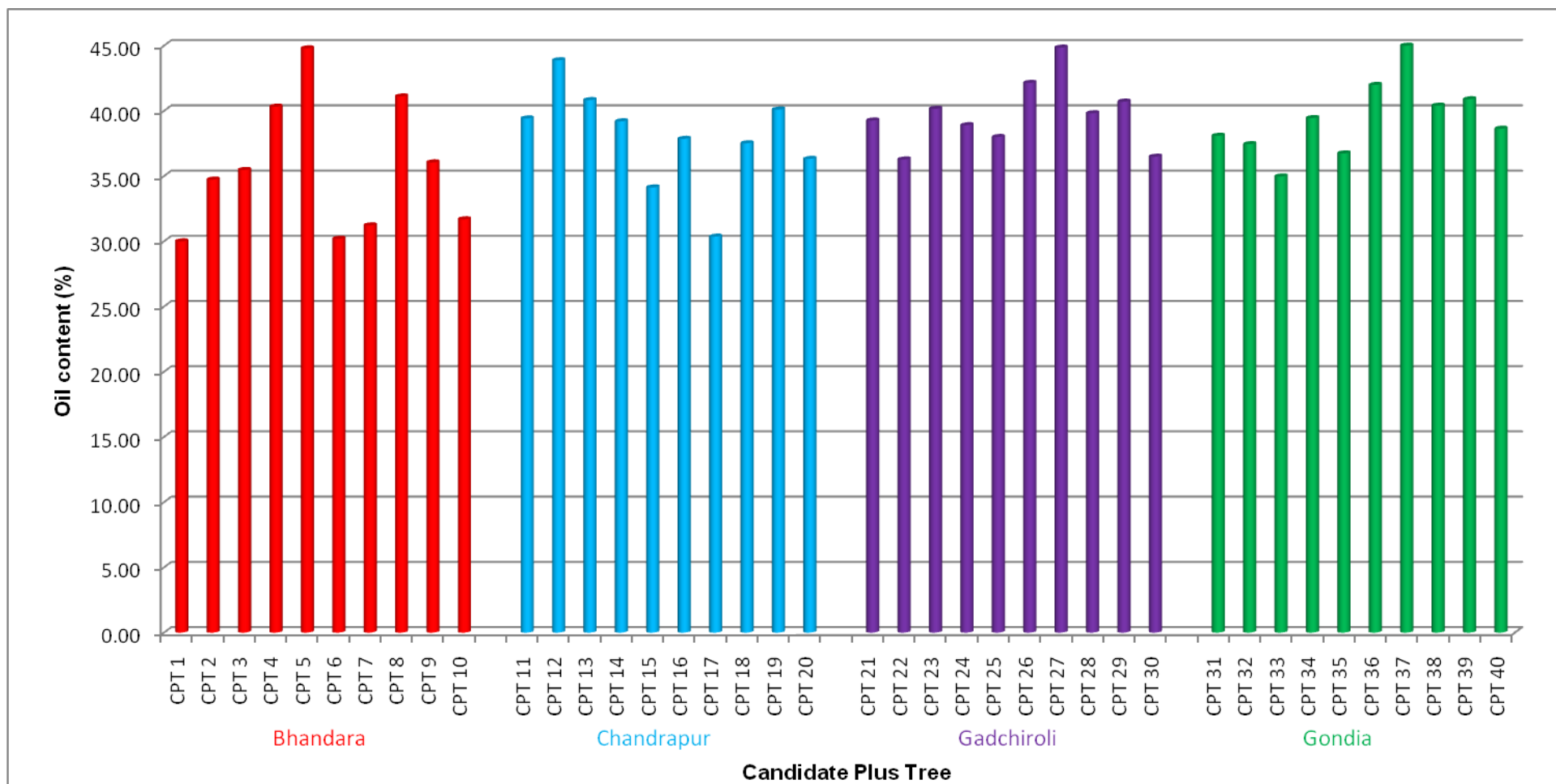
**Fig. 11 Variation in total sugar (%) among 40 CPT's of *Madhuca indica***



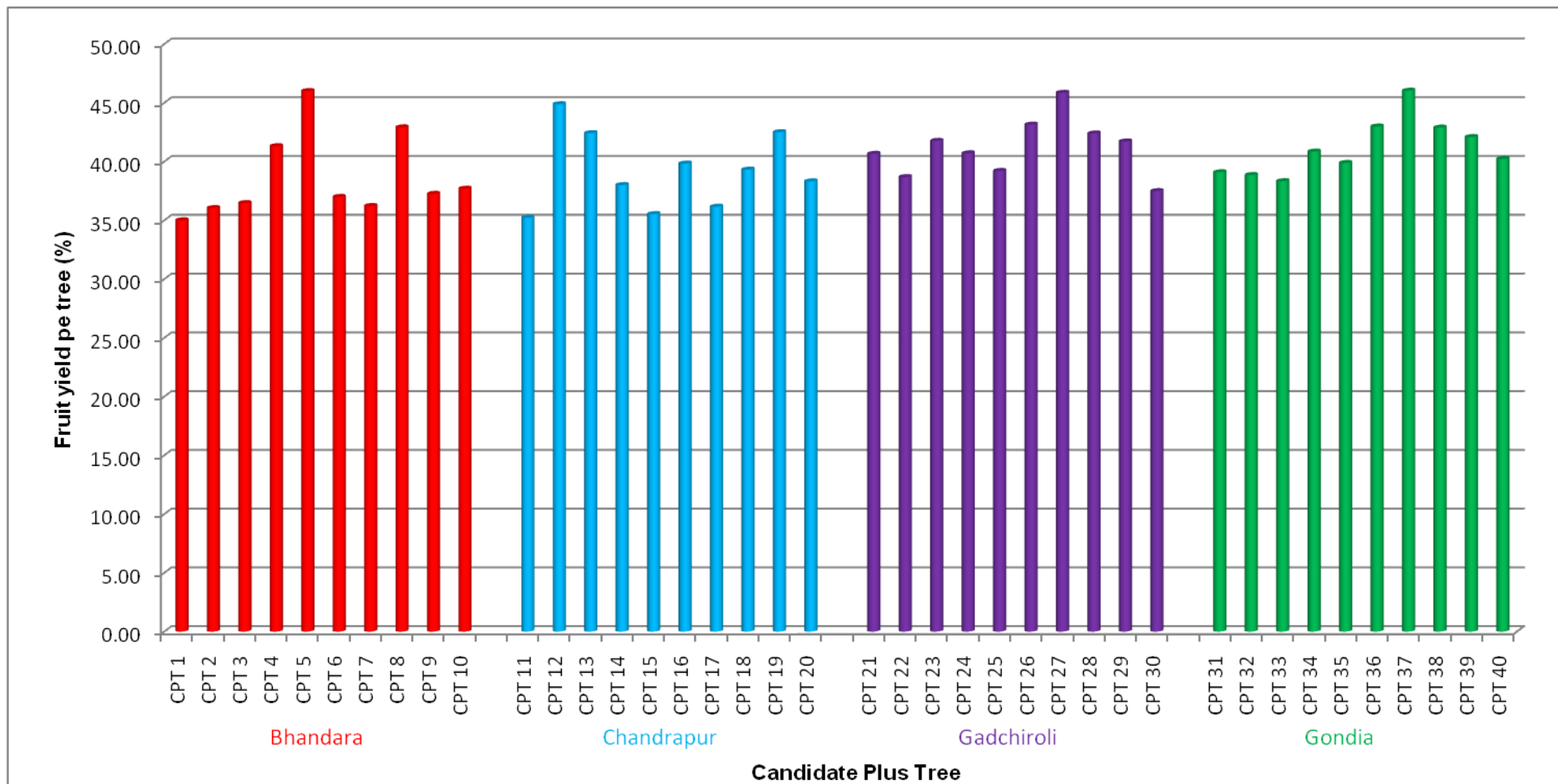
**Fig. 12** Variation in reducing sugar (%) among 40 CPT's of *Madhuca indica*



**Fig. 13** Variation in non-reducing sugar (%) among 40 CPT's of *Madhuca indica*



**Fig. 14 Variation in oil content (%) among 40CPT's of *Madhuca indica***



**Fig. 15 Variation in fruit yield per tree (kg) among 40 CPT's of *Madhuca indica***

#### **4.2.10 Titratable acidity (%)**

The acidity estimates were found in higher magnitude in CPT-5 with value of (16.30 %). CPT-12 (16.10 %) was followed by CPT-5 (16.30 %) and CPT-37 (16.22 %) was at par with CPT-27 (16.02 %). Whereas low acidity was found in CPT-1 with value of (12.00 %).

#### **4.2.11 Total sugar (%)**

The maximum total sugar per cent was found in CPT-12 with value (13.80 %). CPT-27 (13.54 %) was followed by CPT-12 (13.80 %) and CPT-5 (13.60 %) was at par with CPT-37 (13.34 %). However, the minimum total sugar per cent was found in CPT-1 with value (10.10 %).

#### **4.2.12 Reducing sugar (%)**

The maximum reducing sugar per cent was found in CPT-12 with value (10.34 %). CPT-27 (10.02 %) was followed by CPT-12 with value (10.34 %) and CPT-23 (10.12 %) was at par with CPT-26 (9.36 %). However, the minimum reducing sugar per cent was found in CPT-1 with value (6.21 %).

#### **4.2.13 Non reducing sugar (%)**

The maximum non-reducing sugar per cent was found in CPT-40 with value (5.74 %). CPT-39 (5.62 %) was followed by CPT-40 (5.74 %) and CPT-37 (5.66 %) was at par with CPT-5 (5.36 %). However, the minimum non-reducing sugar per cent was found in CPT-15 with value (2.46 %).

#### **4.2.14 Oil content (%)**

The highest oil content per cent was found in CPT-37 of (45.00 %). CPT-5 (44.80 %) was followed by CPT-37 of (45.00 %) and CPT-27 (44.85 %) was at par with CPT-12 (43.88 %). However, the lowest oil content per cent of (30.00 %) was found in CPT-1.

#### **4.2.15 Fruit yield per tree (kg)**

The highest fruit yield was recorded by CPT-37 of (46.03 kg) tree<sup>-1</sup>. CPT-27 (45.85 kg) was followed by CPT-37 (46.03 kg) and CPT-5

(46.00 kg) was at par with CPT-12 (44.88 kg). However, the lowest fruit yield of (35.00 kg) tree<sup>-1</sup> was recorded in CPT-1.

### **4.3 Top five identified superior candidate plus tree**

#### **4.3.1 Weight of fruit (g)**

Weight of fruit was recorded in CPT-27 (Indala, Gadchiroli) which was highest (19.01 g) was closely followed by CPT-37 (Kaneri, Gondia) (18.99 g), CPT-12 (Sonapur, Chandrapur) (18.94 g), CPT-5 (Pimpalgaon, Bandara) (18.71 g), CPT-39 (Silezari, Gondia) (18.08 g) show in (Table No. 4)

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

The highest length of fruit was recorded in CPT-27 (Indala, Gadchiroli) and CPT-37 (Kaneri, Gondia) (6.52 cm) was followed by CPT-39 (Silezari, Gondia) (6.37 cm), CPT-38 (Kaneri, Gondia) (6.13 cm) and CPT-15 (Rajoli chak, Chandrapur) (5.95 cm).

#### **4.3.3 Weight of 100 seed (g)**

The highest weight of 100 seed was found in CPT-37 (Kaneri, Gondia) (270.26 g) was followed by CPT-5 (Pimpalgaon, Bandara) (270.00 g), CPT-27 (Indala, Gadchiroli) (266.05 g), CPT-12 (Sonapur, Chandrapur) (265.66 g) and CPT-4 (Walmazari, Bhandara) (252.94 g).

#### **4.3.4 Weight of seed kernels (g)**

The highest weight of seed kernels was recorded in CPT-15 (Rajolichak, Chandrapur) (6.29 g) was followed by CPT-36 (Koylari, Gondia) (6.00 g), CPT-5 (Pimpalgaon, Bhandara) (5.90), CPT-27 (Indala, Gadchiroli) (5.84 g) and CPT-35 (Koylari, Gondia) (5.82 g).

**Table No. 4: Top five identified superior candidate plus trees**

Sr. No.	Weight of fruit (g)		Length of fruit (cm)		Weight of 100 seed (g)		Weight of seeds kernels (g)		Oil content (%)		Fruit yield per tree (kg)	
1	CPT 5 Pimpalgaon Bhandara	18.71	CPT 15 Rajolichak Chandrapur	5.95	CPT 4 Walmazari Bhandra	252.94	CPT 5 Pimpalgaon Bhandara	5.90	CPT 5 Pimpalgaon Bhandara	44.80	CPT 5 Pimpalgaon Bhandara	46.00
2	CPT 12 Sonapur Chandrapur	18.94	CPT 27 Indala Gadchiroli	6.52	CPT 5 Pimpalgaon Bhandara	270.00	CPT 15 Rajolichak Chandrapur	6.29	CPT 26 Ghot Gadchiroli	42.15	CPT 12 Sonapur Chandrapur	44.88
3	CPT 27 Indala Gadchiroli	19.01	CPT 37 Kaneri Gondia	6.52	CPT 12 Sonapur Chandrapur	265.66	CPT 27 Indala Gadchiroli	5.84	CPT 27 Indala Gadchiroli	44.85	CPT 26 Ghot Gadchiroli	43.15
4	CPT 37 Kaneri Gondia	18.99	CPT 38 Kaneri Gondia	6.13	CPT 27 Indala Gadchiroli	266.05	CPT 35 Koylari Gondia	5.82	CPT 36 Koylari Gondia	41.99	CPT 27 Indala Gadchiroli	45.85
5	CPT 39 Silezari Gondia	18.08	CPT 39 Silezari Gondia	6.37	CPT 37 Kaneri Gondia	270.26	CPT 36 Koylari Gondia	6.00	CPT 37 Kaneri Gondia	45.00	CPT 37 Kaneri Gondia	46.03

#### **4.3.5 Oil content (%)**

The highest oil content was recorded in CPT-37 (Kaneri, Gondia) (45.00 %) was followed by CPT-27 (Indala, Gadchiroli) (44.85 %), CPT-5 (Pimpalgaon, Bhandara) (44.80 %), CPT-26 (Ghot, Gadchiroli) (42.15 %) and CPT-36 (Koylari, Gondia) (41.99 %).

#### **4.3.6 Fruit yield per tree (kg)**

The highest fruit yield per tree was recorded in CPT-37 (Kaneri, Gondia) (46.03 kg) was followed by CPT-5 (Pimpalgaon, Bhandara) (46.00 kg), CPT-27 (Indala, Gadchiroli) (45.85 kg), CPT-12 (Sonapur, Chandrapur) (44.88 kg) and CPT-26 (Ghot, Gadchiroli) (43.15 kg).

### **4.4 Variability parameters studies for its natural habitat**

The variability parameters like genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV), heritability estimates in broad sense ( $h^2$ ) and expected genetic advance (EGA) were estimated for all the characters under study. The results obtained are presented in table 5.

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

It is revealed from Table (5) that genotypic coefficient of variation for different characters ranged from 6.25 per cent (fruit yield per tree) to 28.36 per cent (diameter of fruit). The estimates of genotypic coefficient of variation were recorded slightly high for length of fruit 24.68 per cent followed by weight of seed kernel 19.14 per cent. Whereas the magnitude of genotypic coefficient of variation was comparatively moderate for weight of 100 seed 18.83 per cent and low for oil content per cent and fruit yield per tree 6.25 per cent.

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

It can be revealed from Table (5) that phenotypic coefficient of variation for different characters ranged from 11.65 per cent (fruit yield per tree) to 31.92 per cent (non-reducing sugar). The estimates of phenotypic coefficient of variation were recorded slightly high for

**Table No. 5: Estimation of Mean, Range, GCV, PCV, Heritability and Genetic advance in natural habitat**

Sr. No.	Character	Mean	Range		Genotypic coefficient of variation (GCV) %	Phenotypic coefficient of variation (PCV) %	Heritability estimates (h <sup>2</sup> ) %	Expected genetic advance as % over mean
			Min	Max				
1	Weight of fruit (g)	15.35	10.02	19.01	15.98	18.90	91	19.63
2	Diameter of fruit (g)	3.28	2.02	4.95	28.36	28.99	95	35.16
3	Length of fruit (cm)	4.40	3.02	6.52	24.68	25.30	95	26.58
4	Weight of fruit pulp (mg)	11.59	9.14	16.85	17.23	21.50	84	41.89
5	Weight of dry fruit (g)	5.71	3.52	7.15	17.36	21.13	87	27.49
6	Moisture content of fruit (%)	62.82	57.66	65.61	12.69	25.19	88	63.54
7	Weight of 100 seed (g)	204.26	155.62	270.26	18.83	22.52	98	27.55
8	Weight of seed kernel (g)	4.64	3.15	6.29	19.14	22.98	96	6.17
9	TSS (%)	25.47	24.01	27.50	12.98	15.89	91	26.26
10	Acidity (%)	13.82	12.00	16.30	17.55	19.59	89	25.11
11	Total sugar (%)	11.75	10.10	13.80	11.82	13.95	86	12.81
12	Reducing sugar (%)	7.84	7.13	11.85	13.89	18.68	82	18.13
13	Non-reducing sugar (%)	3.90	2.03	6.95	14.57	31.92	88	34.44
14	Oil content (%)	38.13	30.00	45.00	9.08	14.06	96	42.74
15	Fruit yield per tree (kg)	40.02	35.00	46.03	6.25	11.65	87	42.79

diameter of fruit 28.99 per cent followed by length of fruit 25.30 per cent. Whereas moderate for weight of seed kernel 22.98 per cent. Phenotypic coefficient of variation was comparatively less for fruit yield per tree 11.65 per cent.

#### **4.4.3 Heritability estimates in broad sense ( $h^2$ )**

The heritability estimates were found higher in (98 %) weight of 100 seed, followed by weight of seed kernel (96 %), oil content (96 %) and diameter of fruit (95 %), length of fruit (95 %) whereas low heritability was observed in traits like weight of fruit (91 %), total soluble solid (91 %), titratable acidity (89 %), moisture content of fruit (88 %), non-reducing sugar (88 %), weight of dry fruit (87 %), fruit yield per tree (87 %), total sugar (86 %), weight of fruit pulp (84 %) and reducing sugar (82 %).

#### **4.4.4 Expected genetic advance**

The expected genetic advance (EGA) as per cent over mean is estimated for different characters ranged from 6.17 per cent (weight of seed kernel) to 63.54 per cent (moisture content of fruit) were shown in table 5. Slightly Higher estimates of genetic advance were recorded for fruit yield per tree (42.79 %), oil content (42.74 %), weight of fruit pulp (41.89 %), diameter of fruit (35.16 %), non-reducing sugar (34.44 %), weight of 100 seed (27.55 %), weight of dry fruit (27.49 %), length of fruit (26.58 %), total soluble solid (26.26 %), titratable acidity (25.11 %), weight of fruit (19.63 %), reducing sugar (18.13 %) and total sugar (12.81 %).

#### **4.5 Analysis of variance**

The analysis of variance was in table 6 variation for the character weight of fruit, diameter of fruit, length of fruit, weight of fruit pulp, weight of dry fruit, weight of 100 seed, weight of seed kernel, total soluble solid, titratable acidity, total sugar, reducing sugar, non-reducing sugar, oil content and fruit yield per tree was observed to be significant at 1 % level of significance and moisture content of fruit was observe to be significant at 5 % level of significant it indicating sustainable genetic variability for all the characters except moisture content of fruit among the selected CPT's.

**Table No. 6: Analysis of variance for fifteen physio-chemical characters**

Source of variation	Degree of freedom	Weight of fruit (g)	Fruit diameter (cm)	Fruit length (cm)	Weight of fruit pulp (mg)	Weight of dry fruit (g)	Moisture content (%)	Weight of 100 seed (g)	Weight of kernel (g)	TSS (%)	Titrateable acidity (%)	Total sugar (%)	Reducing sugar (%)	Non reducing sugar (%)	Oil content (%)	Fruit yield per tree (kg)
<b>Replication</b>	4	2.807	0.012	0.061	5.634	0.741	4.909	1867.59	0.679	3.799	1.160	1.405	0.542	1.120	5.273	34.267
<b>Treatment</b>	39	32.53**	4.38**	5.96**	22.19**	5.40**	15.22*	8038.11**	4.31**	4.56**	7.39**	6.07**	0.83**	2.85**	76.76**	46.86**
<b>Error</b>	156	2.406	0.039	0.06	2.225	0.474	9.53	635.934	0.349	1.677	1.941	1.843	0.371	1.231	16.781	15.496

\* Significant at 5 %

\*\*Significant at 1 %

## **4.6 Correlation study**

Correlation studies have been too established to know the relationship between different studies traits, so that the suitable traits can be used for indirect selection for further studies. The selection for one or more traits may results in correlated response for several other traits. With this intention simple correlation coefficient was workout among all physio-chemical character show in table-7.

Perusal of Table-7 revealed that the genotypic correlations were found significant for most of the character combinations studied, thereby suggesting the strong association of the character at genotypic level.

### **4.6.1 Weight of fruit (g)**

Weight of fruit exhibited positive and highly significant correlation with diameter of fruit, length of fruit, weight of fruit pulp, weight of dry fruit, moisture content of fruit, weight of 100 seed, weight of seed kernels, total soluble solid, titratable acidity, total sugar, reducing sugar, non-reducing sugar, oil content and fruit yield per tree.

### **4.6.2 Diameter of fruit (cm)**

Diameter of fruit have positive and highly significant correlation with length of fruit, weight of fruit pulp, weight of dry fruit, moisture content of fruit, weight of 100 seed, weight of seed kernels, total soluble solid, titratable acidity, total sugar, reducing sugar, non-reducing sugar, oil content and fruit yield per tree.

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

Length of fruit has positive and highly significant correlation with weight of fruit pulp, weight of dry fruit, moisture content of fruit, weight of 100 seed, weight of seed kernels, total soluble solid, titratable acidity, total sugar, reducing sugar, non-reducing sugar, oil content and fruit yield per tree.

**Table No. 7: Genotypic and phenotypic correlation coefficient**

Sr. No.	Character		Weight of fruit (g)	Diameter of fruit (cm)	Length of fruit (cm)	Weight of fruit pulp (mg)	Weight of dry fruit (g)	Moisture content (%)	Weight of 100 seed (g)	Weight of seed kernels (g)	Total soluble solid (%)	Titrateable acidity (%)	Total sugar (%)	Reducing sugar (%)	Non-reducing sugar (%)	Oil content (%)	Fruit yield per tree (kg)
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Weight of fruit (g)	G		0.518**	0.564**	0.705**	0.988**	0.439**	0.702**	0.346**	0.780**	0.856**	0.889**	0.589**	0.405**	0.736**	0.840**
		P		0.424**	0.465**	0.482**	0.893**	0.032	0.510**	0.235**	0.326**	0.391**	0.376**	0.316**	0.205**	0.413**	0.325**
2	Diameter of fruit (cm)	G			0.968**	0.678**	0.580**	0.540**	0.701**	0.611**	0.830**	0.715**	0.775**	0.426**	0.491**	0.545**	0.637**
		P			0.956**	0.521**	0.459**	0.179*	0.547**	0.486**	0.428**	0.416**	0.446**	0.304**	0.356**	0.340**	0.321**
3	Length of fruit (cm)	G				0.710**	0.620**	0.532**	0.694**	0.629**	0.867**	0.802**	0.807**	0.457**	0.515**	0.605**	0.721**
		P				0.557**	0.488**	0.163*	0.545**	0.495**	0.440**	0.460**	0.473**	0.334**	0.371**	0.378**	0.359**
4	Weight of fruit pulp (mg)	G				0.707**	0.334**	0.855**	0.539**	0.546**	0.641**	0.410**	0.410**	0.662**	0.404**	0.875**	0.894**
		P					0.478**	0.128	0.627**	0.309**	0.459**	0.408**	0.476**	0.359**	0.268**	0.386**	0.363**
5	Weight of dry fruit (g)	G						0.591**	0.733**	0.343**	0.743**	0.900**	0.913**	0.564**	0.460**	0.779**	0.878**
		P						0.444**	0.514**	0.263**	0.322**	0.387**	0.422**	0.318**	0.267**	0.417**	0.351**
6	Moisture content (%)	G							0.472**	0.049	0.060	0.687**	0.517**	0.082	0.518**	0.568**	0.671**
		P							0.117	0.036	0.065	0.029	0.194**	0.087	0.202**	0.105	0.112
7	Weight of 100 seed (g)	G								0.652**	0.962**	0.958**	0.205**	0.796**	0.326**	0.881**	0.901**
		P								0.463**	0.426**	0.445**	0.531**	0.470**	0.190**	0.469**	0.382**
8	Weight of seed kernels (g)	G									0.762**	0.682**	0.714**	0.459**	0.214**	0.517**	0.585**
		P									0.313**	0.357**	0.280**	0.230**	0.094	0.299**	0.301**
9	Total soluble solid (%)	G										0.244**	0.190**	0.666**	0.614**	0.894**	0.872**
		P										0.323**	0.336**	0.216**	0.254**	0.327**	0.309**
10	Titrateable acidity (%)	G											0.257**	0.806**	0.513**	0.664**	0.243**
		P											0.386**	0.229**	0.255**	0.441**	0.407**
11	Total sugar (%)	G												0.692**	0.327**	0.262**	0.211**
		P												0.742**	0.509**	0.352**	0.302**
12	Reducing sugar (%)	G													0.384**	0.678**	0.785**
		P													0.108	0.253**	0.230**
13	Non-reducing sugar (%)	G														0.460**	0.472**
		P														0.227**	0.183**
14	Oil content (%)	G															0.996**
		P															0.740**
15	Fruit yield per tree (kg)	G															
		P															

\* Significant at 5 %

\*\*Significant at 1 %

#### **4.6.5 Weight of dry fruit (g)**

Weight of dry fruit revealed positive and highly significant correlation with moisture content of fruit, weight of 100 seed , weight of seed kernels, total soluble solid, titratable acidity, total sugar, reducing sugar, non-reducing sugar, oil content and fruit yield per tree.

#### **4.6.6 Moisture content of fruit (%)**

Moisture content of fruit revealed positive and highly significant correlation with weight of 100 seed, weight of seed kernels, total soluble solid, titratable acidity, total sugar, reducing sugar, non-reducing sugar, oil content and fruit yield per tree.

#### **4.6.7 Weight of 100 seed (g)**

Weight of 100 seed has positive and highly significant correlation with weight of seed kernels, total soluble solid, titratable acidity, total sugar, reducing sugar, non-reducing sugar, oil content and fruit yield per tree.

#### **4.6.8 Weight of seed kernels (g)**

Weight of seed kernels has positive and highly significant correlation with total soluble solid, titratable acidity, total sugar, reducing sugar, non-reducing sugar, oil content and fruit yield per tree.

#### **4.6.9 Total soluble solid (%)**

Total soluble solid has positive and highly significant correlation with titratable acidity, total sugar, reducing sugar, non-reducing sugar, oil content and fruit yield per tree.

#### **4.6.10 Titratable acidity (%)**

Titratable acidity has positive and highly significant correlation with total sugar, reducing sugar, non-reducing sugar, oil content and fruit yield per tree.

#### **4.6.11 Total sugar (%)**

Total sugar has positive and highly significant correlation with reducing sugar, non-reducing sugar, oil content and fruit yield per tree.

#### **4.6.12 Reducing sugar (%)**

Reducing sugar has positive and highly significant with non-reducing sugar, oil content and fruit yield per tree.

#### **4.6.13 Non-reducing sugar (%)**

Non-reducing sugar has positive and highly significant correlation with oil content and fruit yield per tree.

#### **4.6.14 Oil content (%)**

Oil content has positive and highly significant correlation with fruit yield per tree.

### **B. Discussion**

The present investigation was “Genetic variability studies in candidate plus tree of *Madhuca indica* Roxb. in eastern vidarbha region of Maharashtra”, was undertaken on forty CPT's of *Madhuca indica* with objectives. To identify the candidate plus tree of *Madhuca indica* in vidarbha region of Maharashtra state. To estimate the genetic variability in candidate plus tree for morphological characters of trees and physio-chemical characters of fruits. To study the correlation of fruit parameters of candidate plus tree.

In a tree improvement programmed the success of selection depends on genetic variability and correlation studies between the characters in the population. The genetic variability estimated in terms of genotypic coefficient of variation and phenotypic coefficients of variation are not adequate for the estimation of heritable variation. The heritability values in broad sense are also helpful in selection on the basis of phenotypic performance of the physio-chemical characters of fruit.

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

The correlation studies provided information on nature, extend and direction of selection, but still it becomes difficult to find out the direct and indirect effect on the components.

Considering this and ultimate aim exploiting all the possibilities for the improvement of the various character studies, the results obtained in the present investigation are discussed here.

#### **4.6 Morphological characters**

Morphological characters reveal variation in all the characters. The morphological was recorded during the investigation.

The average age was 36.27 year and ranged from 33 to 39 years. The average height was 10.85 m and ranged from 8.03 to 13.75 m. The average canopy diameter was 7.38 m and ranged from 4.09 to 9.25 m. The average diameter at base was 29.33 cm and ranged from 26.54 to 30.72 cm. The average diameter at breast height was 26.19 and ranged from 23.06 to 28.39 cm. The average girth at base was 92.13 and ranged from 83.35 to 98.76 cm. The average girth at breast height was 82.26 and ranged from 72.43 to 89.16 cm.

Bangarva *et al.* (2002) conducted an intensive survey in Northern India and southwestern region of Nepal to select plus trees of Shisham (*Dalbergia sissoo*) and selected 63 plus trees on the basis of height, diameter, clear bole, (without forking), stem straightness, low branch angle, resistant to pest and diseases. Further, he has mentioned that progenies showed variation for growth characteristics and stem form. Similar kind of work has already been done in many tropical trees, same result were recorded by Mishra (2008) tree height and basal girth in candidate plus tree in *Jatropha curcas*, by Kotwal (2008) made an attempt to identify various external characters in teak and to quantify them in selection of plus trees to raise clonal seed orchards for producing quality seeds. Navhale *et al.* (2011) selected forty genotypes of *Chebulic myrobalan* from the nearby Dapoli region for the study of variability. These genotypes were studied for six morphological characters of trees and twelve physical parameters of fruits. The analysis of variance revealed significant variation among the genotypes for all characters. On the basis of different characters trees were selected as CPT's of this species.

#### 4.7 Physio-chemical characters

The average weight of fruit was 15.35 g and ranged from 10.02 g to 19.01 g. The average diameter of fruit was 3.28 cm and ranged from 2.02 cm to 4.95 cm. The average length of fruit was 4.40 cm and ranged from 3.02 cm to 6.52 cm. The average weight of fruit pulp was 11.59 mg and ranged from 9.14 mg to 16.85 mg. The average weight of dry fruit was 5.71 g and ranged from 3.52 g to 7.15 g. The average moisture content per cent was 62.82 % and ranged from 57.66 % to 65.61 %. The average weight of 100 seed was 204.26 g and ranged from 155.62 g to 270.26 g. The average weight of seed kernel was 4.64 g and ranged from 3.15 g to 6.29 g. The average total soluble solid per cent was 25.47 % and ranged from 24.01 % to 27.50 %. The average titratable acidity per cent was 13.82 % and ranged from 12.00 % to 16.30 %. The average total sugar per cent was 11.75 % and ranged from 10.10 % to 13.80 %. The average reducing sugar per cent was 7.84 % and ranged from 7.13 % to 8.74 %. The average non-reducing sugar per cent was 3.90 % and ranged from 2.50 % to 5.18 %. The average oil content per cent was 38.13 % and ranged from 30.00 % to 45.00 %. The average fruit yield per tree was 40.02 kg and ranged from 35.00 kg to 46.03 kg.

Similar findings were recorded for the character by Sharma *et al.* (1994) for weight of fruit, by Shrivastava *et al.* (2001) for fruit diameter and fruit length, by Jenner *et al.* (2003) for hundred seed weight, by Mishra (2008) fruit yield and oil content in candidate plus tree in *Jatropha curcas*.

During the present study efforts have been made to attempt preliminary characterization of fruits of the collected germplasm for important qualitative and quantitative character. For morphological characterization minimum descriptors developed by Bioversity International were used. Descriptor is a standardized set of traits, described in plain English that encompasses the whole range of variation for a specific, usually qualitative, and highly heritable trait. IPGRI (now known as Bioversity International) has been a pioneer in developing descriptors for many tropical fruits. However, among different species of *Madhuca indica*, today descriptors are available only for *Madhuca longifolia*, Adopting the

same descriptors, an attempt has been made to develop a set of descriptors for fruit traits of *Madhuca indica* and use the same to characterize different morpho-types. The strength of the descriptor for any species lays its ability to delineate genotypes without redundancy. It is shown in the present study that all the morpho-types of *Madhuca indica* fruits vary with respect to weight, diameter, length, dry fruit weight, pulp weight, seed weight, kernel weight, moisture content, yield and chemical properties like total soluble solid, titratable acidity, total sugar, reducing sugar, non-reducing sugar and oil content. In recent study from Maharashtra, Navhale *et al.* (2011) reported that the forty genotypes of *Chebulic myrobalan* were selected from the nearby Dapoli region for the study of variability. The maximum range of variability observed for morphological characters viz., diameter at base, diameter at breast, girth at base and girth at breast. The estimates of genotypic mean sum of squares indicated comparatively wide range of variation for the characters moisture per cent, TSS and weight of fresh fruits. The estimates of phenotypic variances were found higher than the genotypic variances for most of the characters indicating that these characters were influenced by the environmental factors. The heritability was high for total soluble solids followed by weight of dry fruit, weight of fruit pulp, total sugars and acidity per cent. The genetic advance as per cent of mean was highest for non-reducing sugar followed by weight of fruit pulp, weight of dry fruit, weight of seed and acidity per cent. For selection of candidate plus trees, preference was given to the physical parameters like non reducing sugar per cent, weight of fresh fruit, weight of seed, weight of fruit pulp, moisture per cent and weight of dry fruit as these characters were under genotypic control.

#### **4.8 Top five identified superior candidate plus trees**

Top five candidate plus trees from total forty candidate plus tree were selected in four identified population using standard criteria in weight of fruit, length of fruit, weight 100 seed, weight of seed kernels, oil content and fruit yield per tree characters.

Similar result was found by Pravin *et al.* (2011).

#### 4.9 Genetic variability studies

The characters weight of 100 seed, weight of seed kernel, oil content, diameter of fruit, length of fruit, weight of fruit, total soluble solid exhibited high GCV and PCV values indicating large amount of variation. Moderate and low GCV values are noted in the character titratable acidity, moisture content of fruit, non-reducing sugar, weight of dry fruit, fruit yield per tree, total sugar, weight of fruit pulp and reducing sugar which means that extent of genetic variation observed is somewhat less for these characters among the genotypes studies. There was no much difference observed between GCV and PCV values in almost all the characters, indicating less influence of environments. These results were conformity with findings of the earlier workers like Navhale *et al.* (2011) the estimates of genotypic mean sum of squares indicated comparatively wide range of variation for the characters moisture per cent, TSS and weight of fresh fruits. The estimates of phenotypic variances were found higher than the genotypic variances for most of the characters indicating that these characters were influenced by the environmental factors. The heritability was high for total soluble solids followed by weight of dry fruit, weight of fruit pulp, total sugars and acidity per cent. The genetic advance as per cent of mean was highest for non-reducing sugar followed by weight of fruit pulp, weight of dry fruit, weight of seed and acidity per cent. For selection of candidate plus trees, preference was given to the physical parameters like non reducing sugar per cent, weight of fresh fruit, weight of seed, weight of fruit pulp, moisture per cent and weight of dry fruit as these characters were under genotypic control, which indicated importance of these characters for selection.

With the genetic coefficient of variation alone, it is difficult to determine the relative amount of heritable and non-heritable components of variations present in the population. Estimates of heritability and genetic advance would supplement these parameters.

The heritability estimates for different characters were found in higher magnitude (98 %) weight of 100 seed, (96%) weight of seed kernel, (96 %) oil content, (95 %) diameter of fruit, (95 %) length of fruit, (91

%) weight of fruit, (91 %) total soluble solid (89 %) acidity, (88 %) moisture content of fruit, (88 %) non-reducing sugar, (87 %) weight of dry fruit, (87 %) fruit yield per tree, (86 %) total sugar, (84 %) weight of fruit pulp whereas low heritability was observed in (82 %) reducing sugar.

The expected genetic advance as per cent over mean is estimated for different characters (63.54 %) moisture content of fruit, (42.79 %) fruit yield per tree, (42.74 %) oil content , (41.89 %) weight of fruit pulp, (35.16 %) diameter of fruit, (34.44 %) non-reducing sugar, (27.55 %) weight of 100 seed, (27.49 %) weight of dry fruit, (26.58 %) length of fruit, (26.26 %) total soluble solid, (25.11 %) acidity, (19.63 %) weight of fruit, (18.13 %) reducing sugar, (12.81 %) reducing sugar whereas low expected genetic advance as per cent over mean was observed in (6.17 %) weight of seed kernel.

Navhale *et al.* (2011) estimates of genotypic mean sum of squares indicated comparatively wide range of variation for the characters moisture per cent, TSS and weight of fresh fruits. The estimates of phenotypic variances were found higher than the genotypic variances for most of the characters indicating that these characters were influenced by the environmental factors. The heritability was high for total soluble solids followed by weight of dry fruit, weight of fruit pulp, total sugars and acidity per cent. The genetic advance as per cent of mean was highest for non-reducing sugar followed by weight of fruit pulp, weight of dry fruit, weight of seed and acidity per cent. For selection of candidate plus trees, preference was given to the physical parameters like non reducing sugar per cent, weight of fresh fruit, weight of seed, weight of fruit pulp, moisture per cent and weight of dry fruit as these characters were under genotypic control, which indicated importance of these characters for selection.

Similar result was found by Niveditha *et al.* (2013).

Generally high heritability accompanied with high genetic advance in a characters suggest that the inheritance of such characters is governed mainly by additive gene effects and therefore selection based on phenotypic performance proved useful. It may be mentioned here that during present study characters like weight of 100 seeds, weight of seed

kernel, oil content, diameter of fruit and length of fruit had heritability values along with high genetic advance, Thus, the expression of these traits is predominantly governed by additive gene effects and therefore selection based on phenotypic performance will be useful to improve these characters in future. Moreover it is seen that these traits have less influence of the environment.

During present study estimates of high heritability along with low genetic advance were observed for the character weight of seed kernel. According to Panse and Sukhatme (1954) when 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 this character.

#### **4.10 Correlation study**

Among all the fruit traits considered, majority showed positive and highly significant association as shown in the Table 7. This may suggest the allometric relations between the fruit traits. Hence weight of fruit could be a good indicator of fruit diameter and other fruit trait; however the fruit yield per tree is a result of pollination success. Further, *Madhuca indica* also reproduces asexually through parthenogenesis. Some of the others did not found non-significant relationship among studied physio-chemical fruit traits. For instant, Rajamma (2012) and Niveditha *et al.* (2013) has reported strong correlation between physio-chemical characters in *Garcinia indica* respectively. Review indicated that this relationship is entirely depends upon the species and their growing condition.

## CHAPTER V

### SUMMARY AND CONCLUSION

The present study on “Genetic variability studies in candidate plus tree of *madhuca indica* Roxb. in eastern vidarbha region of Maharashtra” was undertaken on forty CPT's of *Madhuca indica* from Bhandara, Chandrapur, Gadchiroli, and Gondia districts. This experiment was conducted during the year 2015-2017. The statistical design adopted was Randomized Block Design with five replications.

The morphological observations were recorded on age of tree (yrs), height of tree (m), canopy diameter (m), diameter at base (cm), diameter at breast height (cm), girth at base (cm) and girth at breast height (cm). The highest mean was observed for the characters girth at base (92.13 cm), followed by girth at breast height (82.26 cm). The reciprocal result was found in standard deviation and also change in coefficient of variation with highest recorded in canopy diameter (14.43 m) followed by height of tree (14.27 m).

Top five superior candidate plus trees from total forty candidate plus tree were selected in four identified population using standard criteria in weight of fruit, length of fruit, weight 100 seed, weight of seed kernels, oil content and fruit yield per tree characters.

A greater variation was recorded for fruit yield per tree and weight of 100 seed. Result showed that CPT - 5, CPT - 27 and CPT - 37 recorded to be the best among all. Considering seed oil content, CPT - 27 and CPT - 37 recorded higher oil content. In view of biofuel production, CPT's that provide higher oil content can be marked as probable plus tree for future selections and evaluations.

The highest phenotypic coefficient of variation was observed for the character non-reducing sugar (31.92 %) followed by diameter of fruit (28.99 %).

The character which showed higher genotypic and phenotypic coefficient of variation was non-reducing sugar indicating predominance of

additive gene action in the inheritance of this character revealing like hood of favorable response to selection by this character. In respect of other characters studied presence of low genotypic coefficient of variation as well as phenotypic coefficient of variation indicated predominance of non-additive type of gene action in the inheritance characters.

Heritability estimates (broad sense) for the characters studied were ranged from high degree i.e. 82 to 98 per cent, being highest for the character weight of 100 seed (98 %). 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.

High value of genetic advance for the character under study was recorded for the character moisture content of fruit (63.54 %), followed by fruit yield per tree (42.79 %) and oil content (42.74 %). These result of observed 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 this characters on phenotypic values. High heritability coupled with high genetic advanced observed for moisture content of fruit, fruit yield per tree, and oil content indicated that these characters were governed largely through the additive gene effect and improvement of these characters may be achieved through phenotypic selection.

This correlation amongst the volume attributes indicates that all the characters are positive in direction and they are helpful and advantageous for improvement in *Madhuca indica* tree.

Thus, it is concluded that, selection pressure can be exercised on the genotypes possessing more weight of fruit, length of fruit, weight 100 seed, weight of seed kernels, oil content and fruit yield per tree more will be useful in identifying the genotypes as genotypes for further improvement in *Madhuca indica*. Hence, these characters may be given consideration while making selection for the improvement of *Madhuca indica*.

## CHAPTER VI

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