EFFECTS OF SEED SOURCE, STORAGE CONDITIONS AND DURATION ON GERMINATION, SEEDLING TRAITS AND OIL CONTENT IN *Madhuca latifolia* Macbride IN ODISHA

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EFFECTS OF SEED SOURCE, STORAGE CONDITIONS AND DURATION ON GERMINATION, SEEDLING TRAITS AND OIL CONTENT IN *Madhuca latifolia* Macbride IN ODISHA

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Submitted

In the partial fulfillment of the requirements for the Degree of Doctor of Philosophy in Forestry of Mizoram University , Aizawl

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Certificate

We certify that the thesis entitled "Effects of seed source, storage conditions and duration on germination, seedling traits and oil content in *Madhuca latifolia* Macbride in Odisha" submitted by Shri. Saswat Nayak, for the **Degree of Doctor of Philosophy in Forestry** of Mizoram University, Aizawl embodies the record of original investigation under my supervision. He has duly registered and the thesis presented is worthy of being considered for the award of the Ph. D Degree. The work has not been submitted for any degree of another University.

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DECLARATION

I, Saswat Nayak, hereby declare that the subject matter of this thesis entitled, ***"Effects of seed source, storage conditions and duration on germination, seedling traits and oil content in Madhuca latifolia*** **Macbride** ***in Odisha"*** is the record of work done by me and the contents of the thesis did not form basis for the award of any previous degree to me or anybody else, and that the thesis has not been submitted by me for any research degree in any other University/Institute.

This thesis is being submitted to the Mizoram University for the degree of Doctor of Philosophy in the Department of Forestry.

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CHAPTER-1

GENERAL INTRODUCTION

Madhuca latifolia Macb. commonly known as Mahua tree or Butter tree belonging to the family Sapotaceae is a medium-sized - large deciduous tree, attaining a height of 12-18 m with a medium length straight bole, spreading branches and a large rounded crown. It attains a girth up to 2.4 m with greyish to blackish bark having transverse wrinkles and vertical cracks exfoliating in thin scales . It is widely distributed throughout India from the Punjab eastwards through Uttar Pradesh and Bihar upto West Bengal and occurring widely in the states of Odisha, Maharashtra, Gujarat, Madhya Pradesh and Andhra Pradesh. It is found naturally both in the moist and dry deciduous forests with more commonly in dry mixed deciduous forests, dry sal forests and dry teak forests. It is also cultivated in the plains of Northern and Central India. The non-timber forest products (NTFPs) value of this tree is well known.

Odisha is the second largest state in terms of NTFPs production in India and 37% of its population depend upon it for their day to day requirements (Kandari et al., 2012). In Odisha, nearly 40% of the income of the rural people comes from the collection of forest products (Dash, 2001). Orissa is a state consisting of 30 districts with 3000 plant species including 120 orchid species and 63 varieties of mangrove trees. The diversity of plants under different natural forests and its adjoining areas are the main source of the Non timber forest products widely available in the state. Some major NTFPs of the state includes sal seed, sal leaf, siali leaf , bamboos, mahua flowers, mahua seed, char seeds, sal resin, genduli and salai gum-oleoresin, neem seed, medicinal plans etc. Among these NTFPs, the main produces of *Madhuca latifolia* tree i.e mahua flowers and mahua seeds are widely collected, marketed and utilised.

The tree is normally found in the dry tropical and sub-tropical climate where the absolute maximum shade temperature varies from 28.5° to 48.3°C and the absolute minimum temperature from 1.7 to 11.7°C. The mean daily maximum temperature in May varies from 33.1° to 43.0°C whereas the daily minimum temperature of coldest month in January varies from 8.~ to 166°C. The annual rainfall in its natural habitat varies from 750 to 2000 mm or more and up to an altitude of 1200 m (Behl and Sriwasrawa, 2002). The tree is affected by excessive rainfall and is found on waterlogged or low lying clayey soils. The tree grows on a wide variety of soils from acidic to basic range .It thrives well on sandy soil in the dry mixed deciduous forests. It also found to be grown on dry rocky ground, trap, stiff clays and even on salt-affected kankar soil. However, for its better growth and productivity, well drained, deep loam soil is ideal (Bisht et al. , 2018) .

The leaves are shed gradually from February to April and appears again during April or early May shortly after the flowering. The new leaves are coppery red in colour. Leaves are 10-30 cm long, thick and leathery clustered near the ends of the branches. Most of leaves are hard and firm, ellipticor elliptic-oblong, shortly acuminate, pubesc ent or tomentose whenyoung, at length glabrous, base rounded or acute. Petioles long at first pubescent, ultimately glabrous or nearly so. The stipules are long, subulate, densely pubescent, vary caducous .The leaves exudes milky sap when broken.

The plant flowers during the months of March to May; as the flowering starts, the tree is bereft of leaves (Brandis, 1906). the flowers mature in about 32-35 days. Flowers are small and fleshy, dull or pale white in color and in define fascicles near end of branches. Corolla tubular, freshly pale, yellow aromatic and caduceus (Variers,1995). The flowers are strongly scented, exceedingly attractive to men and animals. Fleshy corollas fall off on the ground soon after opening and covers the ground. At this time, the forests in which these treesfound are heavily scented with characteristic odour of the blooms and are often visited by monkeys, squirrels, birds and honey-bees , however, the rate of seed set is low. The flowering in *Madhuca* is not uniform and varies according to local conditions (Kuruvilla, 1989).. The estimated production of mahua flowers is more than one million tonnes in the country (Patel and Naik , 2010) .

Fruits are 2-6 cm long, fleshy and greenish in colour (CSIR, 2006).The seed setting and fruit setting rates in the tree are very low (Kuruvilla, 1989). Under favourable conditions, trees begin to bear fruits at the age of 8-10 years, but usually they do so in the 10-15th year. As the crowns of the individual trees expand, the yield of seed increases upto about 50th year, after which there is no further increase. Trees as old as 200 to 300 years are seen bearing viable fruit. Average yield of flowers in Palamau (Bihar) has been estimated to be 93 kg per tree on an average. In Uttar Pradesh, fruit production per tree is about 20-50 kg/tree from forest area and upto 1.0 to 2.0 quintals of fruits per tree in cultivated area (Rai, 1983). Good seed years are expected once or twice in every three years corresponding to heavy flowerings . Seed crop is sometimes destroyed by high winds in the flowering stage. Due to high oil content of the seeds, it is prone to high damage by insects. The season for collection of seed is very short and a considerable portion of the crop is lost during the monsoon. The ripe fruits are collected by shaking the branches, the fruits are rubbed and worked to get clean seed. The annual production of mahua seeds is around 1,085,300 quintals per year (Anonymous, 2013) and about 450 seeds weigh a kg . Fresh seed has high germinative capacity, but it is soon lost during storage (Dent. 1948), as it is attacked by fungi and insects.

Madhuca latifolia Macb. known for its multipurpose uses. The Sapwood of the tree is reddish-white to brownish-white in colour where as the heartwood is light to dark red. The specific gravity of wood at 12 moisture content is about 929 kg/m^3. The wood is fine, very strong, tough, hard, durable wood and lasts well under water. It can be used for building purposes as beams, door and window frames, posts etc. It is suitable for heavy work such as bridges, piles, sugar presses, cart wheels, ships, boats, sports goods, furniture etc. the seasoned wood are also suitable for agricultural implements, drums and carving. It is also a good fuelwood with calorific values of sapwood and heartwood being 4890-4978 kcal/kg and 5005-5224 kcal/kg respectively.

The flowers and seeds are used widely by the forest dwellers for their subsistence and income generation by selling it or its processed products in the market.

Flowers of the plant are edible and preparation of sugar syrup from dry Mahua flowers, as its sweet property is utilized in the fermentation process (Banerji et al., 1996, Shriwastaet al., 1970, Patel and Naik, 2010). The sugar syrup used in the manufacturing of chocolate or as a sweetening agent in food products (CSIR, 2006; Abhyankar and Narayana, 1942. Dried mahua flowers are an attractive source of fermented products due to the high sugar content. Preparation of mahua wine from fresh flowers (Yadav et al., 2009) where as various products like alcohol, brandy, acetone, ethanol, lactic acid, citric acid and other fermented products have been prepared from the dry mahua (Fowler et al, 1920). Mahua flowers are rich source of sugar containing vitamins and minerals (Singh and Singh, 2005) and are consumed and cooked in different parts of the country (Wealth of India, 1962). Fresh flowers were used prepare the mahua jam and jelly, puree (after manually removing the stamens) and also processed it into sauce (Patel, 2008). Essential oil is extracted from flowers (0.5%) and the flowers are also fed to live stock. Midya and Brahmachary (1996) reported that the fresh flowers of Mahua fragrance mainly contains 2-acetyl-1-pyrroline (2AP), the compound responsible for pleasant a roma in basmati and other scented rice. It was found that 2AP gets synthesized only i n fleshy corolla of mature flowers (Wakte et al., 2011).

Reports show that approximately 75% of the World's production of oils and fats come from plant sources. Although many plant parts yield oil, in actual commercial practices, oil is extracted primarily from seeds of oilseed plants. Mahua is the largest source of natural fat known as mahua butter extracted from its seeds. The fruits are eaten raw and also cooked. The fruit pulp utilised as source of sugar where as the dry husk used for alcoholic fermentation. Reuther et al.(1967) reported that matured (full grown) but still un-riped fruits are made into jam with addition of citric acid. The pulp is also converted into marmalade or syrup, jelly and pickle which are used as food material. Seeds are good source of fixed oil (Singh et al., 2005) . The mahua seed oil is used for edible purposes and permitted for preparation of vegetable oil . It has linoleic and other unsaturated fatty acids which are good for heart patients as it reduces the blood serum cholesterol. The oil is rich in PUFA and the desirable level of oleic and stearic acid for which it can be used as cocoa substitute in confectionary products and production of margarines, cosmetic and pharmaceutical industries. It is used in manufacturing of soap, lubricating grease, fatty alcohols and candles. The seeds used for preparation of defatted flour mainly for bakery products . Saponins after extraction of oil have industrial and commercial uses where as the cake after extraction of oil used as manures and insecticidal properties. The oil content of the seed ranges from 33% to 43% weight of the kernel. For the tribal people mahua oil is the most important tree seed oils and it is widely used as cooking oil by most of the tribes in Odisha, Chhattisgarh, and Maharashtra etc. 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 (Lakshmikanth et al., 2013).

It is well established that many tree species with a wide range of geographical diversity exhibit physiological, morphological, biochemical and genetic variations as an adaptation to varying environmental condition. Mahua is widely distributed in Odisha in all agroclimatic zones and grows under different forest types showing variation in tree growth, flower yield, flower size , incense and sugar content , seed production potential, seed size, shape, colour, seed weight and oil content . Besides natural forests it is widely grown and managed in the agricultural field bunds , unutilised lands and homesteads and also contributes significantly higher income from flowers and seeds than the natural forests .

Although this species is widely distributed throughout the forests of Odisha and also being protected and conserved by the tribal people due to its potential for their livelihood, food security, and cultural perspective studies have not been carried out regarding identifying the potential sources, pockets or zones with regard to quality and quantity of mahua flower and seed oil content . The present study is related to identification of some important sources and zones in Odisha with higher seed oil yield with good quality for different utilisation purposes. The oil yield from the seeds is always the key factor to decide its suitability for nutritional and industrial purposes from economic point of view (Yadav et al., 2011). As mentioned earlier this plant yields a considerable amount of oil, however, the use of this oil for the food industry has been carried out in a limited scale. In Odisha, the mahua oil is principally used for cooking purposes by local tribal population and also is in very small scale whichconveys that seeds as an under-utilized seed type for the production of oil.Besides food industry, mahua butter and its seed oil is reported to have potential use in biodiesel production (Anon, 2010, Arora and Kumar, 2015). According to the past reports, the under-utility of this fat may probably due to the lack of more technical information regarding this species. Only few works has been carried out in other state than Odisha regarding the seed morphology, oil content, physico-chemical properties and fatty acid profile of mahua oil and the effect of geographical and environmental factors on them (Wani and Ahmad, 2013; Divakara and Das, 2014; Hegde et al., 2017) . It has also been observed that even though many trees are protected, the natural regeneration in the wild and farmland is gradually reducing, probably due to climatic conditions and human interference. Therefore, in order to have proper and better utilisation of mahua seed oil besides its conservation and propagation identifying the sources with higher oil content, oil yield and physico-chemical properties is required by studying the genetic diversity in all agroclimatic zones of the state.

Tropical forests are the most biodiversity rich centre on Earth. Primary forests of Asia, particularly those of the Eastern Ghats and Western Ghats of peninsular India are disappearing at an alarming rate due to anthropogenic activities and are replaced by forests comprising inferior species on their land use pattern changed (Bahuguna, 1999) . Besides this the tropical forests are having higher diversity due to species interaction and niche variation, which is a result of favourable climatic (Ojo and Ola-Adams, 1996) and edaphic conditions. Understanding of vegetation composition, diversity of species and their habitats, and comparison with similar other habitats, may become a tool to estimate the level of adaptation to the environment and their ecological significance. Analysis on floristic composition, diversity and growth pattern are essential in understanding the forest ecosystem dynamics (Gentry, 1990; Hartshorn, 1990).The different tree species growing in a forests are interdependent to a certain extent for their growth, reproduction and establishment irrespective of species. *M. latifolia* is growing naturally in most of the dry deciduous and moist deciduous forest under different agroclimatic zones of Odisha in addition to the agricultural and home steads of rural population residing even up to 8-10 km from forest. Similarly, the flowering, seed setting, seed morphology , ripening, oil content and its properties, regeneration and establishment mahua tree also depends upon the species diversity, overall stand density, density of mahua tree in the forest as their interactions and competitions ultimately affect these morpho-chemical characteristics of seed and flower of a particular genotype.

The species diversity, their growth, reproduction potential, regeneration and establishment of natural forests and also of an individual species growing outside the conventional forest under different agro-forestry systems depends upon pysico-chemical characteristics of the soil (Bhatnagar 1965). It has been reported that growth of *Shorea robusta* (sal) and other tree species, such as *Terminalia alata* and *Syzygium cumini*, in tropical forests are highly influenced by nitrogen, phosphorus, potassium, and soil pH (Bhatnagar 1965). Vegetation also plays an important role in soil formation (Chapman and Reiss 1992). The physico-chemical characteristics of forest soils vary in space and time due to variations in topography, climate, physical weathering processes, vegetation cover, microbial activities, and several other biotic and abiotic variables. Therefore dynamic of soil quality and the vegetation of forest are interdependent. *Madhuca latifoila* found growing in the natural forests and also raised and maintained in the agricultural lands under all agroclimatic zones of Odisha vary with the soil conditions which may be ultimately affecting the growth, seed quality and production , oil content with its physico-chemical properties, regeneration and establishment .

The diversity a given species is very important for its adaption to the changing environmental conditions and to cope up with biotic and abiotic stresses, etc. (Gienapp et al. 2008). Studying this variation may be help to identify the trees with high oil content, oil yield and physico-chemical properties which suits for different industrial applications. So, the aim of present study was to identify the high oil yielding seed sources and analyse the variation in seed morphology ,seed oil content and its physico-chemical properties of all ten agroclimatic zones of Odisha along with determining the relationship between those characteristics with edaphic, climatic and ecological parameters of the zones.

The seeds of *Madhuca latifolia* are generally known short-lived as it needs high moisture content to retain is viability. The quality of oil also depends on the moisture retention capacity of the seed as it directly or indirectly affects the extraction and degradation of seed oil. The oil itself contains a number of fatty acids similar to those in cooking oils such as oleic acid, linoleic acid, stearic acid and palmitic acid. The quality of oil extracted from the seeds, depends largely on the conditions under which they have been stored. Even under the best conditions the concentration of fatty acid increases. The oil from fresh seeds has an acid value as low as 3.5 while the Value for oil obtained from old and badly stored seeds may be as high as 60 (Pringi,1990 ; Ajay Kumar, 1991) . Akowuah *et al*. (2012) also reported the effect of storage period of *Jatropa curcas* seeds on the oil yield and FFA content of the extracted oil. As the oil content in seeds also undergo changes with time in post-harvest period oil yield decreased significantly from 35.57% to 31.1% , whereas , the FFA content (%) which is one of the important parameters in the biodiesel production increased from 7.83% to 32.1%.As the oil content in seeds also undergo changes with time in post-harvest period for which the harvested seeds should be properly dried under controlled condition and stored in suitable containers to minimize the loss .

Madhuca latifolia is one of the most important tree species in tribal point of view as it is used for varieties of purposes (Kala, 2011). It has a great spiritual, cultural, medicinal, and ornamental and multiple utility. In Odisha, mahua flowers and fruits are found in most of forest areas and a major source of income for the tribal people residing near the forest. Particularly in the district of Mayurbhanj, Keonjhar, Kandhamal, Sundergarh, Nuapara, Bolangir, Nabarangpur, Angul and Sambalpur, the tribal are very much dependent on mahua tree products for sustaining themselves for around six to seven months in a year. Basically the Mahua flowers are used for preparation of liquor which has high demand in the tribal area because of its low price and mahua seed oil mainly used for cooking purposes and sold in local market for other uses. As reported earlier ,the financial contribution of mahua products (mahua flowers and seeds) are substantially higher than other NTFPs to the total income of tribal people which encourages to study about the collection, processing , storage , marketing and utilisation of these products.

In view of the importance to identify the *Madhuca latifolia* trees with high oil content, oil yield and proper physico-chemical properties suitable for various utilisation purposes, analysing the variation in seed morphological and oil characters for further improvement programme, standardising suitable storage condition for seeds for better oil quality and quantity and understanding the importance of collection, processing and marketing of mahua flowers and seeds , it was decided to undertake the study in all ten agroclimatic zones of Odisha with the following objectives :

1. To assess the extent of variability in seed characters and oil content of *Madhuca latifolia* Macbride from different seed sources of Odisha.
2. To determine the effect of different storage conditions and duration on oil content of *Madhuca latifolia* Macbride .
3. To study the economic importance of fruits and flowers of *Madhuca latifolia* Macbride on the livelihood of the local people.

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Plate 1.1 *Madhuca latifolia* Macbride-Fully grown tree

CHAPTER-2

REVIEW OF LITERATURE

The relevant literature pertaining to the present study on "Effects of seed source, storage conditions and duration on germination, seedling traits and oil content in M*adhuca latifolia* Macbride in Odisha " is reviewed under the following heads:

1. Seed source variability in fruit and seed characters of *Madhuca* and other tree species
2. Seed source variability for germination and seedling characters of *Madhuca* and other tree species
3. Phytosociological association of *Madhuca* and other tree species.
4. Physico-chemical properties of Forest Soils
5. Economic importance of fruits and flowers of *Madhuca* and other NTFP's on livelihood
6. Effect of storage condition and duration on oil content of seeds of *Madhuca*.and other Oil seeds

2.1 Seed source variability in fruit and seed characters of *Madhuca* and other tree species

To study the variability existing in the species in its natural habitat and to select superior genotype for better germination, growth and oil content, it is desirable to screen the naturally available genetic variation so as to ensure that only the best material is utilized for maximum productivity and for further breeding work. Jenner et al. (2003) documented significant differences for seed parameters (seed length, breadth, 100 seed weight) among the 23 one parent families of *Madhuca latifolia* Roxb. Abraham et al. (2010) collected 55 accessions *Madhuca longifolia* (Koenig) J. F. Macbride Seeds. Characterisation and analysis of 7 seed characters were carried out. Variability in seed length, thickness and 100 seed weight indicates scope for utilization of these accessions for selection of promising material for extraction of oil. Oil content of kernels has been evaluated. Kernel oil ranged from 44.43 to 61.50%. Three accessions IC556617 with 61.50, IC556632 with 60.80 and IC556632 with 60.55% of kernel oil are superior to the rest. Wani and Ahmad (2013) studied twenty genotypes of *Madhuca inidica* Gmel. scattered over district Allahabad, and adjoining areas in Uttar Pradesh in their natural range for the pattern of genetic variation. Higher values for phenotypic coefficient of variation as compared to genotypic coefficient of variation in germination and nursery growth parameters indicate that they are greatly influenced by the environment. The heritability and expected genetic gain were also observed to be high for these characters, except for number of leaves per seeding, leaf area, shoot/root ratio and total biomass of seedling. The correlations between germination per cent, germination energy index per cent, mean daily germination, seedling height, seedling collar diameter and internodal length at phenotypic level were positive and significant. The families F15, F18, F19 and F20 showed good performance and are recommended for further genetic improvement programme in this species.

Divakara (2014) evaluated 23 genotypes of *Madhuca latifolia* in Jharkhand based on relationship of seed traits with initial progeny growth performance and divergence studies as a scope for further breeding programme. Variability studies revealed that, more than 12 accessions recorded above average for 100-seed weight (247.5±49.2), oil content (43.8±3.7) and volume index (346.0±97.7). The maximum values observed in studied CPTs were as follows: seed length (39.1 mm) in CPT-15 genotype, seed breadth (19.2 mm) in CPT–8 and CPT–9, aspect ratio (2.2) in CPT-6 and CPT-15, 2D surface area (501.4 and 491.6 mm2) in CPT-9 and CPT-3 respectively. CPT–16 recorded maximum for 100 seed weight (282.4 g) and oil content (51.2%). However, maximum volume index was recorded by CPT–3 (578.3 cm3) followed by CPT–16 (496.0 cm3). The phenotypic and genotypic coefficients of variations are close to each other for all traits, except volume index that exhibited striking difference between PCV (40.0%) and GCV (19.9%) indicating that for most traits genetic control was quite high. 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 plant height (0.73), oil content with volume index (0.71). Hence seeds with large breadth, high seed weight and oil content may be selected for producing better progenies. Since traits viz. 100 seed weight and oil content are under strong genetic control, improvement in these characters can bring improvement in volume index. On the basis of the divergence, the 23 genotypes studied were grouped into 5 clusters, indicating wide diversity. The clustering pattern shows that geographical diversity is not necessarily related to genetic diversity. The genotypes in cluster IV and V were most heterogeneous and can be best used for within group hybridization. Cluster means indicated crosses involving under cluster II and V and cluster II and I may result in substantial segregates and further selection for overall improvement of species.

Munasinghe and Wansapala (2015) determined the variation in seed morphology, seed oil content and the fatty acid profile of *Madhuca longifolia* and the relationship between oil content and fatty acid composition with environmental conditions in Sri Lanka. Seeds were collected from four agro-climatic zones of Sri Lanka and recorded length (2.7333-3.4333cm), width (1.0633-1.2967cm) and the weight (0.9262-1.4018g) which were also found significantly different. Oil from seed kernel was extracted with Soxhlet method using n-Hexane (65-70° C) and the fatty acid profile was determined using GC-MS (Gas chromatography-Mass spectrophotometry) and revealed significant differences in oil content (50.07-53.85%) among agro-climatic zones. Major fatty acids like Oleic, Stearic, Palmitic and Linoleic were found in all four agro-climatic zones and the total saturated fatty acid content (C18:0, C16:0, C14:0, C17:0, C19:0, C22:0, C24:0, C26:0, C20:0 and C8:0) varied from 40.87-47.20%., however, the total unsaturated fatty acid content (C16:1, C18:1, C18:2, C20:1) was within the range of 49.6-53.86% . Oil content and the fatty acid composition were not found correlated with the geographical parameters. Munasinghe and Wansapala (2016) extracted oil from the kernels of *Madhuca longifolia* by soxhlet extraction with n-Hexane giving a yield of 52.22±0.63%. Saponification value (182.79±1.49 mg KOH/g), iodine value (56.28±0.69 g I2/100g), peroxide value (2.78±0.01 meq/kg) and acid value

(3.55±0.03 mg KOH/g) were recorded for the extracted oil. Melting point (33.33±0.24 ºC), Smoke point (169.66±1.25 ºC), specific gravity (0.9272±0.00 at 25 ºC) and refractive index (1.4672±0.00) were also found for the oil extracted . GC-MS analysis of fatty acid profile gave oleic (48.31%), stearic acid (24.50%) palmitic (19.12%) and linoleic (5.11%) as the major fatty acids. Several new fatty acid types that were not reported in the previous studies were identified like palmitoleic acid (C16:0), margaric acid (C17:0), nonadecylic acid (C19:0), cis-gondoic acid (C20:1), lignoceric acid (C24:0), and cerotic acid (C26:0). Taste, odor, mouth feel and organoleptic acceptability were tested with a sensory evaluation. Even though there was a little negative effect of *M. longifolia* seed oil on the taste of deep-fat fried French fries, other tested sensory attributes including odor, mouth feel and overall acceptability were acceptable. When foods prepared by stir frying method, there was no significant difference between two samples prepared with *M. longifolia* seed oil and coconut oil for all the tested sensory attributes.

Hegde (2018) found that the genetic diversity of Mahua (*Madhuca longifolia* var. *latifolia*) in Gujarat has ample opportunity to explore the better genotypes having good oil yielding potential. During the investigation mahua fruits were collected from 13 populations across central and southern parts of Gujarat and revealed that the highest 100 seed weight was recorded in Kevadi population, followed by Kantipada. Considering 100 dry seed weight, Kantipada, Kevadi and Sagtal populations exhibited higher values as compared to other 10 populations. Significant variation were recorded for seed (kernel) oil content ranged from 29.40 to 32.35 per cent , oil yield of kernel also significantly varied from 115.04 g / per kg of kernel - 283.84 g/kg of kernel . Overall study shows that there was a great variation in seed size and seed oil content among studied populations, however, Tejgadh, Anklas and Kukadnakhi sources can be used for further selection and genetic improvement of species. Nimbalkar et al. (2018) selected 48 candidate trees of *Madhuca indica* from Etapalli, Dadagaon, and Jawhar, Maharashtra, India, for Genetic diversity study using ISSR markers. Fourteen ISSR primers revealed a total of 132 polymorphic bands giving overall 92% polymorphism. Genetic diversity, in terms of expected number of alleles (Ne), the observed number of alleles (Na), Nei's genetic diversity

(H), and Shannon's information index (I) was 1.921, 1.333, 0.211, and 0.337, respectively, and suggested lower genetic diversity. Region wise analysis revealed higher genetic diversity for site Etapalli (H = 0.206) and lowest at Dhadgaon (H = 0.140). Etapalli area has forest cover than Dhadgaon and Jawhar whereas in Dhadgaon and Jawhar *Madhuca indica* trees are restricted to field bunds might contribute to lower genetic diversity in these regions. The dendrogram and the principal coordinate analyses showed no region-specific clustering. Higher genetic variance was observed within trees and lower variance among regions. Long-distance dispersal and/or higher human interference might be responsible for low diversity and higher genetic variance within the candidate trees. The review of literature reveals a very limited work carried out on morphometric and oil characters of the seeds of *Madhuca* species in various seed sources and provenances.

However, there are several works carried out on other tree species pertaining to the above aspects. For example, Bergin and Kimberley (1992) revealed considerable genetic variability while studying the variation for seed length in *Podocarpus totara* in 42 sites in New Zealand ranged from 4 mm to 9 mm and also mentioned majority of the provenance showed seed length ranging from 4.5 mm to 5 mm. Veerendra et al. (1996) conducted explanatory survey of 12 provenances of *Azadirachta indica* from Karnataka, Andhra Pradesh and Tamil Nadu, studied for variation in seed characters such as length, width and 100 seed weigth and related considerable genetic variability. Ghatisubramanya provenance (Karnataka) recorded highest coefficient of variance for seed (12.4%) while Rajamundry provenance (Andhra Pradesh) showed highest coefficient of variance for seed width (15%), the Hosakote provenance (Karnataka) recorded highest coefficient of variance of (28%) for 100 seed weight. Sindhuveerendra et al. (1996) conducted exploratory survey of 12 provenances of neem from Karnataka, Andhra Pradesh and Tamil Nadu for study of variation in seed characters such as length, width and 100 seed weight which revealed considerable genetic variability. Deviprasad et al. (1996) revealed that the genetic diversity in rosewood is the most important character to be considered for its genetic improvement to delineate superior varieties. About 110 provenance collections of *Dalbergia latifolia* and 60 provenance collections of other *Dalbergia* species from Western Ghats of Karnataka region had been studied. The results revealed that, different provenances showed significant degree of variation in morphology, growth, wood anatomy and acclimatization to different eco-systems. Sekaran et al. (1997) studied provenance variation in *Cassia auriculata* for pod and seed characteristics and germination. Significant variation in pod length, breadth and seed weight of this species from ten districts in Tamil Nadu state was reported with highest pod length in Kanyakumari (13.3 cm) and Periyar (13.2 cm) and least in Vellanikkara provenance (8.9 cm). Hegde et al. (2000) studied variation for seed characters of *Acacia mangium* and *A. auriculiformis*, study revealed that *A. auriculiformis* had larger and heavier seed than *A. mangium*, but the two species did not differ in seed shape. Kallaje (2000) studied variations in fruit traits of *Garcinia indica* collected from different locations in Uttar Kannada district, Karnataka. Results 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. Gera et al. (2001) studied on Intra-population variation in *Albizzia procera* with respect to seed characters such as seed length, 100 seed weight and percentage of insect damaged and deformed seeds among the 33 trees in Jabalpur. Large amount of variation was recorded in percentage of insect damaged and deformed seed (CV-14.31%) and seed length (8.78%). Tewari et al. (2001) studied on variation and interrelations among seed morphology in *Prosophis juliflora* (SW) DC from 44 different places of Rajasthan, Gujarat and Uttar Pradesh. Sivakumar et al. (2002) studied on Variability in drupe characters and their erelationship on seed germination in Teak (*Tectona grandis* L.f.). Bhat and Chauhan (2002) assessed the seed sources of *Acacia catechu*, the seed length varied from 7.79 mm to 10.41 mm and seed width from 6.06 mm to 8.84 mm. Rajapura seed source excelled all other seed sources for seed length and width. Bisht et al. (2002) studied that there is a variation in seed characteristics of *Azadirachta indica* across different locations in Madhya Pradesh. Kiran Kumar and Devar (2002) studied the variation in fruit and seed traits of *Sapindus trifoliatus* in Karnataka. Maximum fruit weight was recorded in coastal zone (1.95 g) followed by moist deciduous zone (1.83 g) and least in evergreen zone (1.59 g). Sudhir Kumar et al. (2003) studied on seed sources variation of *Jatropha curcus* seeds collected from five different locations in Tamil Nadu. They found that large seeds contained more moisture compared to medium and small seeds that tend to result in higher germination. Number of seeds per kilogram was highest in paripati seed source and lowest in walayar seed source. Ravindra Kumar et al. (2003) assessed seed morphological characteristics of *Prosopis cineraria* on 30 provenances in Rajasthan and Haryana. The average seed weight varied from 39.6 mg/seed in Mukam village (V) provenance to 72.0 g/seed Mukam village (I) provenance. Kumar et al. (2004) studied on seed source variation in *Acacia catechu*. Samples of pods were collected from superior trees at 13 different places of Haryana, J&K, Punjab and Uttaranchal. Radhakrishnan and Vangamudi (2004) observed significant variations among thirty seed sources of *Albezia lebbeck* collected throughout the country for seed quality parameters using image analyzer. Bahar and Singh (2007), studied 13 seed source of *Sapindus murkorosii*, highest seed diameter is found in deothal (13.56 mm) and least in Jachh population (11.54 mm), seed weight was highest in deothal (234.92 gm) and minimum reported from Rajban (130.18 gm).

Reddy et al. (2007) studied on seed source variation in *Pongamia pinnata* for seed and seedling traits in Karnataka. Bahar (2008) studied 29 seed sources of *Albizzia lebbeck* L. and variations were observed in seed length, width, thickness and weight among sources.. Dhillon et al. (2008) studied the pattern of variation in seed characteristics of *Jatropha curcus* among different seed source. Gurunathan et al. (2008) studied on seed source of 16 different seed sources of Jatropha. Kumar et al. (2008) studied variation for seed traits of *Pongamia pinnata* (L.) of agro climatic zones of southern Karnataka. Study revealed that seeds from Central dry zone were recorded maximum seed length, width, thickness, volume and 100 seed weight where as southern transition zone noticed minimum values for most of the seed attributes. Sameer Kumar and Siddiqui (2008) studied in different provenances of *Pongamia pinnata*. The seed characteristics study of 12 provenances from different parts of India i.e. from Tamil Nadu, Kerala, Karnataka, Bihar, and Jharkhand. Patil et al. (2008) studied variability for seed traits of *Pongamia pinnata* (L.) of agroclimatic zones of northern Karnataka. Study revealed that seeds from Northern dry zone were longest, thickest and had higher mass as well as seed volume compared to all other seed sources. Singh and Bhatt (2008) studied on Provenance variation in seed morphology traits of *Dalbergia sissoo* Roxb. Central Himalaya, India among 19 different altitudinal sources from natural stand with respect to seed length, seed breadth, seed thickness, seed weight and seeds germination which revealed considerable genetic variability. Thakur et al. (2008) studied on variation in seed characters of jamun (*Syzygium cumini*). Seed length varied from 1.18 cm (Nangal Jaryala) to 2.12 cm (Ispurl). Seed diameter (1.33 cm) and seed weight (2.82 gm) values were highest in Kutnara.

Arunkumar et al. (2009) studied on morphological variation for fruit characters in *Syzygium cumini*. Ghildiyal et al. (2009) studied on environmental variation in seed characteristics of *Pinus roxburghii* Sarg among 16 provenances of Uttarakhand, India with respect to seed length, seed width, seed thickness and seed weight which revealed considerable genetic variability. Das *et al.* (2010) collected Sixteen *Jatropha curcas* genotypes from four states which were grown in randomized block design and evaluated for 12 characters. The genotypes showed significant differences in most component traits and seed yield, except primary branches/plant, fruits/bunch and seeds/fruit. Mohapatra and Panda (2010) reported that twenty randomly selected seeds of *Jatropha curcas* were collected from different agroclimatic zones of India and studied for variability on growth, phenology and seed characteristics in a progeny trial under tropical monsoon climatic conditions of Bhubaneswar. Parthiban *et al*. (2010) assessed seed physico-chemical properties of *Jatropha curcas* genetic resources. Twenty five seed sources of *J. curcas* investigated in the current study exhibited wide variation for seed physio-chemical properties. The chemical properties of seed sources indicated superiority of more number of seed sources for iodine value, cetane number and saponification value. Hence the *J. curcas* genetic resources tested in this current study could be the potential sources of raw material for biodiesel production. Ghosh and Singh (2011) studied the variation in seed characters of *Jatropha curcas* L. among 6 zones (geographical regions) within India and 4 – 6 provenances within each zone. Lekha and Lalji (2011) studied on Variation in seed characters of *Jatropha curcas* L. with varying zones and provenances. The maximum seed length (19.06 mm) was found in seeds from Nainpur provenance, while Udaipur provenance recorded the lowest seed length of (16.40 mm) followed by Jammu provenance. Hathurusingha et al.(2011) studied the Seed morphometric characters and oil content in *Calophyllum inophyllum* L. of two countries, Australia (southern hemisphere) and Sri Lanka (northern hemisphere). Seven provenances were selected which included three from northern Australia and four from Sri Lanka. Twelve Candidate plus trees (CPTs) each were selected from 2 to 3 different locations within each provenance based on the morphometric and qualitative traits (GBH-100 cm). Shankar and Synrem (2012) studied the Variation in morphometric traits of fruits and seeds of *Prunus nepaulensis* Steud. in Meghalaya, India. Seeds were collected from 7 trees in 3 provenances (Nongstoin, Mawlai and Kshaid) on the Shillong plateau. Seed weight showed the highest coefficient of variation (20.79%), followed by Seed diameter (7.98%) and Seed length showed least coefficient of variation (7.86%). Takuathung et al. (2012) studied the seed morphometric traits of *Senna siamea* (Lam.) among 9 provenances of Thailand. Mean seed length varied from 7.21 to 8.28 mm. Seeds collected from Muang (Songkhla) had the largest value for seed length with the lowest being for seeds collected from Potaram (Ratchaburi-seed lot, 2000). Pavithra *et al.* (2013) evaluated provenance variation and genetic variability in pod and seed traits with 232 candidate plus trees of *Pongamia pinnata* collected from selected agro-ecological zones of southern peninsular India during February-March 2008 to 2010. Significant variation ($P < 0.01$) for pod and seed traits across zones and provenances within zones was recorded. The southern dry and transition zone of Karnataka showed the highest mean value for all the pod and seed traits.

Ndir et al. (2013) reported variability in seed traits, oil content and genetic diversity of *Jatropha curcas* L. according to rainfall gradient in Senegal. Mehdi et al. (2014) investigated inter and intra-population variations of *Stachys inflata.* Kouser et al. (2015) studied variation in the physicochemical attributes of the seeds and extracted seed oils from six varieties (CIM-496, N-121, Z-33, AA-802, Desi, and CIM-534) of cotton (*Gossypium hirsutum* L.) were appraised. The amount of oil and protein in the tested seeds varied from 15.06 to 18.35% and 20.42 and 27.03%, respectively revealing a significant ($p<0.05$) differences among varieties analyzed while the contents of fiber (20.65-21.31%), ash (3.46-4.64%) and moisture (6.36-8.44%) did not vary considerably. Nkouam et al (2017) studied the physico-chemical properties of *Cieba pentandra* fruits from the northern regions of Cameroon in the localities of Mbe (Adamawa), Pitoa (North) and Maroua (Far-North). The seed masses decrease depending on whether the fruit is from Mbe (18.93g), Maroua (16.42g) and Pitoa (14.32g). The fruits of the localities of Adamawa have more seeds and more kapok than the fruits of other two regions. The locality of Pitoa in the North produces fruits with a larger capsule mass. The water and lipid contents of the seeds of Mbe and Maroua are related to one another and all superior to those of Pitoa. Sudrajat et al. (2018) evauated variation in seed morpho-physiological and biochemical traits of Java olive (*Sterculia foetida* L.) populations originated from Java, Bali, Lombok, and Timor Islands, Indonesia which is one of the promising non-edible feed stocks for biodiesel production. Prabakaran et al. (2019) screened Thirty four Plus Trees (PTs) of *Azadirachta indica* based on the tree morphology and biochemical traits to identify the suitable source for high oil and azadirachtin contents in order to establish large scale industrial plantations.

3.2 Seed source variability studies for germination and seedling characters of *Madhuca* and other tree species

Variability in seed source play important role in seed germination and in influencing seedling traits especially during the early stages of growth.Nawa Bahar and Sharma (2013) studied seed germination and growth of seedling in graded and ungraded seed of *Madhuca butyracea* (Cheura). Larger sized seed performed better in comparison to smaller ones and variation in the seedlings size can be avoided to a great extent if the larger seed of uniform size could be used for production of quality seedlings. Wani and Wani (2017) ascertained the growth performance and variance components of *Madhuca indica* of 20 genotypes. Balkrishnan and Veerendra Singh (1995) reported that large seeds recorded higher seedling height in *Albizia lebbeck* (3.07 cm) and *Erythrina indica* (3.86 cm), medium seeds in *Acacia nilotica* (4.98 cm) and small seeds in *Cassia siamea* (3.37 cm) and *Pithecello biumdulce* (4.03 cm). Krishnan and Toky (1996) observed variation in germination among twelve seed sources of *Albezia lebbeck* from India. Bhat and Chauhan (2002), they reported that the germination of *Albezia lebbeck* varied from 16.20 to 38.05 per cent. The Nalgarh attained highest germination (38.07%), which is significantly different from rest of seed sources. It is suggested that heavier seeds possessed higher germination than that of lighter seeds, probably because of more food reserves in endosperm. Munendrappa et al. (1997) reported that the vigour of the *Tectona grandis* seedlings varied among the seed sources. Seeds from Dharwad and Mettupalayum ;[expressed better growth than those from Shimoga and Bengaluru. Similarly Sudhir kumar et al. (2003) reported that the root length and biomass of *Pongamia pinnata* were higher from Salem seeds compared to others in the study. Kundu and Tigerstedt (1997) observed variation in plant height, collar diameter and survival rate of six Neem provenances at three test sites in Bangladesh and India, after 7 months of growing in field. They detected significant site and provenance effects in the studied traits. Three out of six provenances changed their ranks in height growth across the three sites and showed significant genotype and environment interactions. Vinod and Vijay Kumar (1998) studied eight provenances of Neem (*Azadirachta indica*) collected from Kerala Tamil Nadu and Karnataka, which subjected to variability studies for their seeds and seedling characters. Genetic analysis of the various characters indicated more or less equal contribution of both genotype and environment to them. Among the seed characteristics, hundred seed weight was found to possess high heritability coupled with genetic gain. High heritability in conjunction with high genetic gain was recorded for seedling height followed by collar girth. Jayasankar et al. (1999) evaluated provenances of Kerala for seedling attributes in Teak (*Tectona grandis* LINN.F.). Seeds were collected from 7 provenances from Kerala (India) from 10 phenotypically superior trees in each plantation. The Parambikulam drupes were found to be the heaviest among different sources of the Kerala State. Germination test was conducted to study the performance of *Jatropha curcus* seeds collected from different locations and found that there was average germination per cent (84%) in all locations (Sudhir Kumar., 2003). Dhillon et al. (2000) observed seedlings of thirty provenances of shisham (*Dalbergia sissoo*) representing different agro climatic regions of Haryana and were subjected to correlation and path co efficient analysis for seven seedlings traits. The GCV and PCV between different pairs of characters did not give a comprehensive picture of association between them.

Further, path co-efficient analysis revealed that seedling height, weight of leaves and height up to first branch contributed more directly to the collar diameter, an important trait in forest trees at seedling level. Gera et al. (2001) noticed significant differences among the families for the entire seedling parameters studied twenty genotypes of *Albezia procera* sampled from their natural range in Jammu. The family F12 gave the maximum value for seedling height (56.37 cm) and total seedling biomass(5.35 g), further maximum seedling collar diameter was recorded for family F5(0.47 cm). Bhat and Chavan (2002) conducted an experiment to evaluate different seed sources of *Albizia lebbeck*. They found that the sources of Rajapura and Nauni sources of Himachal Pradesh performed better with respect to seed and seedling traits. Jenner et al. (2003) observed significant differences for seedling parameters at one parent level among the 23 one parent families of Mahua (*Madhuca latifolia*) representing different agro climatic zones of Tamil Nadu. Kaushik et al. (2003) reported that the height of the seedling was significantly ($P<0.05$), influenced by the rooting medium. Where large sized seeds gave rise to 32 per cent increase in height compared to small sized seeds. The maximum height of seedling was recorded in large sized seeds (46.77 cm) sown in rooting media containing sand, soil and FYM of 1:1:1. The size of seeds and rooting media also significantly influenced the root length. The root length of large and small sized seeds was recorded 17.60 cm, 12.80 cm respectively. The collar diameter varied significantly in all the treatments studied, in both the rooting media, seedling development in terms of collar diameter increased with increasing seed size and weight. The large sized seeds produced seedlings with more number of leaves their increase was 17 per cent in large seeds compared to smaller ones. They confirmed that dry matter production significantly increased with seed size and growing media. Sudhir Kumar (2003) studied the effect of seed size on germination and seedling growth of *Jatropha curcus*; they found higher germination with heavier seeds. Dhania et al. (2003) studied the provenance variation in pod and seed characteristics of *Albizia chinensis* where he collected seed from wide range of natural distribution in Himachal Pradesh. The performance of seed which contain more food reserves shown higher germination per cent than smaller ones, as which helps in providing more energy for germination. Lavania and Verendra Singh (2004) reported that the seedling length varied significantly from 3.15 cm to 4.99 cm from different seed sources in *Populous ciliate*. Nayak et al. (2004) assessed seed source variation in *Albizia lebbeck* in Karnataka and reported that among five provenances, mean daily germination ranges from 0.728 (Chickmagalur) to 1.382 (Mandya). Lavania and Virendra Singh (2004) reported that the germination of *Populus ciliata* from different seed sources differed significantly with one another at 1 per cent level of significance and ranged from 41.75 per cent in Kathpudia seed source to 71.55 per cent in Nainital seed source. Rawat et al. (2006) studied on variability in *Pinus wallichiana* with respect to seed and germination characteristics in Jharkhand. Luna et al. (2006) conducted study on *Albizia lebbeck* among 20 seed sources with respect to pod, seed and germination traits. The correlation matrixes revealed that statistically significant correlation exist between pod, seed and germination traits. Neelannavar and Chavan (2006), were noticed significant variation in seed characters of 30 seed sources of *Albizia lebbeck* from diverse agro climatic regions of India. Mahto et al. (2006) studied on provenance variation of *Azadiractha indica* in Jharkhand. Sridhar (2006), studied on effect of variations in *Jatropha curcus*. Germination percentage varied from 49.30 to 86.10 percent. Heavy and large seed contained more food reserve than small ones, which is helpful in germination by providing more energy. Large seed had germination percent which varied from 61.90 to 95.23, in medium seed category 47.61 to 91.47 percent and small seed with 39.09 to 71.42 per cent. Chauhan et al. (2007) observed on 42 seed sources of *Pinus roxburghii* for different characters. Genotypic and phenotypic correlation coefficients between different pairs of characters were worked out which became insufficient to explain relationship among characters. Reddy et al. (2007) evaluated seven seed sources of *Pongamia pinnata* (L.) Pierre from Karnataka for germination and seedling traits.

Reddy et al. (2007) studied seed source variation in *Pongamia pinnata* for seed and seedling traits in Karnataka. Germination percentage and their attributes showed significant differences among seed sources. Nawahbahar (2008) Studied on seed source variation in *Albizia lebbeck*. Rawat and Bakshi (2011) studied the provenance variation for seed characteristics of *Pinus wallichiana* among 20 sites in Himachal Pradesh.

Patil *et al.* (2011) reported to identify the best half sibs of *Pongamia pinnata* across its natural distribution areas in Northern Karnataka for further collection of seeds for afforestation or breeding purpose. Shu et al. (2012) identified germplasm resources of *Magnolia officinalis* by test seed traits, seed germination, seedling traits, and seedling growth rate.

Ginwal etal. (2012) carried seed source evaluation trial of *Jatropha curcas* Linn. collected from ten sources from central India representing the states Madhya Pradesh and Maharashtra viz. Gondia, Bichia, Balaghat, Niwas, Khandwa, Burhanpur, Nasik, Chindwara, Kundam and Jabalpur for their growth performance from nursery stage (3 months) to field (two years).

Rahangdale and Dongre (2015) evaluated 22 progenies of seedling seed orchard of *Pongamia pinnata* for seed morphomatric traits, germination traits and seedling at the age of 8 year old provenance trial.. Mohamed et al.(2015) evaluated for growth attributes and genetic divergence of twenty two open pollinated families in *Aquilaria malaccensis* at Forest College and Research Institute, Tamil Nadu Agricultural University; Mettupalayam. Wani and Singh (2016) analysed germination behaviour of *Pongamia pinnata* fresh seed collected from fully grown mature trees after soaking in distilled water for 24 hours at room temperature (280C±20C). Thangjam and Sahoo (2016) studied the effect of seed mass on germination and early growth parameters of the *Parkia Timoriana* (DC.) Merr. in northeast India. Dar and Agnihotri (2017) collected seeds of *Terminalis chebula* from 4 states with 3 different locations for each state (Total 12 provenances) and evaluated for seed morphology, fruit and seed parameters and seed germination under different pre-treatments. Fornah et al. (2017) assess the effect of provenance and seed size on germination and physiological traits of *Gmelina arborea*. Dolley et al . (2019) characterized the fruit morphological parameters and to study the effect of different pre-sowing treatment on seeds of wild edible fruit tree *Phoebe cooperiana* U.N Kanjilal ex A. Das. of Arunachal Pradesh. Fruit and seed morphological parameters were based on 100 fruits collected from Lower Dibang district of Arunachal Pradesh. Thangjam et al. (2019) studied the effect of agroclimate on seed and seedling traits of tree bean (*Parkia timoriana* (dc) merr.) in north east India.

3.3 Study on phytosociological association of *Madhuca* and forest tree species

Phytosociology gives an idea about relative occurrence of plant species in different provenances or forest types. The tree species diversity, distribution, population structure and its association with other species provide baseline information for biodiversity conservation and management of the forest. It also directly and indirectly responsible for the growth and productivity of a tree, species and on whole of the forest ecosystem in terms of timber and non timber forest produce of the forest. There have been several efforts to study the biodiversity with special focus on the dominant tree species in different forest types of India. For example, Seetharam et al. (1999) studied on the assessment of plant biodiversity of dry deciduous forest of Sandur, Karnataka.Ayyappan and Parthasarathy (2001) on the patterns of tree diversity within a large-scale permanent plot of tropical evergreen forest, Western Ghats, India. Sharma and Upadhyaya (2002) studied on the phytosociology, primary production and nutrient retention in herbaceous vegetation of the forestry arboretum on the Aravalli hills at Jaipur, Padalia et al. (2004) on the phytosociological observation on tree species diversity of Andaman Islands, India etc.Reddy *et al.* (2007) studied quantitative floristic inventory of three tropical forest types in Similipal Biosphere Reserve in Eastern Ghats of Orissa, India.

Malik et al. (2007) worked on the phytosociological attributes of different plant communities of Pir Chinasi hills of Azad Jammu and Kashmir and they reported that chemical content of soil played a significant role in giving particular shape of communities. Sahu et al. (2007) worked on the phytosociological study of tropical dry deciduous forests of Boudh district, Orissa, India which reports the basal area and vertical structure of a forest is difficult to summarize as these relies heavily upon the climate and topographic conditions. Tree heights are heavily influenced by the abundance of saplings, richness of nutrients and anthropogenic pressure (since forest fires are recurrent). Reddy et al. (2008) assessed the quantitative structure and floristic composition of tropical forests of Mudumalai Wildlife Sanctuary, Western Ghats, India. Pitchairamu et al. (2008) studied the tree diversity, species richness, basal area, population structure and distribution patterns were investigated in disturbed, moderately disturbed and undisturbed areas of the tropical dry deciduous forest of Piranmalai, Eastern Ghats in Tamil Nadu. Dash et al. (2009) worked on the diversity and distribution pattern of tree species in Niyamgiri hill ranges, Orissa, India which reports the estimation of species diversity helps in understanding the ecological significance of the species in the moist deciduous forest, also shows the species diversity and stem density were observed to decrease with increasing the girth class and altitude and also conclude that hill ranges are rich in tree species even after disturbance due to forest fire, grazing, extraction of economic/medicinal plants and invasion of exotic species. The rich biodiversity repository of Gandhamardhan hills was surveyed by Sahu et al. (2010) in two preservation plots of 100 ha each identified in Nrusinghanath (SITE-I) and Harishankar (SITE-II). The study inventoried a total of 10775 trees belonging to 91 tree species within a 17.6 ha sample area (441 sample plots). The Shannon-Weiner index (H') was 3.92 for SITE-I and 3.31 for SITE-II with Simpson's value 1.0 where the mean stand density was 671 ha-1 and 565 ha-1 respectively. The predominant species found in both the sites were *Diospyros melanoxylon*, *Madhuca indica*, *Cleistanthus collinus*, *Anogeissus latifolia* and *Lagerstroemia parviflora*. Sahu *et al.*(2010) studied the rich biodiversity repository of Gandhamardan hill ranges, Eastern Ghats. The hill range having two preservation plots of 100ha each identified in Nrusinghanath (SITE-I) and Harishankar (SITE-II) range as study area. The present study inventoried a total of 10775 trees belonging to 91 tree species within a 17.6 hectare sampled area (441 plots). The predominant tree species are *Diospyros melanoxylon*, *Madhuca indica*, *Cleistanthus collinus*, *Anogeissus latifolia*, and *Lagerstroemia parviflora.* Sahu *et al*. (2012) analysed the structure of a tropical deciduous forest in Malyagiri hill ranges of Eastern Ghats, Odisha. Kushwaha and Nandy (2012) assessed the community attributes, viz., structure, composition and diversity in the moist and dry sal (*Shorea robusta*) forests in the West Bengal province of India and compare them with the other sal forests of India. Behera and Dhir (2013) studied Phyto-sociological study of woody components in traditional agro-forestry systems of Boudh district of Odisha. Eight different types of agro-forestry systems viz alley cropping, horti-silviculture, home gardens, canal bank plantation, agricultural field bund plantation, boundary plantation, scattered tree planting and block plantation of tree species were observed.

Among the other significant studies, the studies particularly conducted by Devi and Yadava (2006) on floristic diversity assessment and vegetation analysis of tropical semi-evergreen forest of Manipur, North-East India; Sahu and Dhal (2012) on floristic composition, diversity and status of threatened medicinal plants in tropical forest of Malayagiri hill ranges, eastern ghats of India; Erenso et al. (2014) on floristic composition, diversity and vegetation structure of woody plant communities in Boda dry evergreen montane forest in Ethiopia and Sharma and kant (2014) on vegetation structure, floristic composition and species diversity of woody plant communities in Sub-tropical Kandi Siwaliks of Jammu, india documented the forest structure and species composition and provided useful a tool for assessing plant biodiversity and valuable information for effective and sustainable conservation and management of nature reserves.

3.4 Assessment of physico-chemical properties of Forest Soils

The amount of available plant nutrients in the soil is denoted as the soil fertility status (Tamhane et al. 1970). It is that portion of the plant nutrient in the soil which can be readily absorbed and assimilated by the plants and such available nutrients constitutes only a small fraction of the total nutrients contained in the soil (Rattan and Goswami, 2002). The rate of production of a species also depends upon the nutritional status of the soil. For increased production, appropriate soil management information about the present fertility status is of vital importance (Khan et al. 1997). For assessment of fertility status of different nutrients various workers have analysed the soils collected from different depths. According to Brar and Sekhon (1987), Pal and Mukhopadhayay (1992), Sangwan and Singh (1993) and Kumar et al. (1996) knowledge on vertical distribution of macronutrients and micronutrients in soil is quite helpful in nutrient management as many crops have their roots extended below the surface layer. The same fact hold good for all the forest species. Several efforts have been made to characterise the soil under different forest location (Sahu and Mishra, 1994; Maithani et.al 1998)

According to Shah (1999), sandy loam texture is very common in the Shivalik foot hills (Tarai and Bhawar) and Dun valley which support dense sal forests and other valuable timber trees in Rajasthan. The soil texture of study sites was sandy loam type which is suitable for regeneration of high quality trees by (Gupta 1951) studied in Rajasthan. Soil quality evaluation was done by Pierce and Larson(1993). Smal and Olszewska (2008) studied about Nanmangalam reserve forest, Noida, New Delhi and reported about the highest P to be recorded in the meadows. It has been demonstrated that agricultural land use increases the concentration of P due to the application of fertilizers, and this effect usually persists for a long time after cropland abandonment.

Roy *et al.*(2010) assess the degraded forest fringe areas, to promote plantations of various types and to evaluate their impacts on the soil nutrients and carbon content accumulation. The soil organic carbon (SOC) and nutrient content were evaluated and compared between plantations of mixed native species (MNS), some native tree species as *Shorea robusta*, *Dalbergia sissoo*, *Dendrocalamus spp*., certain agro-forestry species and some exotic varieties. The impacts of the plantations on the SOC and the nutrients were firstly analyzed through comprehensive chemical analyses and the results were compared with the soil samples collected prior to plantation forestry. Significant changes were observed in SOC content, in nutrients and in amounts of exchangeable cations. Soil carbon levels were highest under the MNS, *Dendrocalamus* and *Tectona grandis* stands and lowest under *D. sissoo* and *Terminalia arju*na. Total N showed highest levels under *Dendrocalamus* and *Pongamia pinnata* and significantly higher in stands of native species; lowest total N level was observed in D. sissoo plantations. The C/N ratios of the soil varied between 9.2 and 13.5. Mehraj et al. (2010) studied Nutrient Status and Economic Analysis of Soils in Oak and Pine Forests in Garhwal Himalaya and found the higher percent of moisture and water holding capacity was in oak forest and lower in pine forest whereas, the average Soil Organic Carbon in oak forest was 2.19% followed by

1.63% in pine forest. Laxminarayan et al.(2010) during their study on soil samples collected from six districts viz. Ri-Bhoi, Jaintia hills, East Khasi hills, West Khasi hills, West Garo hills and South Garo hills of Meghalaya found the pH and organic carbon content were ranging from 4.27 - 5.56 and 6.1 -52.8 g/kg respectively .

Gunaga (2011) undertaken in 20 seed production areas located in different seed zones of Karnataka, South India showed that there was a greater variation among SPAs in various soil properties like soil pH, organic carbon, available NPK (nitrogen, phosphorus and potassium among three different depths: 0–20 (top), 20–40 (middle) and 40–60 cm (bottom). Organic carbon and available potassium showed significant variations at different depths, where the highest content was recorded in the top layer, followed by middle and bottom layers. Considering associations between soil properties and tree growth, organic carbon was positively associated with dbh (diameter at breast height; $r = 0.500$), stem roundness ($r = 0.351$) and stem volume ($r = 0.250$). Similarly, available nitrogen positively influenced the stem volume ($r = 0.250$). Though the fruit yield varied among SPAs, none of the studied soil parameters showed a significant influence on fruit yield indicating that some other factors like genetic ones, phenology, rainfall overlapping with peak flowering might control it. Data on site quality showed that all existing SPAs studied were growing in poor site conditions, however, this could be one of the factors affecting overall seed yield among SPAs. Chude et al. (2011) observed that the organic carbon content of the soils in both plantations and the control ranged from 1.12 – 2.19% and were rated as low (<2%).

Gairola et al. (2012) studied in moist temperate forest of Garhwal Himalaya and their study revealed that pH of the forest soils was found acidic value ranging from 5.47 to 6.67. Soil chemical properties are the most important among the factors that determine the nutrient supplying power of the soil to the plants and microbes. The chemical reactions that occur in the soil affect processes leading to soil development and soil fertility build up. Rahman et al. (2012) has studied on some physical soil properties like moisture content, particle density, organic matter, bulk density and porosity between planted and deforested sites at surface (0-10cm) and sub surface(10-30cm) soil of North eastern Bangladesh. They found that moisture content at all the soil depths was higher in planted sites than deforested site. The organic matter on both the plantations and deforested site decreased with the increase of soil depth. Deforested site contained lower soil organic matter than plantation site.

Bhasker et al (2014) studied about the the physico-chemical properties of soils were analysed in some forests of Tarai area of Kumaun Himalaya. Debashis et al. (2012) studied about the effects of land use and management practices on soil quality and its indicators has been identified as one of the most important goals of sustainable agricultural land management. In this paper a minimum data set and interpretation were applied to five land use systems around Doon Valley of India to determine the long-term influence of land use on soil quality.

Gautam and Mandal (2013) analyzed the physico-chemical properties of soils of tropical moist forest (Charkoshe jungle) in Sunsari district of eastern Nepal. Yadav et al.(2015) assessed the organic carbon content in the tropical forest soils of Narmada Forest Division**.** Mahapatra (2015) studied some forest soil profiles under natural Sal forest and teak plantation in Korian area of Dhenkanal forest division and found the soil texture in the surface layers of the profiles varied from loamy sand to sandy loam.

Bojko et al. (2016) studied that the gradients of soil physicochemical properties along mountain slopes and across climate-elevation gradients in the Karkonosze Mountains, focusing on the human-impacted zonality of the vegetation cover. The main focus of the study was the environmental consequences, both human-induced and spontaneous, of vegetation changes in the mountains which may occur due to climate change.
Vishnu et al. (2017) studied physico–chemical properties of forest soils in Kerala and found the sand fractions in the forest soils varied from 78 % (moist deciduous forests) to 92 % (shola forests), silt from 4 % (shola forest) to 11 % (Evergreen forest) and clay from 4 % (shola forest) to 12 % (moist deciduous forest).

3.4 Studies on economic importance of fruits and flowers of *Madhuca* and other NTFP's on livelihood

Forests provide significant social and economic benefits at all levels, especially in developing countries. Non-timber forest products (NTFPs) play vital role among the tribal people and provide a source of income and subsistence living. NTFPs like fuel-wood, medicinal plants, wild edible vegetables, house building materials etc. are integral part of day-to-day livelihood activities especially for tribal people. Mahua flowers and seeds are important NTFPs which contribute substantially to the income of the tribal people as compared to other NTFPs of Odisha . The people who collect mahua flowers , seeds and other NTFPs lack in modern technologies and sell forest products at unprocessed stage with lesser price to the processer or to the middle man. Chaturvedi et al.(2012) reported that agriculture as a sole occupation could not provide livelihood to the tribal . Non- Timber Forest Products play a vital role in livelihood of people in and around the forests (Quang, 2006). Importance of NTFP captured the imagination of conservationists around the world, when an article by Peter et al. (1989) published in the 'Nature' claimed that more money could be earned from tropical forests by collecting these products than from logging (Kaimowitz, 2003). The perception that NTFPs are more accessible to rural populations, especially to the rural poor (Saxena, 2003) and that their exploitation is more benign than timber harvesting (Myers, 1988) favoured NTFP becoming economically acceptable ecological option of development. In the context of this study, NTFPs are considered as both direct benefits e.g. food and healthcare as well as indirect benefits such as biodiversity values, ecotourism, cultural and other values. Millions of people throughout the world make extensive use of biological products from the wild (Koziell and Saundres, 2001). Panigrahi et al. (2019) described in detail the availability of non-timber forest produce including mahua flowers and seeds in Odisha, their scope , processing and importance for tribal people. It also include a brief idea and challenges which are faced by the rural people during the collection, processing and marketing of NTFPs and some strategy and policies to overcome the issues and challenges of overexploitation of forest produce. The contribution of *Madhuca* species utilisation in day to to life of the tribal of the country and state of Odisha particular contributing to their socioeconomic upliftment are somewhat less reported.

A collaborative work by Action aid (India) and Vasundhara during 1998 in Bolangir district, Orissa revealed that the rural economy of Bolangir is highly dependent on the collection, consumption and sale of Minor Forest Produce (NTFPs). At a rough estimate 60% of the total households obtain more than a quarter of their annual income from the collection and sale of NTFPs (Mahua flower & Seed and Tamarind). For the poorest sections this dependence on NTFPs goes up to 75% and more.Das and Chattopadhyay (2001) found that Non-Timber Forest Products (NTFP) constitute an important source of food for economically backward communities living in the forests of the Nayagram Range of West Midnapore Forest Division, South-West Bengal. Items collected for household consumption include leaves and young shoots, flowers, fruits, tubers, mushrooms etc. The average annual collection was found to be highest for Mahua (*Madhuca latifolia*) flowers followed by tubers, leafy vegetables, mushrooms and fruits. The consumption pattern of forest edibles varied widely over the FPCs studied. The present study on nutritional aspect confirms the presence of major nutritive elements in forest edibles in appreciable amount. Therefore, NTFPs have immense prospects to provide solution to the problems of hunger, malnutrition and poverty of the rural poor in the world.Rout and Panda (2011) reported that Non-timber Forest Products (NTFP) contribute an integral component of the food for the communities dependent on forests. Their role becomes more significant for less agricultural dependent communities with small land holding residing in remote forests. Fifty-four important NTFP species have been reported to be collected by the villagers in Gandigadha for consumption. However, a few new species like 'Sal' (*Shorea robusta*) leaves, tooth stick and seeds 'Mahula' (*Madhuca indica*) flower and fruit, 'Chara' (*Buchanania lanjan*) fruits, seeds and mushroom are collected and sold to local trade. Kumar et al . (2017) described that mahua tree is a nature reward to tribal's communities in India which produce wide variety of products . The products obtained from tree are consumed by these communities itself or sale in local and regional market. Tree having great spiritual, cultural, medicinal, and ornamental and multiple utility. It has been naturalized in different parts of Karnataka, Orissa, West Bengal, Rajasthan, Maharashtra, and Madhya Pradesh including various regions of India. There are many products namely; flower, seed, oil cake, leaf, timber etc. are obtained from mahua tree. The fermentation waste can also be used as bio fertilizer which is eco-friendly and cheap in comparison to the expensive fertilizers. Current study was undertaken to explore the socio-economic, cultural and livelihood of tribes in relation to wonder tree of *Madhuca indica* and highlight and record in detail the uses of mahua tree growing in around AABR by tribal groups of central India. Satapathy (2018) found that tribes are generating their livelihood status based on collection of Minor Forest Produces (MFPs), like Sal leaf, Mahua flowers, fire-wood, weaving, and handicraft. The availability of Mahua tree for most covers of this district which provides livelihood security to the tribal's in general. The products obtained from tree are consumed by these communities itself or sale in local and regional market. Shrey et al. (2018) examined the collection, consumption, selling, income and employment and also disposal pattern of Mahua by forest dwelling tribes in Chhattisgarh. Kumar et al. (2018) assessed the the production and collection aspects of Mahua (*Madhuca latifolia*) produce in nine villages of Ranchi, Jharkhand. These villages are situated near by the forest and their livelihood depends upon the collection of NTFP produces from the forest. Hegde et al.(2019) reported that Mahua (*Madhuca longifolia* var. *latifolia* Roxb. A. Chev.) tree has religious and aesthetic value in the ethos of many tribes of Gujarat, India. Traditional knowledge of the people about the various uses of mahua is shrinking rapidly due to the change in socioeconomic status.

There is an intricate relationship between livelihood pursuits of tribal communities and surrounding natural resources like forest, land, water-bodies and other flora and fauna. The critical balance between the two is very essential for sustainable livelihoods of forest dwellers in the world in general. The coping mechanisms developed by them are cultural responses to combat the scarcity and poverty conditions that threaten them periodically (Prasad and Eswarappa, 2005).According to a research done by Ravi et al. (2006) in Mysore district, South India, it was found that among the different employment opportunities available, the collection of NTFPs provided the maximum employment to the extent of 50.98 percent of the total employment of the households followed by wage employment (33.95%), agriculture (11.65 %) and allied sector (3.42 %).When the three categories were compared, on an average, 407.13 man days of employment was generated on small farm households per annum, followed by marginal farm households (237.3 man days per annum) and landless households (237.40 man days/annum). With regards to income, the tribal households, in general, earned an average income of Rs 10,849.55 per annum, which is far below the poverty line. The wage income contributed the most (40.78%) to the total income followed by NTFPs (39.47%), agriculture (13.31%) and allied sectors (6.44%).Bhattacharya and Patra (2007) reported that the Gond and Korku tribal communities of Betul District of Madhya Pradesh and Melghat District of Maharashtra use thirty major NTFP species, out of which few NTFP are used for self consumption, few for sale and some of them for both the purposes. Behera (2009) compiled that Orissa is one of the most backward states of India with 47 per cent of the population living below poverty line. Forests constitute 37 per cent of the state's geographical area and are the major source of income for the poor, particularly tribals. For most of the tribal households, forests provide essential food and nutrition, medicine, fodder, fuel, thatch and construction materials and non-farm income. These products are particularly important in relieving the 'hunger periods' during slack periods of agricultural cycle. Tribal households get 23 per cent of their total income from NTFPs resources from the forest areas.

Behera and Nath (2012) studied for valuation of non-timber forest products (NTFPs) flow from tropical dry deciduous forests in Boudh district, Orissa. Forest occupies 40.5 per cent of the geographical area of the district. Being located in the Eastern Ghats its floristic composition is very rich and diverse. According to Vaughan et al., (2013) many NTFPs have considerable markets but mostly are inadequately monitored, economically under regulated, and ecologically poorly understood. The people who harvest wild-grown NTFPs are often referred to as wild crafters. Literature suggests that wild crafters have historically been marginalized and are often reticent to share information or to participate in government-led initiatives. Additionally, forest managers and wild crafters often are unable or unwilling to work together. Social networking has been suggested as a way to improve collaboration between the two stakeholders.

3.6 Effect of different storage condition and duration on oil content of seeds of *Madhuca* and other Oil seeds

A control atmosphere is essential for safe and long term storage of seeds environmental condition which are safe for storage from harvest to planting or extraction of oil are not necessarily safe for longer periods . The control storage is very essential in tropical and sub-tropical condition to maintain high viability and content of seeds for longer period. Roberts (1972) reported that seed deterioration during storage was due to damage to membrane, enzyme, proteins and nucleic acid accumulation with time. Such degenerative changes results in complete disorganization of membrane and cell organelle and ultimately causing death of seed and less of germination and oil content. Sharma *et al*. (1987) studied the effect of collection and storage of Sal (*Shorea robusta*) seed kernel for a period ranging from 15 to 150 days stored under various condition. The yield and quality of the oil extracted from stored kernel after stipulated time period have being determined for the acid, ester, iodine values the effect of storage on the quality of sal seed fat stored for one year has also been examined. Manikantan *et al*. (2004) studied three types of pre-treatments namely instant addition of moisture, conditioned addition of moisture and steaming were applied to 45% size reduced *Pongamia pinnata* seeds (7.6 mm geometric mean diameter) and their effect on hardness, rupture energy and oil recovery were observed. The reduction in hardness and rupture energy and increase in oil recovery was observed in moisture addition treatment. Under steam treatment, the reduction in hardness and rupture energy and increase in oil recovery were observed up to 51.72 kPa for 10 minutes and decreased thereafter. The maximum oil recovery of 55.9% was obtained in 51.72 kPa, 10 minutes steam treatment followed by 40.8% in 75 g conditioned addition of moisture treatment. Sisman (2005) studied the influence of storage condition on sunflower seed oil. In this experiment mass temperature and relative humidity of the stores which varied parallel to changing weather temperature were taken in to consideration. Neg and Anderson (2005) also showed that storage time and storage temperature had significant effect on free fatty acid content in Quinoa (*Chenopedium quinoa*) seed oil (Azhari et al., 2008) reported that, in many instances, the quality of CJO for instance, deteriorates gradually due to improper handling of seeds and inappropriate storage condition.

Abulude *et al*. (2007) studied storage properties of Oils of two Nigerian Oil Seeds *Jatropha curcas* (Physic Nut) and *Helianthus annuus* (Sunflower). They observed that Oils of *Jatropha curcas* and *Helianthus annuus* stored at ambient conditions for four months in four different containers (polythene, glass, metal and plastic bottles) were sampled at one month interval for physico-chemical properties. Increment were noted in all the containers for peroxide value (0.2-1.86 and 0.23-0.44 mEq kg-1). Kesiri *et al.* (2008) studied Candidate plus trees (CPTs) of *Pongamia pinnata*, a potential biodiesel plant occurring across 10 locations in North Guwahati, were identified based on morphological markers (vegetative and reproductive) using combined analysis 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, were evaluated using CROPSTAT software for inferring potential genotypes that can be included in programmes aimed at genetic improvement of the species. Total oil content from the seeds of plus trees was also analysed using solvent extraction procedure at their boiling points. Hexane extraction yielded maximum oil content from seeds (33%) compared with petroleum ether (30%). 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.

Tubić *et al*. (2010) Changes occurring in seed during aging are significant as far as seed quality and longevity are concerned and are a consequence of the effects of different storage conditions. The chemical composition of seed with high oil content is related to specific processes occurring in seed during storage. In this trial, sunflower and soybean genotypes developed in Novi Sad were submitted to accelerated aging for three and five days, and natural aging for six and twelve months, under controlled and conventional (non-controlled) conditions. The obtained results showed that preservation of seed viability depended on storage condition and duration, as well as plant species. Accelerated aging test can be used to predict the length of storage life of sunflower and soybean seed. In comparison to sunflower seed, soybean seed is more sensitive to damage and reduced germination during storage. Akowuah *et al*. (2012) investigated the effect of storage period of Jatropha seeds on the oil yield and FFA content of the extracted oil. The study was carried out for the period of 4 months. The FFA content and seed oil yield was determined before storage as control and regularly at monthly interval. 50g of seed samples at an initial moisture contents of 6.39% wb stored at room temperature and milled using a grinding machine to a particle size of 0.5mm.The Soxhlet apparatus was used to extract the oil using the petroleum ether as solvent. At average marginal moisture increase of 0.1%over the storage period, oil yield decreased significantly from 35.57% to 31.1% conversely, the FFA content (%) which is one of the critical parameters in the biodiesel production process also increased from 7.83% to 32.1%. The study concludes that storage duration and improper handling of Jatropha seeds during storage have an effect on the quality FFA content of the extracted crude oil for biodiesel production. Shaban (2013) Seed ageing is influenced by two environmental factors, RH and temperature. The deterioration of the stored seed is a natural phenomenon and the seeds tend to lose viability even under ideal storage conditions.

Deswal *et al.* (2015) conducted an experiment with objective to study the variation in seed oil content of *Pongamia pinnata* collected from five different agro-climatic zones and storage behaviour of the seeds up to two years. Storing of seeds are done at three moisture level (6%, 9% and normal), two temperature regimes (room temperature and -5^{o}C) and three types of containers (cloth bags, polythene bags and air tight container).

Karabulut *et al.* (2002) studied the changes in physico-chemical properties of soybean oil, which was dehydrogenated for a period of 100 minutes at 220^{o}C and 2.5 atm H2pressure in the presence of Ni (0.18%) catalyst. The study resulted in decrease in iodine value and refractive index during the experiment, however the trans-fatty acid (TFA) content increased with time and reached to 56.76 at the end of the experiment. Zullaikah *et al*. (2005)examined the effect of temperature, moisture and storage time on the accumulation of free fatty acid when they used a two-step acid-catalysed process to produce biodiesel from rice bran oil. Their results showed rice bran stored at room temperature showed that most of the triacyl glycerides were hydrolysed and free fatty acid (FFA) content was raised up to 76 per cent in six months.

Leung *et al*., (2006) conducted an experiment to know the biodiesel degradation characteristics under different storage conditions. The qualities of twelve biodiesel samples, which were divided into 3 groups and stored at different temperatures and environments, were monitored at regular intervals over a period of 52 weeks. The experimental results demonstrated that the biodiesel under test degraded less than 10 per cent within 52 weeks for those samples stored at 4 and 20 °C while nearly 40 per cent degradation was found for those samples stored at a higher temperature, of 40 °C. The results suggested that high temperature, together with air exposure, greatly increased the biodiesel degradation rate. The temperature or air exposure alone, however, had little effect on biodiesel degradation. Water content in biodiesel enhanced biodiesel degradation due to hydrolysis.

Kamau and Nanua (2008) conducted a study to determine storage stability of the oil. Bouaid *et al*. (2009) showed that the acid value, peroxide value and viscosity increased while the iodine value decreased with increasing storage time of the *Brassica carinata* biodiesel. They also found that the fatty acid ethyl esters from *Brassica carinata* oil were very stable. Kapilan and Sekar (2011) examined honge oil by a two-step trans-esterification process using a biodiesel plant. The properties of the honge biodiesel satisfied the biodiesel fuel standards. The honge oil contains more than 50 per cent unsaturated fatty acids which made them prone to oxidation. During the storage period of six months, the acid value and viscosity of the honge biodiesel were increased but the iodine value decreased. This study suggested that the safe storage period of the honge biodiesel is 4 weeks. Pattmarpram *et al*. (2012)

conducted on mild steel storage of palm olein and palm stearin in terms of chemical properties, engine performance and exhausts emission. The degradation study was carried out by keeping biodiesels in dark closed-lid containers at room temperature for up to six months led to slow degradation of biodiesels through oxidative reaction with double bonds in biodiesel.

The above review of literature reveals that although a lot of works pertaining to seed source variability and other aspects have been tried in several tree species, the works pertaining to effect of seed source on seed characters, seed germination and initial growth behaviour of *Madhuca* is largely lacking. Besides, no efforts have been made to study the effect of storage condition and duration on oil seeds of this species, and on the economic importance of this important non-timber forest product species to the household economy of the forest dwellers in the state of Odisha.

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CHAPTER-3

DESCRIPTION OF STUDY SITES AND SOIL ANALYSIS

3.1. MATERIALS AND METHODS

3.1.1 Study site

Odisha with 4.7% of India's land mass and 41.97 million people accounts 3.47% of the population of the country. The state has 51,311 villages comprising of 34.97 million rural population which contributes 83.31% of the total population .The schedule caste (SC) and Schedule tribe (ST) population accounts for 17.13% and 22.85% of the total state population where as 20.55% and 27.42% of the state rural population respectively (Census of GoI, 2011).

On the basis of homogeneity, continuity and physiographical characteristics, Odisha has been broadly divided into four major topographical regions: the coastal plain in the east, the middle mountainous and highlands region in the central part, the central plateaus and the western rolling uplands in the west. Further, Odisha has been divided into 10 Agro-Climatic Zones based on the basis of soil structure, humidity, elevation, topography, vegetation, rainfall and other Agro-Climatic factors. Among the four major topographical regions, the coastal plain in the east consists of the major parts of Agro-Climatic Zones 3 & 4 comprising 10 % of the total area of the state , the Middle Mountainous and Highlands Region consists of Agro-Climatic Zones 1, 2 (part), 5, 6 (part), 7 & 10 comprising of about 70 % area of the state , the Central Plateaus consists of the small parts of Agroclimatic Zones 2 and 6 having 5% area of the state and the western rolling uplands consists of major parts of Agro-Climatic Zones 8 & 9 covering an area of 15 % of the state .

Agroclimatic zone -1 (North Western Plateau) consisting of Sundargarh, parts of Deogarh, Sambalpur & Jharsuguda districts having Hot & moist sub-humid climate with mean maximum summer temperature 38^{o}C, mean minimum winter temperature 15^{o}C, mean annual rainfall 1600mm and broad soil groups of Red, Brown forest, Red & Yellow, Mixed Red & Black soil.

Agroclimatic zone -2 (North Central Plateau) consisting of Mayurbhanj, major parts of Keonjhar district (except Anandapur & Ghasipura block) having Hot & moist sub-humid climate with mean maximum summer temperature 36.6^{o}C, mean minimum winter temperature 11.1^{o}C, mean annual rainfall 1534mm and broad soil groups of Lateritic, Red & Yellow, Mixed Red & Black soil.

Agroclimatic zone -3 (North Eastern Coastal Plain) consisting of Balasore, Bhadrak, parts of Jajpur & hatdihi block of Keonjhar districts having moist sub-humid climate with mean maximum summer temperature 36^{o}C, mean minimum winter temperature 14.8^{o}C, mean annual rainfall 1568mm and broad soil groups of Red, Lateritic, Deltalcalluvial, Coastalalluvial&Saline soil.

Agroclimatic zone -4 (East & South Eastern Coastal Plain) consisting of Kendrapara, Khurda, Jagatsinghpur, part of Cuttack, Puri, Nayagarh & part of Ganjam districts having hot & humid climate with mean maximum summer temperature 39^{o}C, mean minimum winter temperature 11.5^{o}C, mean annual rainfall 1577mm and broad soil groups of Saline, Lateritic, Alluvial, Red & Mixed red & Black soil.

Agroclimatic zone -5 (North Eastern Ghat) consisting of Phulbani, Rayagada, Gajapati, part of Ganjam & small patches of Koraput districts having Hot & moist sub-humid climate with mean maximum summer temperature 37^{o}C, mean minimum winter temperature 10.4^{o}C, mean annual rainfall 1597mm and broad soil groups of Brown forest, Lateritic Alluvial, Red, Mixed Red & Black soil.

Agroclimatic zone -6 (Eastern Ghat High Land) consisting of Sundargarh, parts of Major parts of Koraput and Nabarangpur districts having warm and humid climate with mean maximum summer temperature 34.1^{o}C, mean minimum winter temperature 7.5^{o}C, mean annual rainfall 1522mm and broad soil groups of Red, Mixed Red & Black, Mixed Red & Yellow soil.

Agroclimatic zone -7 (South Eastern Ghat) consisting of Malkangiri & part of Keonjhar districts having Warm & humid climate with mean maximum summer temperature

34.1^{o}C, mean minimum winter temperature 13.2^{o}C, mean annual rainfall 1710mm and broad soil groups of Red, Lateritic, Black soil.

Agroclimatic zone -8 (Western Undulating Zone) consisting of Kalahandi & Nuapada districts having Hot & moist sub-humid climate with mean maximum summer temperature 37.8^{o}C, mean minimum winter temperature 11.9^{o}C, mean annual rainfall 1352mm and broad soil groups of Red, Mixed Red & Black and Black soil.

Agroclimatic zone -9 (Western Central Table Land) consisting of Bargarh, Bolangir, Boudh, Sonepur, parts of Sambalpur & Jharsuguda districts having Hot & moist sub-humid climate with mean maximum summer temperature 40^{o}C, mean minimum winter temperature 12.4^{o}C, mean annual rainfall 1614mm and broad soil groups of Red & Yellow, Red & Black, Black, Brown forest, Lateritic soil.

Agroclimatic zone -10 (Mid Central Table Land) consisting of Angul, Dhenkanal, parts of Cuttack & Jajpur districts having Hot & moist sub-humid climate with mean maximum summer temperature 38.7^{o}C, mean minimum winter temperature 14^{o}C, mean annual rainfall 1421mm and broad soil groups of Alluvial, Red, Lateritic, Mixed Red & Black soil.

Agro- Climatic Zones 1, 2, 5, 6, 7, 8, 9 & 10 comprising about 80 % of the area of Odisha are considered as Highland regions consisting of 21 Districts where as ACZ- 3 & 4 are considered as Lowland/Coastal regions with 9 Districts. Under different agroclimatic zones various forest types of Odisha are found due to variation in climatic , edaphic and geographical conditions . Odisha is fifth largest state of India in terms of forest cover which has total forest and tree cover of 55,338 km^2 which is 35.54 % of the state geographical area and 6.90% of India’s forest and tree cover (FSI-India state of forest report 2017) with 18 forest types belonging to 4 forest type groups i.e. Tropical semi-evergreen, Tropical dry deciduous , Tropical moist deciduous and Littoral and swamp forest (FSI-India state of forest report 2017).

The study was conducted in forests located in 10 agroclimatic zones (ACZs) of Odisa (Figure 3.1).These were ACZ-1- Sundargarh (Ramlata Reserve Forest), ACZ-2-Mayurbhanj (Similipal Reserve Forest, Chandbil), ACZ-3-Balasore (Tinkosia-Naranpur- Gobipalla Forest),, ACZ-4-Nayagarh (Baispalli--Buguda-Banigochha Forest), ACZ-5-Kandhamal (Siringi Reserve Forest, Balliguda), ACZ-6-Nabarangpur (Ranigarh-Papadahandi-Mahendra Forest Area), ACZ-7-Malkangiri (Haldikund-Ramgiri Forest Area), ACZ-8-Nuapada (Sunabeda Wildlife Reserve), ACZ-9-Bolangir (Khaprakhol-Harishankar Reserve Forest), ACZ-10-Angul (Bambro forest Area).

3.1.2 **Climate**

The climate of Odisha falls under the category of tropical monsoon type of climate. Standing on the coastal belt, the weather in Odisha is greatly influenced by the sea. The climate of the region is tropical resulting in very high temperature in the months of April and May. On the contrary, the Eastern Ghats of the state experience an extremely cold climate.

There are three major seasons - Summer (March-June), Rainy Season (July-September) and the Winter (October-February). Odisha (Orissa) lying just South of the Tropic of Cancer, has a tropical climate. It is warm almost throughout the year in the Western districts of Sundergarh, Sambalpur, Baragarh, Bolangir, Kalahandi and Mayurbhanj with maximum temperature hovering between 40-46^{0}C and in winter, it is intolerably cool. In the coastal districts, the climate is equable but highly humid and sticky. The summer maximum temperature ranges between 35-40^{0}C and the low temperatures are usually between 12-14 ^{0}C. Winter is not very severe except in some areas in Koraput and Phulbani where minimum temperature may drop to 3-4 ^{0}C. The average rainfall is 150 cm, experienced as the result of south west monsoon during July-September. The month of July is the wettest and the major rivers may get flooded. The state also experiences small rainfall from the retreating monsoon in the months of October-November. January and February are dry (Fig. 3.2).

3.1.3 **Soil sampling and analysis**:

Representing Pedon one from the natural forest site and one from the agricultural land near to that forest site with adequate representation of *M. latifolia* was selected during the month of November 2016. The dimension of each Pedon was $1x1x1m^3$. After selection of sites for representative profile, rectangular pits were dug 1m length, 1m breadth, and 1m depths at each of the locations. The wall of the pit under examination was made vertical and planned down by means of shovel and khurpi to give a smooth surface, care was taken not to disturb the natural structure. The horizons in the profile were made each at 25cm interval of depth (0-25 cm, 25-50 cm, 50-75 cm and 75-100 cm) and demarcated by drawing line with a spade. Soil samples from each layer were collected with the help of khurpi from the wall of the profile and kept carefully in new polythene packets for further analysis.

Collected soil samples were brought to the laboratory and spread over a paper. The coarse concretions, stones, pieces of roots, leaves, and other un-decomposed organic residues present were removed. Large lumps of moist soil were broken to small pieces. Samples were air dried at room temperature of 20-25^{o}Cand relative humidity of 20% to 60% inside the laboratory. Samples were mixed to expose bottom layer to top for uniform drying. After air drying soil samples were then crushed gently with help of a wooden hammer and sieved through a 2 mm sieve. The materials larger than 2 mm were discarded. The sieved soils were stored with proper labelling in polythene bottles for analysis of physical and chemical properties.

Soil pH and moisture content percentage was determined within 36 hours of sampling following standard procedures (Anderson and Ingram, 1993). Soil organic carbon of soil samples was examined by Walkley-Black rapid titration method (Walkley and Black, 1934). One gram of oven dried (at 105° C) soil was placed in a 500 ml Erlenmeyer flask and 10 ml 1 N potassium dichromate ($K_2Cr_2O_7$) was added. 20 ml of concentrated Sulphuric acid (H_2SO_4) was added and swirled the flask until the soil and reagents are mixed. After half an hour, 200 ml distilled water was added to the solution followed by addition of 10 ml Ortho-phosphoric acid (H_3PO_4) and 1 ml of diphenylamine (($(C_6H_5)_2NH$ indicator. The undigested dichromate was determined by titrating against 0.5 mol l^{-1} (0.5 N) ferrous ammonium sulphate ($Fe\ (NH_4)_2(SO_4)_2.H_2O$). SOC concentration was estimated using the following equation:

$$\mathrm{SOC}\ (\%) = \frac{\mathrm{N} \times (\mathrm{B} - \mathrm{S}) \times 0.003 \times 100}{\mathrm{W}} \times \mathrm{CF}$$

Where,

N is the normality of the $FeSO_4$ solution (from blank titration),

B is the volume (ml) required in blank titration,

S is the volume (ml) required in actual titration,

W is the weight (g) of oven-dried soil sample

CF is the correction factor set by Walkley and Black (1.32 considering recovery of 76 %).

The percentage recovery (RC) compared with dry combustion TOC is given by the equation:

RC=100 x $SOC_{(WB)}$ / TOC (De Vos et al., 2007)

The correction factor (CF) is calculated as 100 / RC (%).

The electrical conductivity (EC) was measured from supernatant solution using a digital conductivity meter(Model: Digital conductivity meter 611 (B). Available nitrogen was estimated by using alkaline $KMnO_4$ method (Subbiah and Asija, 1956).Available phosphorous in the soil was determined by Bray's 1 method (Bray and Kurtz, 1945) as out lined by Page et al., (1982). P concentration was analyzed by the help of spectrophotometer (Model: Systronics 166) at 660nm. P concentration was calculated from the standard graph prepared by taking different P concentration. Available Potassium was determined by taking 5 gm soil sample in 100 ml conical flask and 25 ml of 1N NH_4OAC solution with the help of mechanical shaker and the K concentration in the filtrate was recorded by help of a Flame photometer (Model: Systronics 128). Available sulphur in the soil was determined by turbidimetric method (Chesnin and Yien, 1951) using Systronics spectrophotometer (Model 166).

3.2 RESULTS

3.2.1 Soil characteristics

The pH showed marked variations between the ACZs and ranged from 5.29 (ACZ-4) to 7.40 (ACZ-3) in forest sites while it ranged from 5.31 in AEZ-5 to 8.59 in ACZ-10 in agriculture site (Table 3.1). The pH values showed a gradual increase from surface soil depth (0-25 cm) to lowest soil depth (75-100 cm) in all sites irrespective of ACZ. The soil pH values in ACZs in agricultural site was remarkably ($P<0.05$) higher than the corresponding sites under the forest land. The electrical conductivity (EC) of soil which showed the concentration of soluble salts in soil ranged from 0.016 – 0.084 dS/m in forest sites and from from0.029 – 0.167 dS/m. in agricultural sites (Table 3.2). There was, however, no distinct depth-related trend with respect to the EC values in the sites. The values of soil organic carbon (SOC) showed wide fluctuations between the ACZs and the sites. In general, the forest sites showed significantly ($P<0.05$) higher SOC in forest sites than agricultural sites when compared between the corresponding the ACZs and there was also no clear depth-wise trend with respect to it value in different sites (Table 3.3).

The available Nitrogen (N) content in the soil ranged from 50 kg ha-1 (ACZ-2) to 175 kg ha^{-1} (ACZ-9) in forest stands while it ranged from 62.5 kg ha^{-1} (AEZ-3) to 175 kg ha-1 (ACZ-5) in agricultural lands (Table 3.4) and both the sites showed a wide variations with respect to its value, besides, there were no clear depth-related trend.

The available Phosphorus (P) content, similarly, showed wide variations between ACZs, however, it varied significantly ($P<0.05$) when compared between the sites (Table…).

There was also a conspicuous decline in its value with the increase soil depth in both the sites. In majority of ACZs, the agricultural stands registered higher available phosphorus than the corresponding ACZs in forest stand. The available P ranged from as low as 2.15 kg ha^{-1} (ACZ-2) to as high as 15.76 kg ha^{-1} (ACZ-1) in forest stands and from 4.36 kg ha-1 (ACZ-4) to 10.20 kg ha-1 in agricultural stands. The top soil (0-25 cm) registered 2-3 fold higher in P content when compared to the lowest (75-100 cm) in most of the ACZs and this was true in both the sites. The available Potassium (K) on the other hand, showed a remarkable variation with respect to its value between the ACZs and within the soil profile. There was no clear depth-related trend in its value in all the sites and ACZs, however, the agricultural stands registered higher P values in most sites (Table 3.5). The available K estimated ranged from 69.80 kg ha-1 (ACZ-3) to 956 kg ha^{-1} (ACZ-5) in forest stands and it ranged from 40.33 kg ha^{-1} (ACZ-10) to 827 kg ha^{-1} (ACZ-8) in agricultural stands (Table 3.6).

The available Sulphur (S) content were remarkably ($P<0.05$) higher in the forest stands than the agricultural stands (Table 3.7) and this true in all the ACZs barring ACZ-3 and ACZ-10. The S value ranged from 5.92 kg ha^{-1} (ACZ-3) to 84.00 kg ha^{-1} (ACZ-9) in forest stands while it ranged from 7.77 kg ha^{-1} (ACZ-5) to 16.65 kg ha^{-1}(ACZ-6). The pooled soil-depth mean value of various physicochemical parameters (Table 3.8 and 3.9) also revealed wide fluctuations in values between ACZs and between forest and agricultural sites.

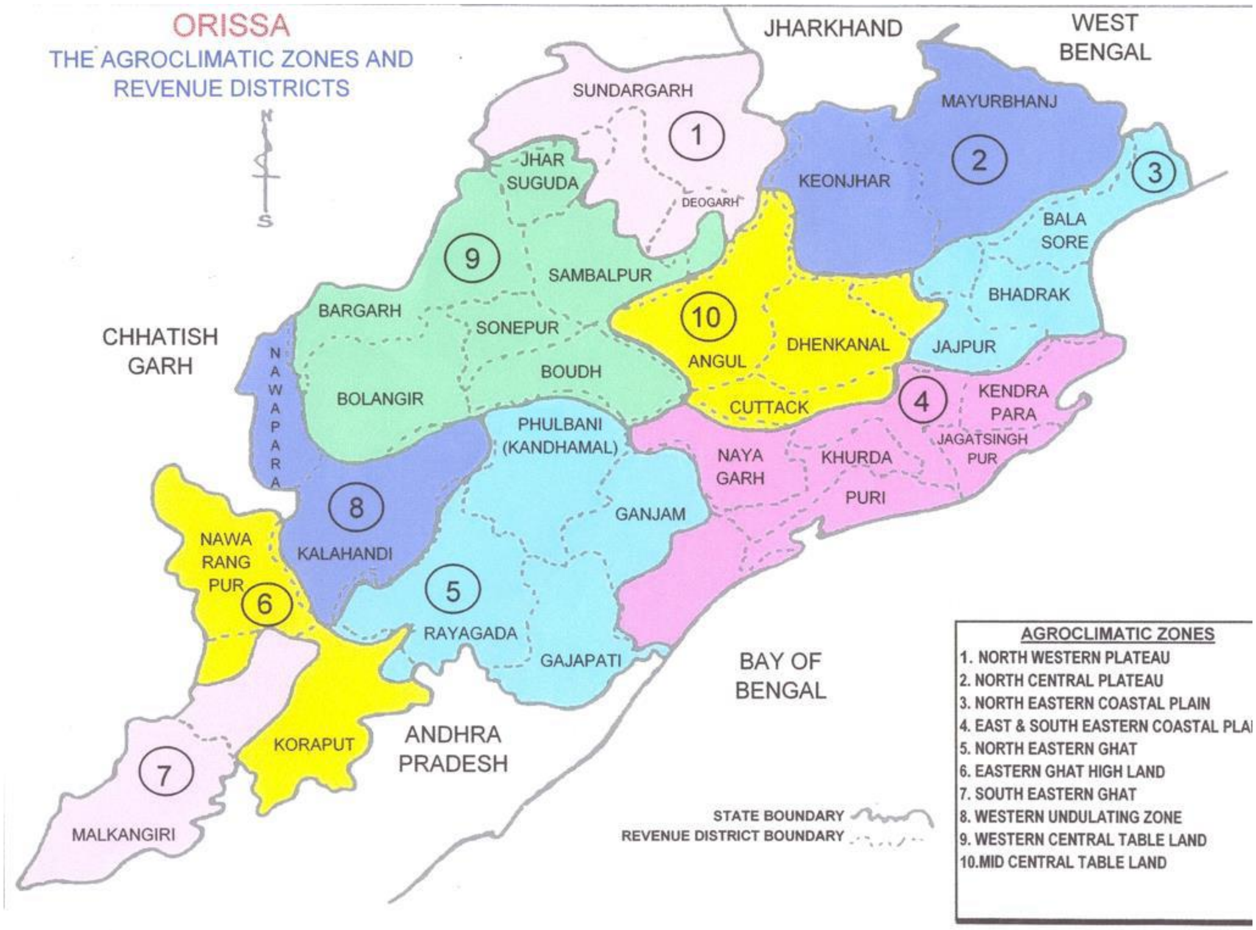


Figure 3.1 Agroclimatic zones of Odisha

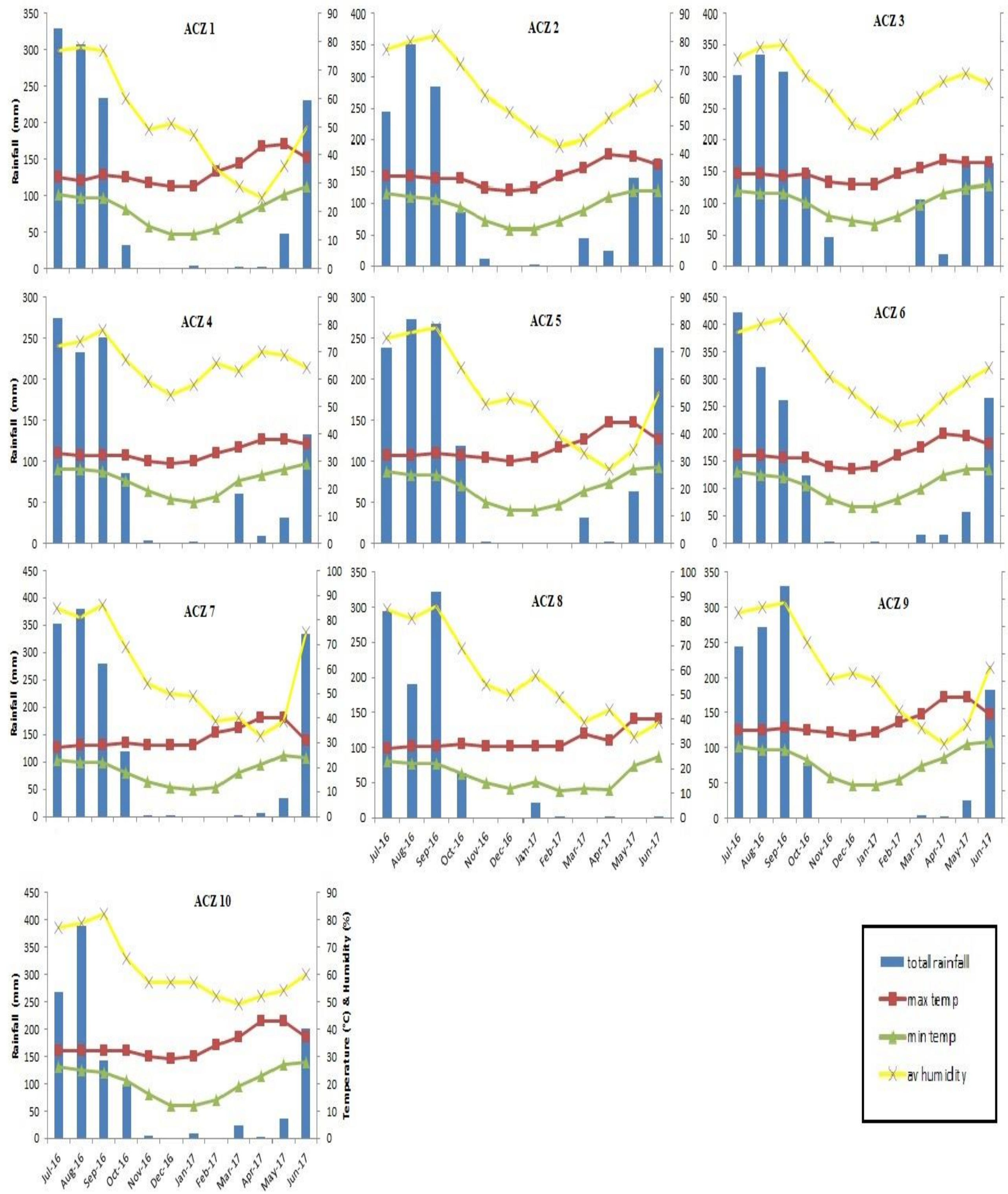


Figure 3.2. Climatogram showing total monthly rainfall and mean monthly minimum and maximum temperature of different Agrocliclimatic zones of Odisha.

Table 3.1: Variation of pH in soil profiles across different agroclimatic zones(ACZs)

Soil profile	ACZ-1	ACZ-2	ACZ-3	ACZ-4	ACZ-5	ACZ-6	ACZ-7	ACZ-8	ACZ-9	ACZ-10
Forest land										
0-25 cm	5.49	5.68	6.40	5.29	5.40	5.71	5.38	5.40	5.63	8.55
25-50cm	5.48	5.87	6.53	5.63	6.03	6.06	5.40	5.48	5.80	6.68
50-75cm	5.64	6.01	6.57	5.74	6.43	6.10	5.53	6.10	5.80	6.35
75-100cm	5.72	6.13	7.40	6.10	6.45	6.29	5.74	6.08	6.16	6.28
Mean	**5.58**	**5.92**	**6.73**	**5.69**	**6.08**	**6.04**	**5.51**	**5.77**	**5.85**	**6.97**
Agricultural land										
0-25 cm	5.78	5.96	7.78	5.61	5.98	6.07	5.87	6.55	6.11	6.29
25-50cm	5.97	6.23	7.93	6.07	7.47	6.42	6.43	6.36	6.43	7.29
50-75cm	6.21	6.43	7.06	6.28	6.4	6.07	6.67	6.19	6.23	8.77
75-100cm	6.29	6.59	7.57	6.14	5.31	6.13	6.56	6.24	6.69	8.59
Mean	**6.06**	**6.30**	**7.59**	**6.03**	**6.29**	**6.17**	**6.55**	**6.34**	**6.37**	**7.74**
T value	**7.264 ****	**9.704****	**2.748**	**3.098**	**0.392**	**0.989**	**6.084****	**2.166**	**12.121****	**0.705**

Forest land :ACZ-1- Sundargarh (Ramlata Reserve Forest), ACZ-2-Mayurbhanj (SimilipalReserve Forest, Chandbil), ACZ-3-Balasore (Tinkosia-Naranpur-Gobipalla Forest),, ACZ-4-Nayagarh (Baispalli--Buguda-BanigochhaForest), ACZ-5-Kandhamal (Siringi Reserve Forest, Balliguda), ACZ-6-Nabarangpur (Ranigarh-Papadahandi-Mahendra Forest Area), ACZ-7-Malkangiri (Haldikund-Ramgiri Forest Area), ACZ-8-Nuapada (Sunabeda Wildlife Reserve), ACZ-9-Bolangir (Khaprakhol-Harishankar Reserve Forest), ACZ-10-Angul (Bambro forest Area),**Agricultural land :**ACZ-1-Sundargarh (Jareikela), ACZ-2-Mayurbhanj (Chandbil), ACZ-3-Balasore (Sialimada), ACZ-4-Nayagarh (Gurah), ACZ-5-Kandhamal (Kanjamendi), ACZ-6-Nabarangpur (Dabugaon), ACZ-7-Malkangiri (Sugriguda), ACZ-8-Nuapada (Tadiba), ACZ-9-Bolangir (Bhainsa), ACZ-10-Angul (Baniadohali)

Table 3.2: Variation of Electrical Conductivity (EC) in soil profiles across agroclimatic zones (ACZs)

Soil profile	ACZ-1	ACZ-2	ACZ-3	ACZ-4	ACZ-5	ACZ-6	ACZ-7	ACZ-8	ACZ-9	ACZ-10
Forest land										
0-25 cm	0.038	0.042	0.071	0.087	0.065	0.058	0.129	0.094	0.075	0.214
25-50cm	0.025	0.036	0.055	0.113	0.134	0.05	0.059	0.021	0.036	0.107
50-75cm	0.016	0.027	0.087	0.026	0.079	0.025	0.041	0.020	0.030	0.066
75-100cm	0.016	0.019	0.117	0.019	0.091	0.03	0.021	0.023	0.056	0.084
Mean	**0.024**	**0.031**	**0.083**	**0.061**	**0.092**	**0.041**	**0.063**	**0.040**	**0.049**	**0.118**
Agricultural land										
0-25 cm	0.062	0.067	0.135	0.053	0.069	0.093	0.098	0.087	0.079	0.072
25-50cm	0.097	0.045	0.197	0.037	0.103	0.085	0.076	0.130	0.064	0.135
50-75cm	0.041	0.032	0.091	0.076	0.042	0.073	0.052	0.118	0.043	0.303
75-100cm	0.029	0.032	0.076	0.054	0.06	0.065	0.068	0.050	0.087	0.167
Mean	**0.057**	**0.044**	**0.125**	**0.055**	**0.069**	**0.079**	**0.074**	**0.096**	**0.068**	**0.169**
T value	**2.554**	**3.009**	**1.067**	**0.211**	**2.538**	**11.769 ** **	**0.685**	**2.030**	**2.986**	**0.659**

Table 3.3: Variation of Soil Organic Carbon (SOC) in soil profiles across different agroclimatic zones (ACZs)

Soil profile	ACZ-1	ACZ-2	ACZ-3	ACZ-4	ACZ-5	ACZ-6	ACZ-7	ACZ-8	ACZ-9	ACZ-10
Forest land										
0-25 cm	1.11	0.85	0.49	1.60	0.44	1.23	1.27	1.47	1.34	0.27
25-50cm	0.62	0.72	0.61	1.31	0.19	0.91	1.67	0.63	0.78	0.29
50-75cm	0.91	0.65	0.36	0.54	0.10	0.65	0.96	0.91	0.93	0.59
75-100cm	0.63	0.43	0.44	0.27	0.21	1.07	0.27	0.73	0.78	0.63
Mean	**0.82**	**0.66**	**0.48**	**0.93**	**0.24**	**0.97**	**1.04**	**0.93**	**0.96**	**0.45**
Agricultural land										
0-25 cm	0.43	0.34	0.38	0.46	0.38	0.48	0.42	0.38	0.44	0.59
25-50cm	0.38	0.29	0.38	0.49	0.63	0.25	0.51	0.53	0.41	0.61
50-75cm	0.36	0.25	0.32	0.37	0.85	0.53	0.37	0.38	0.37	0.72
75-100cm	0.31	0.27	0.34	0.38	0.65	0.32	0.32	0.46	0.36	0.7
Mean	**0.37**	**0.29**	**0.36**	**0.43**	**0.63**	**0.40**	**0.41**	**0.44**	**0.40**	**0.66**
T value	**4.404***	**4.978***	**3.016**	**1.756**	**2.342**	**3.763***	**2.480**	**2.299**	**4.708***	**3.247***

Key as in Table 3.1

Table 3.4: Variation of available Nitrogen(N) in soil profiles across different agroclimatic zones (ACZs)

Soil profile	ACZ-1	ACZ-2	ACZ-3	ACZ-4	ACZ-5	ACZ-6	ACZ-7	ACZ-8	ACZ-9	ACZ-10
Forest land										
0-25 cm	112.50	75.00	112.50	112.50	150.00	125.00	112.50	125.00	125.00	87.50
25-50cm	62.50	112.50	100.00	112.50	87.50	62.50	100.00	112.50	150.00	100.00
50-75cm	50.00	62.50	62.50	87.50	112.50	50.00	75.00	137.50	112.50	175.00
75-100cm	62.50	50.00	125.00	62.50	125.00	125.00	100.00	125.00	175.00	162.50
Mean	**71.88**	**75.00**	**100.00**	**93.75**	**118.75**	**90.63**	**96.88**	**125.00**	**140.63**	**131.25**
Agricultural land										
0-25 cm	100.00	62.50	75.00	87.50	125.00	125.00	100.00	100.00	112.50	112.50
25-50cm	75.00	75.00	75.00	112.50	187.50	175.00	87.50	112.50	137.50	87.50
50-75cm	112.50	100.00	62.50	112.50	137.50	100.00	125.00	112.50	100.00	112.50
75-100cm	87.50	87.50	50.00	100.00	175.00	112.50	112.50	175.00	87.50	137.50
Mean	**93.75**	**81.25**	**65.63**	**103.13**	**156.25**	**128.13**	**106.25**	**125.00**	**109.38**	**112.50**
T value	**2.132**	**1.019**	**0.602**	**1.333**	**2.186**	**2.164**	**1.306**	**0.870**	**0.096**	**0.245**

Key as in Table 3.1

Table 3.5: Variation of available Phosphorus (P) in soil profiles across different agroclimatic zones (ACZs)

Soil profile	ACZ-1	ACZ-2	ACZ-3	ACZ-4	ACZ-5	ACZ-6	ACZ-7	ACZ-8	ACZ-9	ACZ-10
Forest land										
0-25 cm	15.76	2.83	8.40	3.89	10.20	7.26	8.67	3.36	6.37	6.00
25-50cm	6.02	2.65	9.60	3.36	7.80	4.95	6.37	3.54	3.18	7.20
50-75cm	3.36	2.31	9.00	5.49	9.00	3.18	4.25	3.36	3.18	6.60
75-100cm	4.78	2.15	6.00	4.60	6.00	2.65	3.01	4.78	3.18	8.40
Mean	**7.48**	**2.49**	**8.25**	**4.34**	**8.25**	**4.51**	**5.58**	**3.76**	**3.98**	**7.05**
Agricultural land										
0-25 cm	10.20	9.60	7.80	8.34	11.40	6.60	10.66	11.40	8.40	54.40
25-50cm	9.12	9.12	7.80	6.56	6.00	6.00	9.12	33.80	7.80	9.60
50-75cm	7.80	7.80	7.20	5.29	12.70	10.20	7.23	20.50	6.00	6.00
75-100cm	7.26	6.60	6.14	4.36	10.20	9.60	5.61	21.10	5.49	9.00
Mean	**8.60**	**8.28**	**7.24**	**6.14**	**10.08**	**8.10**	**8.16**	**21.70**	**6.92**	**19.75**
T value	**0.493**	**11.037****	**2.125**	**1.508**	**1.327**	**1.803**	**12.192****	**3.907***	**5.062***	**1.066**

Table 3.6: Variation of available Potassium in soil profiles across different agroclimatic zones (ACZs)

Soil profile	ACZ-1	ACZ-2	ACZ-3	ACZ-4	ACZ-5	ACZ-6	ACZ-7	ACZ-8	ACZ-9	ACZ-10
Forest land										
0-25 cm	270.14	126.33	104.80	180.09	930.00	189.50	405.88	270.14	449.96	105.00
25-50cm	139.78	157.24	373.60	153.21	956.90	252.67	361.53	138.43	204.28	138.40
50-75cm	147.84	196.53	71.20	211.00	903.10	278.20	513.40	159.93	252.67	173.30
75-100cm	134.40	268.92	69.80	195.74	817.10	266.11	572.54	172.03	251.32	124.90
Mean	**173.04**	**187.26**	**154.85**	**185.01**	**901.78**	**246.62**	**463.34**	**185.13**	**289.56**	**135.40**
Agricultural land										
0-25 cm	265.76	187.52	124.45	276.57	297.76	248.62	235.67	434.15	153.21	96.75
25-50cm	327.83	252.67	120.91	324.34	56.44	327.93	278.56	794.37	138.43	40.33
50-75cm	288.56	278.20	170.63	289.89	173.38	252.62	288.67	827.91	147.84	83.31
75-100cm	211.00	251.32	230.65	278.67	366.92	262.67	185.13	124.18	120.81	51..00
Mean	**273.29**	**242.43**	**161.66**	**292.37**	**223.63**	**276.39**	**247.01**	**545.15**	**140.07**	**73.46**
T value	**2.405**	**2.184**	**0.075**	**4.973***	**7.210****	**1.087**	**3.377***	**2.004**	**2.939**	**3.312***

Key as in Table 3.1

Table 3.7: Variation of available Sulphur (S) in soil profiles across different agroclimatic zones (ACZs)

Soil profile	ACZ-1	ACZ-2	ACZ-3	ACZ-4	ACZ-5	ACZ-6	ACZ-7	ACZ-8	ACZ-9	ACZ-10
Forest land										
0-25 cm	16.00	20.00	12.95	41.00	18.88	56.00	12.00	25.00	84.00	9.62
25-50cm	12.00	33.00	10.36	27.00	15.54	20.00	20.00	10.00	51.00	8.88
50-75cm	21.00	27.00	5.92	23.00	8.51	39.00	42.00	33.00	13.00	8.88
75-100cm	20.00	21.00	20.35	21.00	10.36	33.00	31.00	65.00	44.00	14.06
Mean	**17.25**	**25.25**	**12.40**	**28.00**	**13.32**	**37.00**	**26.25**	**33.25**	**48.00**	**10.36**
Agricultural land										
0-25 cm	12.50	13.85	15.91	14.06	9.96	16.65	12.00	14.80	16.00	11.47
25-50cm	11.47	15.17	15.54	15.54	8.51	15.91	11.47	15.54	15.54	14.06
50-75cm	8.51	10.36	9.96	13.65	7.77	5.55	8.51	15.17	13.00	11.47
75-100cm	8.51	12.50	7.77	12.50	9.62	12.95	12.50	14.43	14.06	9.96
Mean	**10.25**	**12.97**	**12.30**	**13.94**	**8.97**	**12.77**	**11.12**	**14.99**	**14.65**	**11.74**
T value	**2.374**	**4.219***	**0.024**	**3.242***	**2.052**	**3.093**	**2.103**	**1.546**	**2.394**	**0.704**

Key as in Table 3.1

Table 3.8: Variation in the mean soil parameters from forest land across different agroclimatic zones (ACZs)

Soil profile	ACZ-1	ACZ-2	ACZ-3	ACZ-4	ACZ-5	ACZ-6	ACZ-7	ACZ-8	ACZ-9	ACZ-10
Forest land										
pH	5.58	5.92	6.73	5.69	6.08	6.04	5.51	5.77	5.85	6.97
EC	0.024	0.031	0.083	0.061	0.092	0.041	0.063	0.040	0.049	0.118
Organic Carbon	0.82	0.66	0.48	0.93	0.24	0.97	1.04	0.93	0.96	0.45
Available Nitrogen	71.88	75.00	100.00	93.75	118.75	90.63	96.88	125.00	140.63	131.25
Available Phosphorus	7.48	2.49	8.25	4.34	8.25	4.51	5.58	3.76	3.98	7.05
Available Potassium	173.04	187.26	154.85	185.01	901.78	246.62	463.34	185.13	289.56	135.40
Available Sulphur	17.25	25.25	12.40	28.00	13.32	37.00	26.25	33.25	48.00	10.36

Key as in Table 3.1

Table 3.9: Variation in the mean soil parameters from Agricultural land across different agroclimatic zones (ACZs)

Soil profile	ACZ-1	ACZ-2	ACZ-3	ACZ-4	ACZ-5	ACZ-6	ACZ-7	ACZ-8	ACZ-9	ACZ-10
Agriculture land										
pH	6.06	6.30	7.59	6.03	6.29	6.17	6.55	6.34	6.37	7.74
EC	0.057	0.044	0.125	0.055	0.069	0.079	0.074	0.096	0.068	0.169
Organic Carbon	0.37	0.29	0.36	0.43	0.63	0.40	0.41	0.44	0.40	0.66
Available Nitrogen	93.75	81.25	65.63	103.13	156.25	128.13	106.25	125.00	109.38	112.50
Available Phosphorus	8.60	8.28	7.24	6.14	10.08	8.10	8.16	21.70	6.92	19.75
Available Potassium	273.29	242.43	161.66	292.37	223.63	276.39	247.01	545.15	140.07	73.46
Available Sulphur	10.25	12.97	12.30	13.94	8.97	12.77	11.12	14.99	14.65	11.74

Plate 3.1*Madhuca latifolia* in Natural Forest

Plate 3.2 *Madhuca latifolia* in Agricultural field

CHAPTER-4

TREE DIVERSITY AND ECOLOGICAL STATUS OF *Madhuca latifolia* (Roxb.) J.F. Macbr. IN FORESTS OF ODISHA

4.1 Introduction

Madhuca latifolia (Roxb.) J.F. Macbr. (popularly known as Mahua tree) is a species of much ecological and economic importance to the people of Odisha, and therefore this species is subjected to much human pressure for extraction of its flower and seeds which in turn may lead to change in vegetation structure of this species. The data on characteristics, classification, relationship and distribution of plant communities are useful to describe the population dynamics of each species and how they relate to the other species in the same community. The ecological status of a species and its distribution pattern can well be described by studying various ecological attributes and this information are vital for proper planning and managment. Quantitative study of vegetation is important in understanding the ecosystem dynamics as it describes the vegetation in terms of floristic composition, diversity and phytomass, explains or predicts its pattern and helps in classifying it in a meaningful way. To determine the biodiversity of an area ecologists have devised a number of formulae, indices and models to estimate species richness in a community and to explain the distribution and abundance of the species (Kunin et al2000). Jaccard (1912) and Sorenson (1948) derived formulae to measure similarity between habitats orcommunities based on species composition. Fisher et al.(1943); Shannon and Weiner (1949); Simpson (1949); Pielou (1975); Smith (1986) and Magurran (1988) developed and used different formulae and indices of diversity and suggested appropriate tools for different situations. Simpson (1949) successfully formulated an index known as Simpson's index of dominance. The value of Simpson's index increases as the index of general diversity decreases. The most widely accepted tool for measuring diversity is the Shannon and Weiner's (1949) index commonly known as the Shannon's index of general diversity.Trees are important component of vegetation and therefore their diversity must be constantly monitored to for maintaining species and habitat diversity (Attua and Pabi 2013). Stand tree density has an important implication not only on stand growth and yield but also on the forest health and subsequently on forest ecosystems (Wassihum et al 2019, Zhang et al 2019). Stand density index is often calculated to relate to the tree-size heterogeneity to stand heterogeneity (Zeller et al 2018). Several studies have been carried out in on plant diversity in tropical deciduous forests of Eastern Ghats (Reddy et al 2011, Panda et al 2013), wet evergreen forests of Western Ghats (Parthasarathy et al 1992, Parthasarathy 2001), Andaman and Nicobar islands (Rasingam and Parthasarathy 2009), however, there are limited studies on different forest reserves of Odisha with special reference to the stands that are dominated with Mahua trees.Though the objectives of this chapter is not to have a detailed regeneration study of *M. latifolia* and to relate as to how the disturbance/human pressure plays important role in vegetation structure, nevertheless a comparison of the study between forests under different agroecological zones on its ecological status and tree associates, will be vital in understanding stand structure and demography which may play important role in conservation and management of this important forest resource in the state.Thispaper aims to assess tree species diversity and composition in different forest under 10 agroclimatic zones of Odisha, with special reference of Mahua tree.

4.2 Materials and Methods

4.2.1 Study area and selection of plots

The study was conducted in forests located in 10 agroclimatic zones (ACZs) of odhisa (Fig 4.1).These were ACZ-1- Sundargarh (Ramlata Reserve Forest),ACZ-2-Mayurbhanj (Similipal Reserve Forest, Chandbil),ACZ-3-Balasore (Tinkosia-Naranpur-Gobipalla Forest), ACZ-4-Nayagarh (Baispalli--Buguda-Banigochha Forest),ACZ-5-Kandhamal (Siringi Reserve Forest, Balliguda), ACZ-6-Nabarangpur (Ranigarh-Papadahandi-Mahendra Forest Area), ACZ-7-Malkangiri (Haldikund-Ramgiri Forest Area), ACZ-8-Nuapada (Sunabeda Wildlife Reserve), ACZ-9-Bolangir (Khaprakhol-Harishankar Reserve Forest), ACZ-10-Angul (Bambro forest Area).In this study of tree associates in natural forests and the ecological status of *M. latifolia* was studied.

4.2.2 Tree Vegetation Sampling

For studying the tree associates and ecological status of *M. latifolia* in the forests under different provenances/agroclimaticzones (ACZ) twenty five random quadrats/plots each measuring 20 m x 20 m were selected during 2016-17. All the trees having ≥30 cm girth at breast height (gbh- above 137 cm from the ground) that were present in the quadrats/plots were identified, recorded and evaluated for the phytosociological attributes. The area of each sampled plots were measured using a tape along the boundary and permanent study plots were laid within and marked with paint for reference. Geographical co-ordinates at the centre of these plots were taken using a hand held GPS.All trees present in each sampled plot were identified and recorded by their botanical name, or by local name and later confirmed from published books.Flora of Presidency of Madras (Gamble and Fischer 1915-1935) and Flora of Orissa (Saxena and Brahmam 1990)was consulted. The stand structures were measured in terms of species composition, frequency, basal area, importance value index and association index.

4.2.3 Tree species composition, diversity and community indices

Data recorded in 2016 were pooled by different plot categories to estimate density (D), frequency (F), abundance (A), Total basal area as dominance, and the relative values respectively (Misra 1968, Muller-Dombois and Ellenberg 1974). Importance value index (IVI) was calculated as sum of relative values of density (RD), frequency (RF), and dominance (RD) (Curtis, 1959). Tree species diversity index, *H'*; Concentration of dominance of trees, *Cd*; Tree species richness index, *SRI* and evenness index, *E* was calculated using the formula as given in the references below:

1. Shannon–Weiner diversity index, *H'* (Shannon and Weiner 1949):

$$H' = -\sum_{5=1}^{s} pilnpi$$

Where, *H'* is the Shannon–Weiner diversity index *pi* is the proportion of individuals in the i^{th} species i.e. (ni/N).

2. Simpson Index of Dominance, *Cd*(Simpson 1949):

$$Cd = \sum_{i=0}^{n} \mathrm{p}i^2$$

Where, p_i = proportion of individual in the $\underline{i}^{th}$ species.

3. Marglef richness index, *SRI* (Margalef 1958):

$$SRI = \frac{S-1}{ln\,(N)}$$

Where, *S* is the total number of species

N the number of individuals

4. Evenness index, E (Pielou 1975)**:**

$$E = \frac{H'}{ln\,S}$$

Where, *H*' is the Shannon–Weiner diversity index

S is the total number of species.

5. Sorensen's similarity index (Sorensen 1948):

$$\mathrm{S} = \frac{2\mathrm{C}}{\mathrm{A}+\mathrm{B}}$$

Where, S = Sorensen's similarity coefficient

A = Number of species present in sample A

B = Number of species present in sample B

C = Number of species present in both samples

6. Dispersion pattern of a species is given by its abundance to frequency ratio (A/F) and the ranges of values for determining dispersion pattern are presented by Cottam and Curtis (1956) as regular (< 0.025), random (0.025 - 0.05) and contiguous (> 0.05).

7. Association Index: The inter-specific association was evaluated by association index which helps in determining the main associates of a important species in the forest. It was estimated by the equation

$$\text{Association Index of a Species (A)} = \frac{\text{Total no. of quadrants in which species A occurs along with another species (B) in the stand}}{\text{Total no. of quadrant in which species A occurs in that stand}} \times 100$$

Each tree species recorded in the forest plots in different ACZswere classified by family and genera.

4.3 Results and Discussion

4.3.1 Taxonomic diversity and species richness:

The phytosociology and diversity attributes of tree species are given in Table 4.1. Tree species richness in forests of different ACZs varied to a great extent. The forests of ACZ-8 (Nuapada) had maximum number of tree species (29) followed by ACZ-6 (Nabarangpur) 26 species, ACZ-9 (Bolangir) and ACZ-10 (Bambro forest under Angul) 23 each, ACZ-2 (Mayurbhanj) 22 species, ACZ-5 (Kandhamal) 20 species, ACZ-1 (Sundargarh) 19 species, ACZ-4 (Nayagarh) 18 species, ACZ-3 (Balasore) 17 species and the lowest 15 species in the forests under ACZ-7 (Malkangiri). The family-wise distribution of tree species in different ACZs is given in Table 2.

The results showed that a total of 54 tree species belonging to 29 families were encountered from the forests of different ACZs. Fabaceae was the most dominant family contributing 9 species, followed by Rubiaceae which contributed 6 species. Combretaceae, Moraceae, Anacardiaceae each contributed 4 species while Phyllanthaceae, Meliaceae; Myrtaceae was represented by 2 species each. The other families which were represented in the tree flora included Rubiaceae, Mimosoideae, Bombcaceae, Lecythidaceae, Arecaceae, ceasalpinaceae, Poaceae, Burseraceae, Boraginaceae, Detariodeae, Apocynaceae, Lythraceae, Sapotaceae, Euphorbiaceae, Annonaceae, Oleaceae, Sapindaceae, Dipterocarpaceae, Bignoniaceae, Ebenaceae and Rhamnaceae, each of which contributed one species each. The number of families contributing to tree diversity also varied widely among the forests of ACZs. Anacardiceae was the most dominating family followed by Combetaceae, Fabaceae, Phyllanthaceae and Ruabiaceae in contributing to tree taxonomic diversity in the study area.

4.3.2 Ecological diversityand Association index:

The Shannon diversity index of treesvaried from 1.6846 inforests under ACZ-3 to 2.5604 in ACZ-9. Pileu's evenness index varied from 0.532 (ACZ-05) to 0.817 (ACZ-9). Simpson's dominance index varied from 0.03425 (ACZ-10) t0 0.33516 (ACZ-5) and Margalef species richness varied from 2.784 (ACZ-3) to 5.415 (ACZ-8). The Shannon-Wiener index (H′) for all the natural forests studied under different agroclimatic zones ranges from 1.592–2.560with maximum in ACZ-9 (2.560) and minimum in ACZ-5 (1.592). These values indicate that the present dry deciduous and moist deciduous forests studied arehaving species diverse system. The diversity values for Indian forests were reported by many researchers in the range of 0.83 to 4.1 (Parthasarthy et al 1992, Vishalakshi 1995, Rasingam amd Parthasarathy 2009, Shukla 2009). Thus, the diversity values of tree species found in this present study is well within the earlier reported range of Indian tropical forests. However, the values do not figure closer to the higher side of the reported range (4.1) which may be due to the higher anthropogenic interferences in these forests for collections of mahua flowers, seeds, other NTFPs and fuel wood directly or indirectly affecting soil erosions, soil moisture, plant growth and regeneration of species. Knight (1975) also explained that anthropogenic activities areresponsible for the lower species diversity in some tropical forests.There are other explanations for the diversity patterns which suggest that along with the main factors such as speciation, the geological history of the site, climate and precipitation as functions of latitudinal and altitudinal position (Gentry, 1988, 1992, Lieberman et al 1985, Vázquez and Givnish, 1998), and edaphic properties (Misra and Ramakrishnan 1983, Gentry 1988), a few other crucial factors such as competition (Huston 1979, 1980, Tilman 1982, Ashton 1989), and spatial and temporal micro-niche availability also influence the diversity (Tilman and Pacala 1993). The extent of dominance (Simpson's index) in the present study was lower but within the range reported in other forests (Knight 1975, Visalakshi 1995, Lalfakawma et al 2009).

4.3.3 Similarity:

Sorensen's index of qualitative similarity of trees indicated maximum similarity (60.61) between the forest stands under ACZ-4 and ACZ-7, followed by ACZ-6 and ACZ-7 (53.66) and ACZ-3 and ACZ-4 (51.43) and ACZ-4 and ACZ-6 (50.0) and ACZ-3 and ACZ-7 (Table4.3). The least similarity in tree species was found between ACZ-5 and ACZ-9 (18.60).

4.3.4 Associate index and spatial distribution pattern:

The association index of species for *M. latifolia* varied widely (Table 4) and the most important associates were *Shorea robusta*, *Termimalia bellerica*, *Buchnania lanzan* and *Lagerstoemia parviflora*. Majority of the tree species showed clumbed or contiguous distribution. This was true in all ACZs studied except ACZ-7 (Malkangiri) and ACZ-9 (Bolangir) forests(Table 5). Regular distribution pattern was observed in very few trees growing in the ACZs. The tree species which showed regular distribution in AEZs included *M. latifolia*, *T. bellerica*and *L. parviflora* in ACZ-1, *T. tomentosa* in ACZ-2, *S. cumuni* in ACZ-3, *M.latifolia*, *S. cumuni* and *T. tomentosa* in ACZ-4, *M. indica* and *S. anacardium* in ACZ-5, *S. cumuni*, *M. latifolia* and *F. religiosa* in ACZ-6, *M. latifolia*, *P. marsupium* and *D. melanoxylon* in ACZ-7, *D. strictus* and *M. latifolia* in ACZ-8, *D. paniculata* and *M. latifolia* in ACZ-9 and *B. lanzan*, *B. retusa* and *M. latifolia* in ACZ-10. The per cent of tree species showing contiguous or clumbed distribution in different ACZs were ACZ-2 (73%) >ACZ-5 (70%) >ACZ-1 (68%) >ACZ-7 (67%) >ACZ-8

(66%) >ACZ-6 (62%) >ACZ-10 (61%) >ACZ-4 (44%). Higher number of tree species, however, was observed with random distribution in ACZ-7 (67%) and ACZ-9 (57%).*M. latifolia* showed random dispersal pattern in most of the agroclimatic zones and contiguous dispersal pattern in few agroclimatic zones. This may be due to the degraded edaphic conditions of the forest created by anthropogenic activities which donot favour the growth and establishment of the mahua seedlings and saplings though the species is has a a very high germination rate.In most of the agroclimatic zone, *S. robusta*, *M. latifolia* and *B.lanza*n showed higher IVI values. The tree species with higher IVI values indicate good regenerating capability, more adaptability and wide ecological amplitude. In the present study *S .robusta*, *M. latifolia* and *B. lanza*n showed wider adaptability and good regenerating ability in different forests under various agroclimatic zones. The IVI of *M. latifolia* was in the order of ACZ-5 (84.27)>ACZ-8 (78.55)>ACZ-2> (76.74)>ACZ-9 (71.22)>ACZ-1 (54.77) which indicates its adaptability, regenerating ability and establishment in the respective forests.

4.3.5 Density:

The density of tree species varied widely between and within the forest stands across the ACZs (Table 4.4). In ACZ, *Shorea robusta* had highest density (131.25 individuals ha^{-1}), followed by *Madhuca latifolia* (56.25 ha^{-1}), *Buchnania lanzan* (50.00ha^{-1}), *Cleistanthus collinus* (46.87 ha^{-}), *Lagerstoemia parviflora* (28.12 ha^{-1}), both *Diospyrus melanoxylon* and*Terminalia bellerica* (21.87 ha^{-1}) where as *Bombax ceiba, Cassia fistula, Bridelia retusa, Holarrhena antidysenterica, Mallotus philipinensis, Anogeissus latifolia* and *Chloroxylon swietenia*had lower number of individuals ha^{-1}. *S. robusta* invariably, was the most dominat tree species in majority of the ACZs. In addition the other most common and notable species in terms of their tree density, in the study area were *Madhuac latifolia, Lagerstromea parviflora, Cleistanthus collinus, Lannea coromandelica, Terminalia bellerica and Terminalia chebula, Semecarpus anacardium*. Some tree species had a very restricted distribution. For example, *Artocarpus heterophyllus* and *Ficus bengalensis* were found onlyin ACZ-5 (Kandhamal forest areas). Similarly, *Miliusa tomentosa* was restricted to ACZ-6 (Nabarangpur forests), *Nyctanthes arbortristis* to ACZ-10 (Bamro forests under Angul), *Stereospermus suaveolens* to ACZ-6 (Nabarangpur forests) and *Zizyphus mauritiana* to ACZ-9 (Bolangir forests). Under ACZ-3*S. robusta* had maximum tree density (306.75 ha^{-1}), followed by *Buchnania lanzan* (145.25ha^{-1}),*Madhuca latifolia* (127.25 ha^{-1}), *Terminalia tomentosa* (50.00 ha^{-1}), *Terminalia bellerica* (18.00 ha^{-1}), *Lannea coromandelica* and *Syzygium cumini* (13.50 ha^{-1}), *Anogeissus latifolia* (11.25 ha^{-1}), *Careya arborea* (6.75 ha^{-1}), where as the minimum density (2.25 ha^{-1}) were recorded for *Terminalia chebula, Diospyrus melanoxylon, Bridelia retusa, Bombax ceiba, Cassia fistula, Bridelia retusa, Semecarpus anacardium, Pterocarpus marsupium, Adina cordifolia, Albizia procera* and *Morinda tinctoria*.In ACZ-4, similarly*S.robusta* hadmaximum density (122.50 ha^{-1}) followed by *M.latifolia* (40.00 $ha^{-1)}$, *Buchnania lanzan* (35.00ha^{-1}), *Adina cordifolia* (27.50ha^{-1}), *Terminalia tomentosa* and *Schleichera oleosa* (17.50 ha^{-1} each). In ACZ-5 besides *S. robusta* (236.50ha^{-1}) and *M. latifolia* (123.25ha^{-1}), the other tree species which showed higher tree density were *M. indica* (21.50ha^{-1}), *B. lanzan* (18.25ha^{-1}), *S. anacardium* (15.00ha^{-1}). The other constituent tree species which were of less important in this ACZ were *Syzygium cumini*, *Dendrocalamus strictus*, *Pterocarpus marsupium*, *Ficus glomerata*, *Ficus religiosa and Toona ciliata*).In ACZ-6, the maximum density of *Shorea robusta* and *Holiarhena antidysenterica* (155.5ha^{-1}) were found followed by *Syzygium cumini* (58.25ha^{-1}) , *Buchnania lanzan and Terminalia tomentosa* (52.75ha^{-1}) , *Madhuca latifolia* and *Ficus religiosa* (44.25ha^{-1}), *Syzygium cerasoides* (33.25ha^{-1}), *Diospyrus melanoxylon* and *Pterocarpus marsupium* (19.25ha^{-1}), *Terminalia chebula*, *Anogeissus latifolia* and *Careya arborea* and *Miliusa tomentosa* (13.75ha^{-1}) , *Schleichera oleosa* (11ha^{-1}), *Lannea coromandelica* (8.25ha^{-1}), *Semecarpus anacardium* (5.5ha^{-1}), however, minimum density (2.75ha^{-1}) were found in case of *Terminalia bellerica, Lagerstoemia parviflora, Bombax ceiba, Cassia fistula, Bridelia retusa, Grewia tilifolia, Dalbergia panniculata, Adina cordifolia* and *Hardwica binnata.* In ACZ-7, 15 major tree species were recorded with maximum density of *Shorea robusta* (170ha^{-1}), *Syzygium cerasoides* (75ha^{-1}),*Lagerstoemia parviflora* (65ha^{-1}), *Syzygium* *cumini* (50ha^{-1}), *Madhuca latifolia* (35ha^{-1}), *Diospyrus melanoxylon* (25ha^{-1}), *Terminalia tomentosa* (15ha^{-1}), *Pterocarpus marsupium* (10ha^{-1}), however, minimum density (5ha^{-1}) was observed for *Terminalia bellerica*, *Buchnania lanzan, Semecarpus anacardium, Ixora arborea , Schleichera oleosa, Adina cordifolia* and *Stereospermum suaveolens***.**Under ACZ- maximum density (150ha^{-1}) for *Cleistanthus collinus* and *Schleichera oleosa* were reported followed by *Buchnania lanzan and Dlbergia panniculata* (45ha^{-1}), *Terminalia tomentosa* (37.5ha^{-1}), *Madhuca latifolia* and *Dendrocalamus strictus* (30ha^{-1}), *Chloroxylon swietenia* and *Gardenia latifolia* (25ha^{-1}), *Lannea coromandelica and Dalbergia latifolia* (12.5ha^{-1}), *Lagerstoemia parviflora, Anogeissus latifolia, Cassia fistula , Pterocarpus marsupium, Adina cordifolia and Hardwica binnata* (10ha^{-1}), *Semecarpus anacardium* (7.5ha^{-1}), *Holiarhena antidysenterica and Butea monosperma* (5ha^{-1}), *Terminalia bellerica, Bahunia roxburghiana, Careya arborea, Grewia tilifolia, Nyctanthes arbortristis* and *Soymida febrifuga* (2.5ha^{-1}). Incase of ACZ-9,maximum density for *Buchnania lanzan* and *Butea monosperma* (70ha^{-1}) were reported followed by *Madhuca latifolia* and *Dlbergia panniculata* (60ha^{-1}), *Cleistanthus collinus, Diospyrus melanoxylon* and *Zizyphus mauritiana* (32.5ha^{-1}), *Lannea coromandelica ,Anogeissus latifolia, Semecarpus anacardium, Aegele marmelos* and *Terminalia tomentosa* (12.5ha^{-1}), *Bridelia retusa* (10ha^{-1}), *Terminalia bellerica, Lagerstoemia parviflora, Pterocarpus marsupium* and *Schleichera oleosa* (7.5ha^{-1}),*Careya arborea* (5ha^{-1}), *Terminalia chebula, Cassia fistula, Grewia tilifolia, Mitragyna parviflora* and *Acacia leucophloea* (2.5ha^{-1}). In ACZ-10, *Shorea robusta* (112.5ha^{-1}) was the most dominant species contributing to the number of individuals to the stand followed by *Buchnania lanzan* (50ha^{-1}), *Madhuca latifolia* (37.5ha^{-1}), *Terminalia bellerica* (25ha^{-1}), *Cleistanthus collinus, Diospyrus melanoxylon*a and *Bridelia retusa* (20.75ha^{-1}), *Lagerstoemia parviflora* and *Pterocarpus marsupium* (16.5ha^{-1}), *Lannea coromandelica, Syzygium cerasoides* and *Nyctanthes arbortristis* (12.5ha^{-1}), *Mangifera indica, Mitragyna parviflora* and *Dendrocalamus strictus* (8.25ha^{-1}), *Terminalia chebula, Anogeissus latifolia, Bombax ceiba, Cassia* *fistula, Holiarhena antidysenterica, Semecarpus anacardium, Grewia tilifolia, Soymida febrifuga* and *Terminalia tomentosa* (4ha^{-1}).

The density of trees (>30 cm dbh) in different forests under various ACZs varied from 342.5 to 789.5 stemsha^{-1} with maximum number encountered in ACZ-2 and minimum in ACZ-4. Reddy et al (2011) reported 527-665 stems ha^{-1}in tree diversity study in tropical forest of Similipal Biosphere Reserve, Odisha whereas Sahu et al (2010) foundmean stand density as 671 ha^{-1} in Site-I and 565ha^{-1} in Site-II as the arboreal taxa diversity of tropical forests of Gandhamardan Hill Range in Odisha.In tropical forests of south Western Ghatsdensity of trees in various tropical evergreen forests ranged from 852 to 965 stems ha^{-1} in the medium elevation of forests of Kalakad (Parthasarathy 2001), 583 stems ha^{-1} in Kalakad-Mundanthurai area (Ganesh et al 1996), a range of 270-673 trees ha^{-1} in Veragalaiar forests, Anamalais (Ayyappan and Parthasarathy 1999), 435 to 767 trees ha^{-1} in Eastern Ghats of Andhra Pradesh (Naidu and Kumar 2016). The range of density of tree species in our study falls within the range of 276-905 stems/ha reported for trees ≥15 cm gbh in other tropical forests (Sundarapandian and Swamy 1997,Bhadra et al 2010). The density of tree species reported in other tropical sites across the world also shows similar trend as in Costa Rica from 448 to 617 ha^{-1} (Heaney and Proctor 1990); in Brazil from 420 to 777 ha^{-1} (Campbell et al 1992) and in Malaysia 250 to 500 ha^{-1}(Primack and Hall 1992). Higher stand tree density nevertheless is desirable for optimum forest growth and yield. However, stand density is also important in explaining the degree to which the growing space is available for tree growth (Reyes-Herandez and Comeau 2015) and changes in stand density as a result of tree mortality (owing to various anthropogenic or natural factors) may adversely affect individual tree sizes. *M. latifolia* showed higher density in ACZ-2 (137.5 stems/ha), ACZ-3 (127.25 stems ha^{-1}) and ACZ-5 (123.25 stems ha^{-1}) and contributes alone 17.41%, 17.91% and 26.63% respectively to the total tree density in these ACZs. This indicates these three zones are more favourable for proper establishment, growth and development of *M. latifolia.*

4.3.6 Dominance:

In ACZ-1, based on the IVI value the most dominant species was *S. robusta* (96.04) followed by *M. latifolia* (54.22), *Buchnania lanzan*(27.93), *Lagerstoemia parviflora* (22.16), *Cleistanthus collinus* (16.80), *Diospyrus melanoxylon* (12.10)and*Terminalia bellerica* (11.55).The other species that were co-dominant in the forest of this ACZ were*Bahunia roxburghiana* (5.03), *Semecarpus anacardium* (4.98), *Lannea coromandelica* (4.54), *Careya arborea* (3.71), *Mallotus philipinensis* (3.25), *Holarrhena antidysenterica* (3.14), *Anogeissus latifolia* and *Bombax ceiba* (3.05), *Chloroxylon swietenia* (2.89),*Bridelia retusa* (2.84), however, the lowest IVI was recorded for *Cassia fistula* (2.83).IVI was found highest in ACZ-2 for *Shorea robusta* (77.95) followed by *Madhuca latifolia* (76.74), *Buchnania lanzan* (22.66), *Terminalia tomentosa* (19.85), *Diospyrus melanoxylon* (13.43), *Cleistanthus collinus* (10.51), *Ixora arborea* (9.89), *schleichera oleosa* (7.73) , *Syzygium cumini* (7.37) , *Terminalia chebula* (5.81) , *Pterocarpus marsupium* (5.62) , *Mangifera indica* (4.61), *Terminalia bellerica* (4.43), *Adina cordifolia* (4.07), *Garuga pinnata* (3.99), *Chloroxylon swietenia* (3.98), *Bombax ceiba* (3.72), *Dalbergia latifolia* (3.11), *Lannea coromandelica* (3.02), *Bridelia retusa* (2.95), *Acacia pennata* (2.89) , where as, lowest were found in case of *Anogeissus latifolia* and *Cassia fistula* (2.78).Highest IVI was recorded for *Shorea robusta* (125.89) in agroclimatic zone 3 which was followed by *Madhuca latifolia* (49.29), *Buchnania lanzan* (45.9), *Terminalia tomentosa* (21.52), *Syzygium cumini* (11.11), *Terminalia bellerica* (9.19), *Lannea coromandelica* (9.04) , *Anogeissus latifolia* (6.99) *Careya arborea* (5.98), *Albizia procera* (2.14), *Pterocarpus marsupium* and *Morinda tinctorial* (1.89), *Terminalia chebula* (1.83), *Semecarpus anacardium* (1.81), *Bridelia retusa* (1.80) , however,lowest IVI was recorded for both *Diospyrus melanoxylon* and *Adina cordifolia* (1.78).For ACZ-4, the highest IVI was observed in case o*f Shorea robusta* (116.8) followed by *Madhuca latifolia* (34.8), *Buchnania lanzan* (20.86), *Schleichera oleosa* (20.35), *Adina cordifolia* (16.79), *Terminalia tomentosa* (13.9), *Bridelia retusa* (12.55), *Syzygium cumini* (12.47), *Semecarpus anacardium* (7.81), *Lannea coromandelica* (6.69), *Diospyrus melanoxylon* (5.84), *Cleistanthus collinus* (5.34), *Anogeissus latifolia* (5.12), *Albizia procera* (5.02), *Bahunia roxburghiana* (3.74), *Pterocarpus marsupium* (2.46), *Lagerstoemia parviflora*, *Grewia tilifolia* and *Morinda tinctoria* (2.34), where as, the lowest IVI was observed for *Ixora arborea* (2.29). In ACZ-5, thehighest IVI was recorded for*Shorea robusta* (87.02) followed by*Madhuca latifolia* (84.27), *Mangifera indica* (39.11), *Semecarpus anacardium* (14.11), *Buchnania lanzan* (11.17), *Ficus glomerate* (7.54), *Terminalia chebula* (7.36), *Ficus religiosa* (6.84), *Terminalia bellerica* (5.61), *Ficus bengalensis* (5.5), *Dendrocalamus strictus* (5.11), *Caryota urens* (4.81), *Terminalia tomentosa* (4.3), *Cassia fistula* (3.9), *Atrocarpus heterophyllus* (3.1),*Tamarindus indica* (2.58), *Anogeissus latifolia* (2.14), *Pterocarpus marsupium* (1.87), *Toona ciliata* (1.8), however, the lowest IVI was recorded for *Syzygium cumini* (1.79). The IVI was found to be highest in ACZ-6 for both*Shorea robusta* and *Holiarhena antidysenterica* (92.03), followed by *Madhuca latifolia* (30.64), *Ficus religiosa* (30.64), *Syzygium cumini* (28.88), *Buchnania lanzan* and *Terminalia tomentosa* (19.43), *Diospyrus melanoxylon* (12.70),*Careya arborea* (12.00), *Pterocarpus marsupium* (10.56), *Syzygium cerasoides* (10.50), *Terminalia chebula* and *Miliusa tomentosa* (7.27),*Schleichera oleosa* (6.82), *Anogeissus latifolia* (6.05), *Lannea coromandelica* (4.51), *Terminalia bellerica* and *Adina cordifolia* (4.33), *Bombax ceiba* (3.26), *Semecarpus anacardium* (2.81), *Grewia tilifolia* and *Dalbergia panniculata* (2.15), *Bridelia retusa* (1.98), *Lagerstoemia parviflora* and *Hardwica binnata* (1.93), however, the lowest IVI was found in case of *Cassia fistula* (1.90). The highest IVI in case of ACZ-7 was recorded for *Shorea robusta* (128.87) followed by *Syzygium cerasoides* (31.29), *Madhuca latifolia* (30.8), *Lagerstoemia parviflora* (25.48), *Syzygium cumini* (23.47), *Diospyrus melanoxylon* (15.05), *Pterocarpus marsupium* (9.11), *Terminalia tomentosa* (6.83), *Terminalia bellerica* (5.00) , *Schleichera oleosa* (4.65), *Stereospermum suaveolens (*4.23), *Semecarpus anacardium* (4.08), *Adina cordifolia* (4.04), *Buchnania lanzan* (4.03), however, lowest IVI was recorded for *Ixora arborea* (4.00).For ACZ-8, the highest IVI was recorded for both *Madhuca latifolia* and *Dendrocalamus strictus* (78.55) followed by *Cleistanthus collinus* and *Schleichera oleosa* (52.63), *Buchnania lanzan* and *Dlbergia panniculata* (25.48), *Terminalia* *tomentosa* (22.98), *Chloroxylon swietenia* and *Gardenia latifolia* (11.42), *Anogeissus latifolia* and *Adina cordifolia* (7.23), *Lagerstoemia parviflora* and *Pterocarpus marsupium* (7.08), *Lannea coromandelica* and *Dalbergia latifolia* (6.73), *Cassia fistula* and *Hardwica binnata* (6.63), *Terminalia chebula* and *Ixora arborea* (5.11), *Semecarpus anacardium* (3.74), *Holiarhena antidysenterica* and *Butea monosperma* (2.87), *Terminalia bellerica* and *Nyctanthes arbortristis* (2.51), *Bahunia roxburghiana*, *Careya arborea* , *Soymida febrifuga*, where as, the lowest IVI was recorded for *Erythrina suberosa* and *Grewia tilifolia* (2.17).IVI were observed highest for both *Madhuca latifolia* and *Dalbergia panniculata* (71.22) in ACZ-9 followed by *Buchnania lanzan* and *Butea monosperma* (34.25), *Diospyrus melanoxylon* (32.3), *Cleistanthus collinus* and *Zizyphus mauritiana* (15.96), *Lannea coromandelica* and *Aegele marmelos* (9.59), *Anogeissus latifolia* and *Terminalia tomentosa* (8.84), *Bridelia retusa* (8.83), *Semecarpus anacardium* (7.61), *Terminalia bellerica* and *Pterocarpus marsupium* (6.86), *Lagerstoemia parviflora* and *Schleichera oleosa* (6.21), *Careya arborea* (4.17), *Mitragyna parviflora* (2.49), *Grewia tilifolia* (2.13), *Terminalia chebula* and *Acacia leucophloea* (2.07), however, lowest IVI was observed in case of *Cassia fistula* (2.04)in this ACZ. The highest IVI was found in ACZ-10 for *Shorea robusta* (58.23) followed by *Buchnania lanzan* (28.25), *Terminalia chebula* (20.59), *Cleistanthus collinus* (20.14), *Madhuca latifolia* (17.39), *Soymida febrifuga* (14.17), *Mitragyna parviflora* (10.24), *Lannea coromandelica* (8.99), *Nyctanthes arbortristis* (8.33), *Grewia tilifolia* (7.73), *Lagerstoemia parviflora* (7.37), *Terminalia bellerica* (6.69), *Semecarpus anacardium* (6.50) *Cassia fistula* (5.64), *Syzygium cerasoides* (5.15) *Dendrocalamus strictus* (5.05), *Anogeissus latifolia* (3.17), *Mangifera indica* and *Terminalia tomentosa* (3.02), *Bombax ceiba* and *Holiarhena antidysenterica* (2.77), *Bridelia retusa* and *Pterocarpus marsupium* (2.67), however, the lowest IVI was recorded for *Diospyrus melanoxylon* (2.5) in this ACZ.

4.3.7 Dominance-diversity curve and distribution of basal area in different girth class:

The dominance-distribution curve showing a lognormal distribution also supports that these forests are species-rich and heterogeneous communities (Magurran 1988) and represent a more complex community, ordered by a multiplicity of interactions.The distribution of basal area in the study sites revealed that majority of species were in intermediate girth class barring sites ACZ-8 and ACZ-10 (Figure 3). In the later two stands, the frequency distribution of tree size in the forest exhibited somewhat reverse J-shaped (a clear trend in ACZ-10) which revealed that a majority of the tree population in these stands were younger ones. The contribution of *M. latifolia* to the stand basal area varied widely from as low as 8.06% (in ACZ-4) to as high as 60.01% (in ACZ-6). The other stands where basal area of *M. latifolia* was significantly higher were ACZ-2 (46.75%), ACZ-5 (37.04%), ACZ-8 (35.36%), ACZ-9 (32.85%) and ACZ-1 (26.09%). Many studies have reported decreasing species richness with increasing girth class of trees in various tropical forests (Panda et al 2013).

4.3.8 Ecological Status of *M. latifolia:*

The density of *M. latifolia* in most of the forests under respective agroclimatic zones was found next to the density of *S.robusta* except ACZ-6 and 7 where the position of *M. latifolia* is 3rd in decreasing order of density (Table 5). In case of agroclimatic zone 10 with *S.robusta*at highest density, *M. latifolia* recorded at 5th position. However, the incase of ACZ-8, *C.collinus* found maximum density and *M. latifolia* in 3rd position and in AEZ-9*B.lanzan* with highest density followed by *M. latifolia.* Among all the ACZs, *M. latifolia* recorded for maximum density in ACZ-2 (137.5ha^{-1}) and minimum for ACZ-8 (30ha^{-1}), however, the relative density was found maximum incase of ACZ-5 (26.52) and minimum for ACZ-10 (4.73). The frequency of occurrence of *Madhuca latifolia* was found to be 100% in all the forests under respective agroclimatic zones; however, the relative frequency was recorded maximum in forest under ACZ-5 (20.83) and minimum in forest under ACZ-10 (11.53). Within the agroclimatic zone, Abundance was found second highest incase of *Mahuca latifolia* next to *Shorea robusta* in ACZ- 2, 3 and 5. However, among the agroclimatic zones maximum abundance was recorded for *Madhuca latifolia* in agroclimatic zone 2 (5.50) and minimum was recorded for agroclimatic zone 8 (1.20).Relative dominance was observed highest incase of *Madhuca latifolia* in ACZ- 5, 8 and 9, however, observed second highest for *Madhuca latifolia* after *Shorea robusta* in agroclimatic zones 1, 2, 3, 6, 7 and 10. Among the ACZs, relative dominance value of *Madhuca latifolia* was recorded maximum for AEZ-8 (57.85) where as minimum value was recorded for ACZ-4 (8.03). With in each agroclimatic zone, Importance Value Index (IVI) was recorded highest for *Madhuca latifolia* under ACZ-8 and 9, where as, IVI recordedsecond highest for *Madhuca latifolia* after *Shorea robusta* under agroclimatic zone 1, 2, 3, 4, 5 and 6 . Among the agroclimatic zones, maximum value of IVI for *Madhuca latifolia* was observed in ACZ-5 (84.27) and minimum value of IVI for *Madhuca latifolia* was observed for ACZ-10 (28.25). The tree size heterogeneity of this species was clearly related to stand density and the stands with larger trees were less heterogenous in tree size.

Table 4.1. Phytosociological and diversity attributes of tree species in the forest stands in the study area.

Parameters	ACZ-1	ACZ-2	ACZ-3	ACZ-4	ACZ-5	ACZ-6	ACZ-7	ACZ-8	ACZ-9	ACZ-10
No. of species	19	22	17	18	20	26	15	29	23	23
No. of families	14	13	11	13	11	19	11	17	14	17
Density (individuals ha^{-1})	425	790	710	343	460	740	480	663	478	415
Basal area (m^2 ha^{-1})	44.12	107.04	93.46	33.14	26.54	87.40	100.48	37.19	77.39	36.67
Shannon Diversity Index (H´)	2.2713	2.0760	1.6846	2.3009	1.5923	2.0760	2.0306	2.5254	2.5604	1.8035
Pielou Evenness Index (J´)	0.771	0.662	0.595	0.768	0.532	0.787	0.750	0.750	0.817	0.567
Simpson Dominance Index (Cd)	0.1520	0.2285	0.2266	0.1691	0.3352	0.1251	0.1892	0.1503	0.1039	0.0343
Margalef Species Richness Index (D_{mg})	3.664	4.193	2.784	3.862	3.374	4.741	3.067	5.415	4.368	4.984

ACZ-1- Sundargarh (Ramlata Reserve Forest),ACZ-2-Mayurbhanj (Similipal Reserve Forest, Chandbil),ACZ-3-Balasore (Tinkosia Naranpur Gobipalla Forest),, ACZ-4-Nayagarh (Baispalli--Buguda-Banigochha Forest), ACZ-5-Kandhamal (Siringi Reserve Forest, Balliguda), ACZ-6-Nabarangpur (Ranigarh-Papadahandi-Mahendra Forest Area), ACZ-7-Malkangiri (Haldikund-Ramgiri Forest Area), ACZ-8-Nuapada (Sunabeda Wildlife Reserve), ACZ-9-Bolangir (Khaprakhol-Harishankar Reserve Forest), ACZ-10-Angul (Bambro forest Area)

Table4.2. Family-wise tree distribution in the forest stands in different ACZs.Key as inTable 1.

Family	ACZ-1	ACZ-2	ACZ-3	ACZ-4	ACZ-5	ACZ-6	ACZ-7	ACZ-8	ACZ-9	ACZ-10
Anacardiaceae	3	3	3	3	3	3	2	3	3	4
Annonaceae	-	-	-	-	-	1	-	-	-	-
Apocynaceae	1	-	-	-	-	1	-	1	-	1
Arecaceae	-	-	-	-	1	-	-	-	-	-
Bignoniaceae	-	-	-	-	-	-	1	-	-	-
Bombacaceae	1	1	-	-	-	1	-	-	-	1
Boraginaceae	-	-	-	1	-	1	-	1	1	1
Burseraceae	-	1	-	-	-	-	-	-	-	-
Caesalpiniaceae	1	-	-	-	1	1	-	1	1	1
Combretaceae	2	5	4	2	4	4	2	4	4	4
Detarioideae	-	-	-	-	-	1	-	1	-	-
Dipterocarpaceae	1	1	1	1	1	1	1	-	-	1
Ebenaceae	1	1	1	1	-	1	1	-	1	1
Euphorbiaceae	1	-	-	-	-	-	-	-	-	-
Fabaceae	1	3	1	2	2	2	2	6	4	1
Lecythidaceae	1	-	1	-	-	1	-	1	1	-
Lythraceae	1	-	-	1	-	1	1	1	1	1
Meliaceae	-	-	-	-	1	-	-	1		1
Mimosoideae	-	-	1	1	-	-	-	-	-	-
Moraceae	-	-	-	-	4	1	-	-	-	-
Myrtaceae	-	1	1	1	1	2	2	-	-	1
Oleaceae	-	-	-	-	-	-	-	1	-	1
Phyllanthaceae	2	2	1	2	-	1	-	1	2	2
Poaceae	-	-	-	-	1	-	-	1	-	1
Rhamnaceae	-	-	-	-	-	-	-	-	1	-
Rubiaceae	-	2	2	3	-	1	2	3	1	1
Rutaceae	1	1	-	-	-	-	-	1	1	-
Sapindaceae	-	1	-	1	-	1	1	1	1	-
Sapotaceae	1	1	1	1	1	1	1	1	1	1

Table4.3. Sorensen's similarity index of trees between forest stands under different ACZs.

	ACZ-1	ACZ-2	ACZ-3	ACZ-4	ACZ-5	ACZ-6	ACZ-7	ACZ-8	ACZ-9	ACZ-10
ACZ-1	100.00	29.27	38.89	27.03	25.64	35.56	35.29	29.17	33.33	47.62
ACZ-2		100.00	46.15	45.0	38.10	41.67	48.65	31.37	35.56	40.0
ACZ-3			100.00	51.43	43.24	41.86	50.0	30.43	40..00	45.00
ACZ-4				100.00	31.50	50,0	60.61	33.33	43.90	43.90
ACZ-5					100.00	34.78	40.00	24.49	18.60	37.21
ACZ-6						100.00	53.66	43.64	40.82	44.90
ACZ-7							100.00	31.82	42.11	42.11
ACZ-8								100.00	38.46	46.15
ACZ-9									100.00	47.83
ACZ-10										100.00

Key as inTable 1.

Table 4.4. Association index (AI) of tree species in *M. latifolia* stands in the forests of different agroclimaticzones (ACZs) studied.

Tree species	Family	Species code	ACZ-1	ACZ-2	ACZ-3	ACZ-4	ACZ-5	ACZ-6	ACZ-7	ACZ-8	ACZ-9	ACZ-10
Acacia leucophloea (Roxb.) Willd.	Fabaceae	ACL	-	-	-	-	-	-	-	-	0.10	-
Acacia pennata (L.) Willd.	Fabaceae	ACP	-	0.16	-	-	-	-	-	-	-	-
Adina cordifolia (Roxb.) Hook. f. & Benth	Rubiaceae	ADC	-	0.16	0.09	0.40	-	0.11	0.20	0.30	-	-
Agele marmelos L.	Rutaceae	AGM	-	-	-	-	-	-	-	-	0.40	-
Albizia procera (Roxb.) Benth.	Mimosoideae	ALP	-	-	0.09	0.20	-	-	-	-	-	0.16
Anogeissus latifolia Wall ex Bedd	Combretaceae	ANL	0.13	0.16	0.27	0.20	0.06	0.22	-	0.30	0.30	-
Artocarpus heterophyllus Lam	Moraceae	ARH	-	-	-	-	0.06	-	-		-	-
Bahunia roxburghiana Voigt	Fabaceae	BAR	0.13	-	-	0.10	-	-	0.20	0.10	-	-
Bombax ceiba L.	Bombacaceae	BOC	0.13	0.16	-	-	-	0.11	-	-	-	0.16
Bridelia retusa (L.) A.Juss	Phyllanthaceae	BRR	0.13	0.16	0.09	0.30	-	0.11	-	-	0.20	0.66
Buchnania lanzan Spreng	Anacardiaceae	BUL	0.63	0.83	1.00	0.60	0.33	0.55	-	0.80	0.60	1.00
Butea monosperma (Lam.) Taub.	Fabaceae	BUM	-	-	-	-	-	-	-	0.10	0.60	-
Careya arborea Roxb	Lecythidaceae	CAA	0.13	-	0.27	-	-	0.33	-	0.10	0.20	-
Caryota urens L.	Arecaceae	CAU	-	-	-	-	0.06	-	-		-	-
*Cassia fistula*Linn.	Caesalpiniaceae	CAF	0.13	0.16	-	-	0.13	-	-	0.30	0.10	0.16
Chloroxylon swietenia DC	Rutaceae	CLS	0.13	0.16	-	0.20	-	-	-	0.30	-	-
Cleistanthus collinus Bentham & Hooker	Phyllanthaceae	CLC	0.25	0.50	-	-	-	-	-	0.80	0.50	0.50
Dalbergia latifolia Roxb	Fabaceae	DAL	-	0.16	-	-	-	-	-	0.20	-	-
Dalbergia paniculata Roxb.	Fabaceae	DAP	-	-	-	-	-	0.11	-	0.80	1.00	-
Dendrocalamus strictus (Roxb.) Nees	Poaceae	DES	-	-	-	-	0.06	-	-	1.00	-	0.33
Diospyros melanoxylon Roxb.	Ebenaceae	DIM	0.38	0.50	0.09	0.20	-	0.44	0.60	-	0.60	0.33
Erythrina suberosa Roxb.	Fabaceae	ERS	-	-	-	-	-	-	-	0.10	-	-
Ficus bengalensis L.	Moraceae	FIB	-	-	-	-	0.20	-	-	-	-	-
Ficus glomerata Roxb.	Moraceae	FIG	-	-	-	-	0.06	-	-	-	-	-
Ficus religiosa L.	Moraceae	FIR	-	-	-	-	0.06	1.00	-	-	-	-
Gardenia latifolia Ait.	Rubiaceae	GAL	-	-	-	-	-	-	-	0.30	-	-

Garuga pinnata L.	Burseraceae	GAP	-	0.16	-	-	-	-	-	-	-	-
Grewia tilifolia Vahl.	Boraginaceae	GRT	-	-	-	0.10	-	0.11	-	0.10	0.10	0.16
Hardwica binnata Roxb.	Detarioideae	HAB	-	-	-	-	-	0.11	-	0.30		
Holiarhena antidysenterica (Linn.) Wall. Synonym *H. pubescens* (Buch.Ham.) Wall. ex G. Don.	Apocynaceae	HOA	0.13	-	-	-	-	0.55	-	0.10	-	0.16
Ixora arborea Roxb. ex Sm	Rubiaceae.	IXR	-	0.33	-	0.10	-	-	0.20	0.10	-	-
Lagerstoemia parviflora Roxb.	Lythraceae	LAP	0.88	-	-	0.10	-	0.11	0.80	0.30	0.30	0.33
Lannea coromandelica (Houtt.) Merr	Anacardiaceae	LAC	0.13	0.16	0.36	0.20	-	0.22	-	0.20	0.40	0.33
Madhuca Latifolia (Roxb.) J. F. Macbr,	Sapotaceae	MAL	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Mallotus phillipines (Lamarck) Müller	Euphorbiaceae	MAP	0.13	-	-	-	-	-	-	-	-	-
Mangifera indica L.	Anacardiaceae	MAI	-	0.16	-	-	0.60	-	-	-	-	0.16
Miliusa tomentosa (Roxb.) J. Sinclair	Annonaceae	MIT	-	-	-	-	-	0.33	-	-	-	-
Mitragyna parviflora (Roxb.) Korth	Rubiaceae	MIP	-	-	-	-	-	-	-	-	0.10	0.16
Morinda tinctoria Roxb.	Rubiaceae	MOT	-	-	0.09	0.10	-	-	-	-	-	-
Nyctanthes arbortristis L.	Oleaceae	NYA	-	-	-	-	-	-	-	0.10	-	0.33
Pterocarpus marsupium Roxb.	Fabaceae	PTM	-	0.33	0.09	0.10	0.06	0.44	0.40	0.30	0.30	0.33
Schleichera oleosa (Lour.) Oken	Sapindaceae	SCO	-	0.33	-	0.40	-	0.33	0.20	0.80	0.30	-
*Semecarpus anacardium*Linn.	Anacardiaceae	SEA	0.13	-	0.09	0.30	0.46	0.11	0.20	0.10	0.30	0.16
Shorea robusta Gaertn	Dipterocarpaceae	SHR	0.88	0.66	1.00	1.00	0.80	0.55	0.80	0.10	-	0.83
Soymida febrifuga (Roxb.) Juss	Meliaceae	SOF	-	-	-	-	-	-	-	-	-	0.16
Stereospermum suaveolens DC.(Syn. S. chelonoides)	Bignoniaceae	STS	-	-	-	-	-	-	0.20	-	-	-
Syzigium cerasoides(Roxb.) Raiz.	Myrtaceae	SYC	-	-	-	-	-	0.22	0.80	-	-	0.16
Syzigium cumuni L.Skeels.	Myrtaceae	SYCU	-	0.33	0.54	0.50	0.06	0.88	0.80	-	-	-
Tamarindus indica L.	Fabaceae	TAI	-	-	-	-	0.06	-	-	-	-	-
Terminalia bellerica (Gaertn.) Roxb.	Combretaceae	TEB	0.63	0.16	0.36	-	0.20	0.11	0.20	0.10	0.30	0.66
Terminalia chebula Retz.	Combretaceae	TEC	0.38	0.33	0.09	-	0.26	0.33	-	0.10	0.10	0.16
Terminalia tomentosa (Roxb.) Wight & Arn.	Combretaceae	TET	-	0.66	0.72	0.50	0.13	0.55	0.20	0.60	0.30	0.16
Toona ciliata M.Roem	Meliaceae	TOC	-	-	-	-	0.06	-	-	-	-	-
Zizyphus mauritiana (L.) Gaertn.	Rhamnaceae	ZIM	-	-	-	-	-	-	-	-	0.50	-

Key as inTable 1.

Table 4.5. Density (D) and importance value index(IVI) of tree species in the forests of different agroclimaticzones (ACZs) studied.

	AEZ-1		AEZ-2		AEZ-3		AEZ-4		AEZ-5		AEZ-6		AEZ-7		AEZ-8		AEZ-9		AEZ-10	
Species	D	IVI	D	IVI	D	IVI	D	IVI	D	IVI	D	IVI	D	IVI	D	IVI	D	IVI	D	IVI
ACL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.50	2.07	-	-
ACP	-	-	4.0	2.89	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ADC	-	-	8.25	4.07	2.25	1.78	27.50	16.79	-	-	2.75	4.33	5.0	4.04	10.00	7.23	-	-	-	-
AGM	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12.50	9.59	-	-
ALP	-	-	-	-	2.25	2.14	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ANL	3.12	3.05	4.0	2.78	11.25	6.99	5.0	5.12	3.25	2.14	13.75	6.05	-	-	10.00	7.23	12.50	8.84	4.0	2.50
ARH	-	-	-	-	-	-	-	-	3.25	3.10	-	-	-	-	-	-	-	-	-	-
BAR	6.25	5.03					5.0	3.74							2.50	2.27				
BOC	3.12	3.05	4.0	3.72	-	-	-	-	-	-	2.75	3.26	-	-	-	-	-	-	4.00	5.05
BRR	3.12	2.84	4.0	2.95	2.25	1.80	10.0	12.55	-	-	2.75	1.98	-	-	-	-	10.00	8.33	20.75	20.59
BUL	50.0	27.93	70.75	22.61	145.25	45.90	35.0	20.86	18.25	11.17	52.75	19.43	5.0	4.03	45.00	25.48	70.0	34.25	50.0	20.14
BUM	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.00	2.87	70.00	34.25	-	-
CAA	6.25	3.71	-	-	6.75	5.98	-	-	-	-	13.75	12.0	-	-	2.50	2.27	5.0	4.17	-	-
CAU	-	-	-	-	-	-	-	-	6.5	4.81	-	-	-	-	-	-	-	-	-	-
CAF	3.12	2.83	4.0	2.78	-	-	-	-	5.0	3.90	2.75	1.90	-	-	10.00	6.63	2.50	2.04	4.0	2.67
CLS	3.12	2.89	12.50	3.98	-	-	-	-	-	-	-	-	-	-	25.00	11.42	-	-	-	-
CLC	46.87	16.80	29.0	10.51	-	-	-	-	-	-	-	-	-	-	150.00	52.63	32.50	15.96	20.75	8.09
DAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12.50	6.73	-	-	-	-
DAP	-	-	4.0	3.11	-	-	-	-	-	-	2.75	2.15	-	-	45.00	25.48	60.00	71.22	-	-
DES	-	-	-	-	-	-	-	-	1.5	5.11	-	-	-	-	30.00	78.55	-	-	8.25	10.24
DIM	21.87	12.10	37.50	4.73	2.25	1.78	7.50	5.84	-	-	19.25	12.70	25.0	15.05	-	-	32.50	32.30	20.75	8.33
ERS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.50	2.27	-	-	-	-
FIB	-	-	-	-	-	-	-	-	5.0	5.50	-	-	-	-	-	-	-	-	-	-
FIG	-	-	-	-	-	-	-	-	1.5	7.54	-	-	-	-	-	-	-	-	-	-
FIR	-	-	-	-	-	-	-	-	1.5	6.84	44.25	30.64	-	-	-	-	-	-	-	-
GAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25.00	11.42	-	-	-	-
GAP	-	-	8.25	3.99	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GRT	-	-	-	-	-	-	2.50	2.34	-	-	2.75	2.15	-	-	2.50	2.17	2.50	2.13	4.0	2.77
HAB	-	-	-	-	-	-	-	-	-	-	2.75	1.93	-	-	10.00	6.63	-	-	-	-
HOA	3.12	3.14	-	-	-	-	-	-	-	-	155.50	92.03	-	-	5.00	2.87	-	-	4.0	3.17

IXR	-	-	37.50	9.89	-	-	2.50	2.29	-	-	19.25	10.56	5.0	4.0	2.50	5.11	-	-	-	-
LAP	28.12	22.16	-	-	-	-	2.50	2.34	-	-	2.75	1.93	65.0	24.48	10.00	7.08	7.50	6.21	16.50	6.69
LAC	6.25	4.54	4.0	3.02	13.50	9.04	10.0	6.69	-	-	8.25	4.51	-	-	12.50	6.73	12.50	9.59	12.50	7.37
MAL	56.25	54.77	137.50	76.74	127.25	49.29	40.0	34.80	123.25	84.27	44.25	30.64	35.0	30.80	30.00	78.55	60.0	71.22	37.50	28.25
MAP	3.12	3.25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MAI	-	-	4.0	4.61	-	-	-	-	21.50	29.11	-	-	-	-	-	-	-	-	8.25	6.50
MIT	-	-	-	-	-	-	-	-	-	-	13.75	7.27	-	-	-	-	-	-	-	-
MIP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.50	2.13	8.25	5.15
MOT	-	-	-	-	2.25	1.89	2.50	2.34	-	-	-	-	-	-	-	-	-	-	-	-
NYA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.50	2.51	-	-	12.50	7.73
PTM	-	-	8.25	5.62	2.25	1.89	2.50	2.46	1.5	1.87	-	-	10.00	9.11	10.00	7.08	7.50	6.86	16.50	14.07
SCO	-	-	12.50	7.73	-	-	17.50	20.35	-	-	11.00	6.82	5.0	4.65	150.00	52.63	7.50	6.21	-	-
SEA	9.37	4.98	-	-	2.25	1.81	7.50	7.81	15.0	14.11	5.50	2.81	5.0	4.08	7.50	3.74	12.50	7.61	4.0	5.64
SHR	131.25	96.04	337.50	77.95	306.75	125.89	1222.50	116.80	236.50	87.02	155.50	92.03	170.0	128.89	-	-	-	-	112.50	58.23
SOF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.50	2.27	-	-	4.0	3.02
STS	-	-	-	-	-	-	-	-	-	-	-	-	5.0	4.23	-	-	-	-	-	-
SYC	-	-	-	-	-	-	-	-	-	-	33.25	10.50	75.0	31.29	-	-	-	-	-	-
SYCU	-	-	16.50	7.37	13.50	11.11	12.50	12.47	1.50	1.79	58.25	28.88	50.00	23.47	-	-	-	-	-	-
TAI	-	-	-	-	-	-	-	-	1.5	2.58	-	-	-	-	-	-	-	-	-	-
TEB	21.87	19.21	8.25	4.43	18.0	9.19	-	-	5.0	5.61	2.75	4.33	5.0	5.0	2.50	2.51	7.5	6.86	25.0	17.39
TEC	18.75	11.55	8.25	5.81	2.25	1.83	-	-	6.50	7.36	13.75	7.27	-	-	2.50	5.11	2.50	2.07	4.0	2.67
TET	-	-	25.0	19.85	50.0	21.52	17.50	13.90	3.25	4.30	52.75	19.43	15.0	6.83	37.50	22.98	12.50	8.84	4.0	3.02
TOC	-	-	-	-	-	-	-	-	1.5	1.80	-	-	-	-	-	-	-	-	-	-
ZIM	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	32.50	15.96	-	-

Key as inTable 1, Species code as in Table 44.

Table 4.6 Ecological Status of *M. latifolia* in natural forests under different agroclimatic zones (ACZs) of Odisha

Site	Density ha^{-1}	Relative Density	Relative Frequency	Total Basal Area (m^2ha^{-1})	Relative Dominance	Dispersal Pattern	IVI
ACZ-1	56.25±3.2	13.23	15.68	11.51	25.85	0.02	54.77
ACZ-2	137.50±11.7	17.36	12.76	50.04	46.60	0.05	76.74
ACZ-3	127.25±13.3	17.89	15.94	14.46	15.46	0.05	49.29
ACZ-4	40.00±3.6	11.67	15.15	2.67	8.03	0.01	34.8
ACZ-5	123.25±19.5	26.52	20.83	9.83	36.91	0.04	84.27
ACZ-6	44.25±4.6	8.20	12.32	5.25	10.11	0.01	30.64
ACZ-7	35.00±3.2	7.29	14.70	8.76	8.80	0.01	30.80
ACZ-8	30.00±2.6	6.81	13.8	13.15	57.85	0.01	78.55
ACZ-9	60.00±5.4	15.58	13.69	25.42	41.94	0.02	71.22
ACZ-10	37.50±4.2	4.73	11.53	4.40	11.97	0.01	28.25

Key as inTable 1.

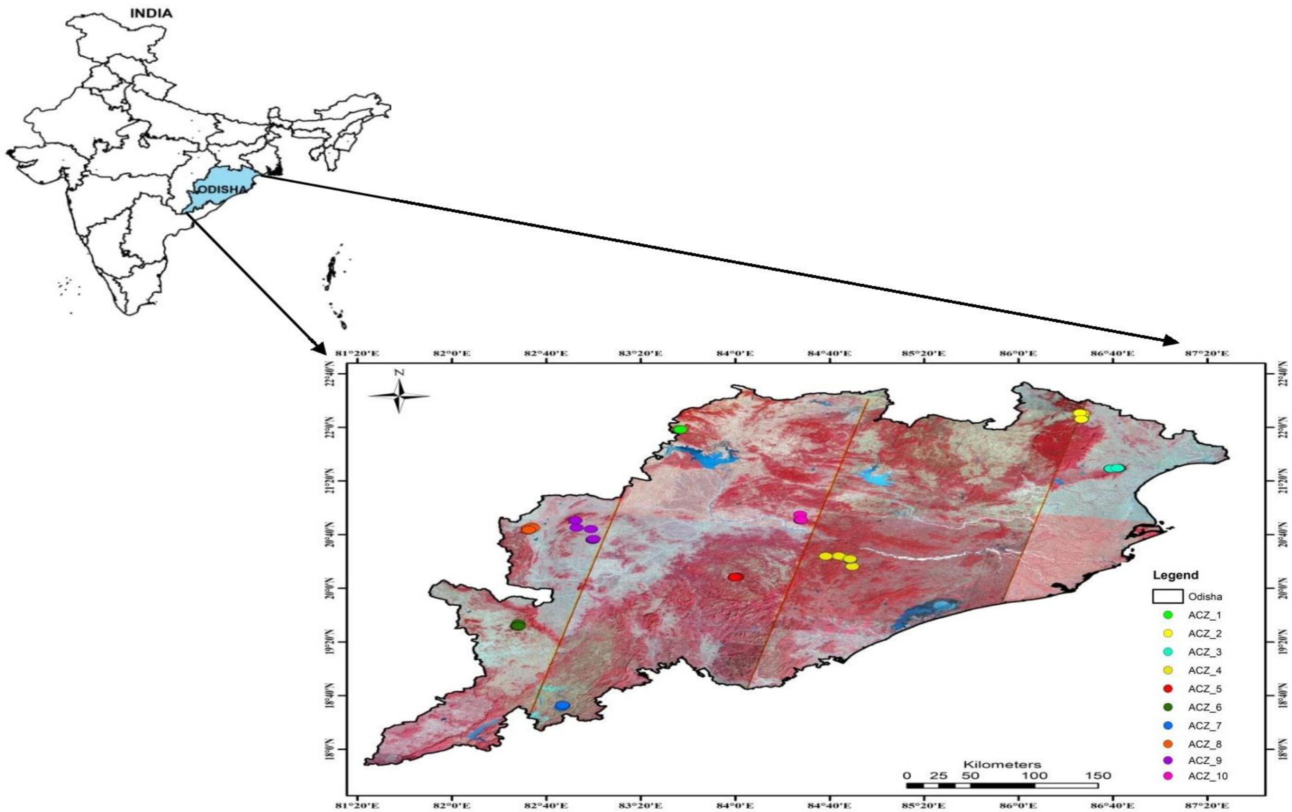


Figure 4.1.Map showing the location of study area.ACZ-1- Sundargarh (Ramlata Reserve Forest), ACZ-2-Mayurbhanj (Similipal Reserve Forest, Chandbil), ACZ-3-Balasore (TinkosiaNaranpurGobipalla Forest),, ACZ-4-Nayagarh (Baispalli--Buguda-Banigochha Forest), ACZ-5-Kandhamal (Siringi Reserve Forest, Balliguda), ACZ-6-Nabarangpur (Ranigarh-Papadahandi-Mahendra Forest Area), ACZ-7-Malkangiri (Haldikund-Ramgiri Forest Area), ACZ-8-Nuapada (Sunabeda Wildlife Reserve), ACZ-9-Bolangir (Khaprakhol-Harishankar Reserve Forest), ACZ-10-Angul (Bambro forest Area)

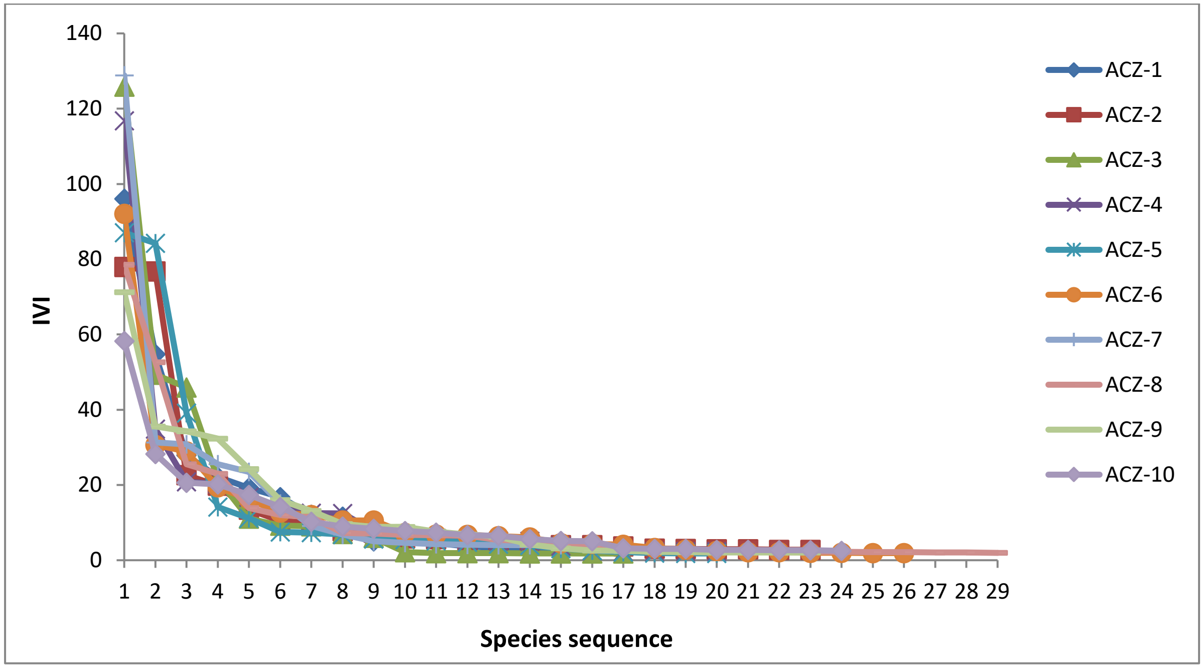


Figure 4.2 Dominance-diversity curve for trees in different forests.Key as in Figure 4.1.

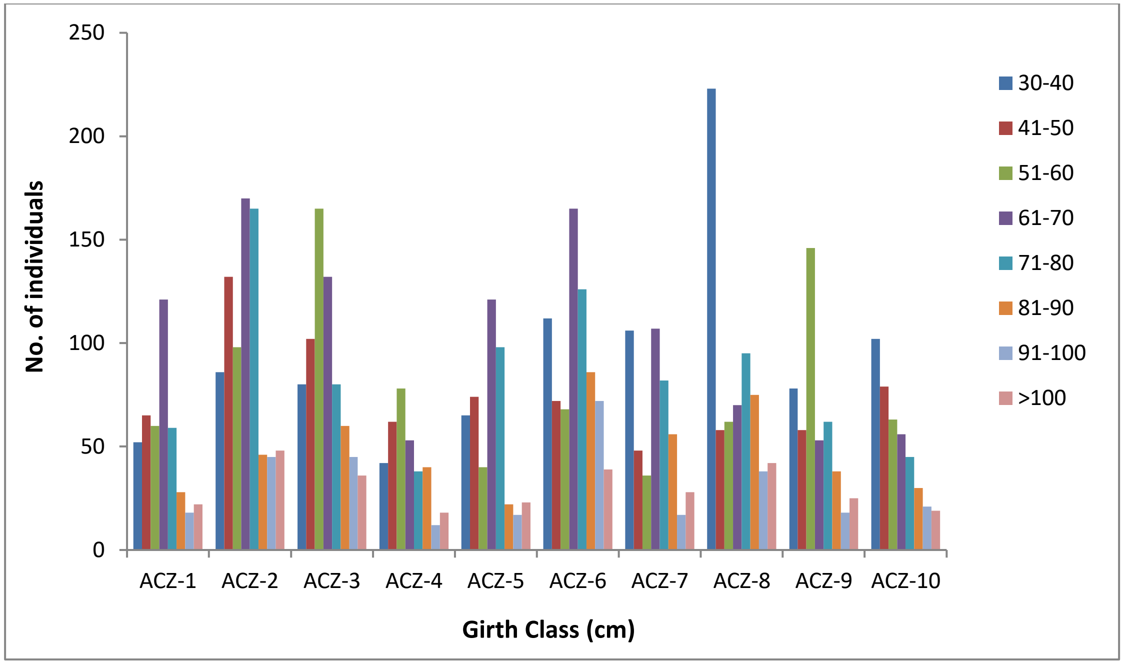


Figure 4.3 Density-diameter distribution of tree species in different forest of Odisha.Key as in Figure 4.1.

CHAPTER-5

EFFECT OF SEED SOURCE ON MORPHOMETRIC SEED TRAITS AND OIL CONTENTS OF *Madhuca latifolia*

5.1 Introduction

Provenance studies in forest trees are very important as it helps in identifying the best and highly adaptable provenance. In fact forest tree improvement programme starts with the scanning of provenances/ seed source capable of providing best-adapted trees (Suri, 1984). Increase in yield and resistance to disease can be achieved through the selection and use of seed from good provenance. Seed source studies are also desirable to screen the naturally available genetic variation to utilize the best material for maximum productivity and for further breeding programme (Shiv Kumar and Banerjee, 1986). Seed traits are crucial fitness-related traits that are expected to underpin survival and reproductive success of plants in different environments. Seed oils serve as the primary energy source to the developing embryo during the heterotrophic stage (Pujar et al. 2006), prior to the initiation of photosynthesis. The quantity and quality of stored oils in seeds is crucial in determining plant fitness, germination success (Linder, 2000), emergence and establishment of a plant (Bewley and Black, 1994).

Studies of the biogeographic distribution of seed oil content in plants are fundamental to understanding the mechanisms of adaptive evolution in plants as seed oil is the primary energy source needed for germination and establishment of plants. However, seed oil content as an adaptive trait in plants is poorly understood. Some studies have shown that the pattern of oil composition in seeds may be influenced by latitude and between species (Linder, 2000, Sanyal and Linder, 2013).However, there are scanty information pertaining to effect of seed source on oil content and quality and especially, in case of *M. latifolia*.

This chapter deals with study on variations of Candidate Plus Trees (CPTs) of *M. latifolia* whose morphometric traits and oil contents and quality were analyzed across 10 seed sources to identify suitable seed sources with high oil content and for production of quality seedlings for mass afforestation in different forestry and agroforestry programmes.

5.2 Materials and Methods

5.2.1 Selection of candidateplus tree:

Ten phenotypically superior trees aged (25-30 years) having good history of seed production and without insect or pest attach, from each provenance (referred to here as agro-climatic zone) covered under the study for forest and agriculture sites were marked for collection of fruits. Care was taken that each candidate or plus was atleast 100 m apart from each other to ensure maximum genetic variations and to minimize inbreeding depression.

5.2.2 Assessment of morphometric traits of *M. latifolia*

Fruits were collected separately from the ten candidate plus trees of *M. latifolia*. From each tree, 3 samples of fruits were collected randomly with 100 fresh and fully ripened matured fruits per sample . These fruits were then let dry in shade for 10 days and then seeds were extracted by using secateurs.Morphological characters of thefruits and seeds such as fruit length (cm) , fruit width (cm) , seed length (cm) , seed width (cm) , kernel length (cm) , kernel width (cm),100 fruits weight (gm) , 100 seed weight (gm), 100 kernel weight (gm) were measured by using vernier calliper and digital balance.

5.2.3Analysis of oil contents and other physicochemical contents of seeds of *M. latifolia*

Kernels from sample seeds collected from each sample tree of different agroclimatic zone and were dried at 55^{o}C in hot air oven for 48 hrs. 50 g of dried kernels were taken and grinded and reduced to suitable fine meal in pestle mortar. The ground sample were then placed in the thimble in the extraction chamber of Soxhlet apparatus .The extraction chamber was fixed over a round bottom flask containing Petroleum ether (40^{0}C-60^{0}C) as extraction solvent. Then a condenser was fitted over the extraction chamber of Soxhlet apparatus. The Soxhlet apparatus was kept over the heating element and allowed to heat at 70^{0}C. When the temperature reached boiling point of Petroleum ether it started boiling which was evaporated and then condensed and fall in to the thimble containing the ground kernel. The oil was extracted by hot Petroleum ether falling on the kernel in the thimble. When the extracted oil and Petroleum ether mixture reached the maximum in the extraction chamber it siphoned out and went back to the round bottom flask. The extraction was carried out for 15 times or till the solvent in the extraction chamber became clear containing no oil. The round bottom flask containing the mixture Petroleum ether and oil was removed and distilled till no petroleum ether left over in the flask containing the oil. The flask was kept till it cooled down and the weight of the flask containing the oil was recorded. The oil content (%) was calculated as:

$$\text{Percentage of Oil Content} = \frac{W_2 - W_1}{50} \times 100$$

Where, W_1- Weight of the empty flask in gram (g), W_2- Weight of flask with oil in gram (g), W_3- Weight of kernel in gram (g). The oil yield (g) from kernels was

calculated on basis of oven dry weight of kernels and oil content (%) as

Oil yield (g) = Oil content (%) x Oven dry kernel weight (g)

The oil density was calculated as:

$\rho = M/V$

Where,

ρ is the density,

M is the mass,

V is the volume

It is expressed by 1,000 kg/m^3 = 1,000 g/l = 1 g/cm^3

The specific gravity was calculated by using the formula:

$$\text{Specific gravity} = \frac{\text{(Weight of the bottle with oil – Weight of the empty bottle)}}{\text{(Weight of the bottle with water – Weight of the empty bottle)}}$$

5.2.1.5.5 Acid value

The acid value was determined by directly titrating the oil in an alcoholic medium with aqueous KOH solution. About 3gm of oil was taken in a flask to which 30ml of a mixture of equal volumes of alcohol and ether was added. Then 1mL of phenolphthalein indicator was added to the above flask and titrated with 0.1 N potassium hydroxide until the solution remained faintly pink after shaking for 30sec (AOAC Method) . Acid value was calculated with the following formula:

Acid value = (M × V) × (N/W)

Where,M= Molecule weight of Potassium hydroxide (56.11)

V= Volume (ml),N = Normality of the Potassium hydroxide solution, W= Weight of the Oil sample taken (g)

7.2.1.5.6 Free Fatty Acid (FFA %) Free Fatty Acids (FFA) are the result of the breakdown of oil or biodiesel. FFA% is usually used to describe the FFA content of oils. Free fatty acids is frequently expressed as the percentage of free acids present in the sample. The percentage of free fatty acids in most of the oils and fats is calculated on the basis of oleic acid (AOAC Method) . It was calculated as:

Free Fatty Acid (FFA %) = 0.5 x Acid value of Oil

7.2.1.5.7 Saponification value

The saponification value is the number of mg of Potassium hydroxide required to neutralize the free acids and saponify the esters contained in 1.0 g of the oil.1.5-2 g of the oil was placed in a tared 250 mL flask and weighed accurately. 25.0mL of 0.5N alcoholic Potassium hydroxide was added to it and the flask was refluxed for 90 min such that the contents were frequently rotated. Then 1mL of phenolphthalein indicator was added and titrated the excess Potassium hydroxide with 0.5 N Hydrochloric acid . A blank determination under the same condition was also performed (AOAC Method) . The titration also can be carried out and the saponification value was calculated by:

$$\textbf{Saponification value} = \frac{[M_r \times (V_b - V_T) \times N]}{W}$$

Where,

M_r = Molecule weight of potassium hydroxide, 56.11

V_b = Volume of 0.5 N hydrochloric acid consumed in the blank test (mL)

V_T = Volume of 0.5 N hydrochloric acid consumed in the actual test (mL)

N= Normality of the hydrochloric acid

W= Weight of the substance taken for the test (g)

7.2.1.5.8 Iodine Value

The iodine value is an identity characteristics nature of oil. The iodine value of an oil or fat is defined as the grams of iodine absorbed by 100g sample. The iodine value or iodine number e generally represents the degree of un-saturation or the number of carbon-carbon double bonds in fats or oils.About 1g of oil sample was weighed into a 500mL volumetric flask. 15mL of carbon tetrachloride was added to the sample and swirled to ensure that the sample is completely dissolved. 25mL of Wijs solution was then dispensed into the flask containing the sample using a pipette. The flask was stopper and swirled to ensure complete mixing. The sample was then placed in the dark for 30 minutes at room temperature. The flask was removed from storage to which 20ml of 10% Potassium iodide (KI) solution was added which was followed by 150mL of distilled water. Then the mixture was titrated with 0.1N thiosulphate ($Na_2 S_2 O_3$) solution by adding gradually and with constant shaking till the yellow colour had disappeared. After that, 1.5mL of starch indicator solution was added to it and the titration was continued until the blue colour disappeared (AOAC Method) . A blank determination was conducted simultaneously.

The iodine value was calculated using the formula below:

Iodine value = 12.69 (V_2 - V_1) / W

Where, N = normality of thiosulphate solution,

V_1 = Volume of thiosulphate solution used in test,

V_2 = Volume of thiosulphate solution used in blank,

W = Weight of sample

5.3 Statistical analysis

The data regarding the variation in all the seed characters of *Madhuca latifolia* Macb.were then subjected to Analysis of variance (ANOVA) as described by Snedecor and Cochran (1980) 2^{nd}. Edition. The data were analyzed in statistical package MStatC. Coefficient of variance (CV%) among studied traits were also calculated. Significant difference between forest and agricultural land for the mean values of fruits and seed characters were tested by comparison of means through T-test .

5.4 RESULTS

5.4.1 Variation in morphometric characters of fruits of *M. latifolia*

5.4.1.1 Variation in fruit length of *M. latifolia*

The fruit length of the species varied from 3.09cm-6.20cm in case of collected from forest lands. It varied in ACZ-1(4.47 cm-5.93 cm) with mean fruit length of 5.32 cm , ACZ-2(3.75 cm-6.20 cm) with mean fruit length of 4.94 cm , ACZ-3(3.09 cm-5.10 cm) with mean fruit length of 4.31 cm , ACZ-4 (4.18 cm-6.05 cm) with mean fruit length of 5.16 cm , ACZ-5(3.59 cm-5.51 cm) with mean fruit length of 4.70 cm , ACZ-6(4.12 cm-4.49 cm) with mean fruit length of 4.36 cm , ACZ-7(3.87 cm-4.61 cm) with mean fruit length of 4.29 cm , ACZ-8(3.78cm-5.10 cm) with mean fruit length of 4.59 cm , ACZ-9(3.45 cm-4.44 cm) with mean fruit length of 3.98 cm and ACZ-10(3.43 cm-5.80 cm) with mean fruit length of 4.45 cm (Table-5.1).The coefficient of variation varies between 2.18-7.33 for all agroclimatic zones with maximum in ACZ-3 followed by ACZ-4> ACZ-5 > ACZ-2 > ACZ-9 > ACZ-7 > ACZ-1 > ACZ-10 > ACZ- 8 > ACZ- 6.

Similarly, the studies on variation in the fruit length of *M. latifolia* collected from agricultural lands of different agroclimatic zones of Odisha were found significant. The fruit length of all provenances varies from 3.44 cm-6.12 cm . The fruit length varies in ACZ-1 (3.88 cm-6.12 cm) with mean fruit length of 4.40 cm , ACZ-2(4.30 cm-8.14 cm

) with mean fruit length of 5.18 cm , ACZ-3(4.61 cm-4.91 cm) with mean fruit length of 4.74 cm , ACZ4 (3.99 cm-5.12 cm) with mean fruit length of 4.69 cm , ACZ- 5(3.72 cm-5.18 cm) with mean fruit length of 4.48 cm , ACZ6(3.97 cm-5.29 cm) with mean fruit length of 4.37 cm , ACZ-7(3.46 cm-5.21 cm) with mean fruit length of 4.28 cm , ACZ-8(3.44cm-5.46 cm) with mean fruit length of 4.17 cm , ACZ-9 (4.36 cm-5.17 cm) with mean fruit length of 4.65 cm and ACZ-10(3.73 cm-5.93 cm) with mean fruit length of 4.73 cm(Table-5.2) . The coefficient of variation varies between 1.33-7.44 in different agroclimatic zones with maximum in ACZ-6 followed by ACZ-7 > ACZ-5> ACZ-2> ACZ-1> ACZ-10> ACZ-8> ACZ-9> ACZ-4> ACZ-3 (Figure 5.1).

5.4.1.2 Variation in fruit width of *M. latifolia*

The fruit width of all provenances varies from 2.03 cm-3.52 cm . The fruit width varies in ACZ-1 (2.60 cm-3.13 cm) with mean fruit width of 2.88 cm , ACZ2 (2.53 cm-3.35 cm) with mean fruit width of 2.81 cm , ACZ-3 (2.68 cm-3.28cm) with mean fruit width of 2.97 cm , ACZ4 (2.56 cm-3.52 cm) with mean fruit width of 2.87 cm , ACZ-5 (2.68 cm-3.44 cm) with mean fruit width of 2.96 cm , ACZ-6 (2.69 cm-2.98 cm) with mean fruit width of 2.86 cm , ACZ7 (2.03 cm-2.41 cm) with mean fruit width of 2.22 cm , ACZ-8 (2.38 cm-2.86 cm) with mean fruit width of 2.60 cm , ACZ-9 (2.72 cm-3.17 cm) with mean fruit width of 2.88 cm and ACZ-10 (2.46 cm-3.36 cm) with mean fruit width of 2.90 cm (Table-5.1). The coefficient of variation varies between 1.88-6.19 for all agroclimatic zones with maximum in ACZ–5 (6.19) followed by ACZ–2 (6.02) >ACZ–3(5.32) >ACZ–1(5.18) >ACZ–4(5.03) >ACZ–10(3.84) >ACZ–6(3.32) >ACZ–9(3.01) >ACZ–7(2.85) >ACZ–8(1.88) (Figure 5.2).

Similarly, the studies on variation in the fruit width of *M. latifolia* collected from agricultural lands of different agroclimatic zones of Odisha were found significant . The fruit width of all provenances varies from 2.28 cm-4.10 cm. The fruit width varies in ACZ-1 (2.65 cm-3.09 cm) with mean fruit width of 2.85 cm , ACZ-2 (2.55 cm-3.37 cm) with mean fruit width of 2.79 cm , ACZ-3 (3.04 cm-4.10 cm) with mean fruit width of 3.55 cm , ACZ4 (2.62 cm-2.99 cm) with mean fruit width of 2.81 cm , ACZ-5 (2.54 cm-3.01 cm) with mean fruit width of 2.81 cm , ACZ-6 (2.54 cm-2.96 cm) with mean fruit width of 2.77 cm , ACZ-7 (2.59 cm-4.01 cm) with mean fruit width of 3.25 cm , ACZ-8 (2.28 cm-3.10 cm) with mean fruit width of 2.71 cm , ACZ-9 (2.70 cm-3.03 cm) with mean fruit width of 2.89 cm and ACZ10 (2.52 cm-2.99 cm) with mean fruit width of 2.79 cm (Table-5.2). The coefficient of variation varies between 2.24-8.92 for all agroclimatic zones with maximum in ACZ–3 (8.92) followed by ACZ–7(7.59) >ACZ–5(5.61) >ACZ–2(4.32) >ACZ–6(4.11) >ACZ–8(3.86) >ACZ–9(2.98) >ACZ–1(2.75) >ACZ–4(2.61) >ACZ–10(2.24) (Figure 5.2)..Between different agroclimatic zones for fruits collected from forest areas of all agroclimaticzones , the mean fruit width varies from 2.22 cm –2.97 cm with maximum in ACZ3 and minimum in ACZ-7. However,the values of ACZ-1, ACZ-4 , ACZ-6 and ACZ-9 ;ACZ-3 and ACZ-5 are found to be statistically at par with each other. The coefficient of variation for the mean values of fruit width of different zones found to be 3.00 (Table-5.1). Similarly, for different agroclimatic zones for fruits collected from agricultural areas of all agroclimaticzones , the mean fruit width varies from 2.71 cm – 3.55 cm with maximum in ACZ-3 and minimum in ACZ-8 .However , the values of ACZ-2 and ACZ-10 ; ACZ-4 and ACZ-5 are found to be statistically at par with each other. . The coefficient of variation for the mean values of fruit width of different zones found to be 1.36 (Table-5.2) .

5.4.1.3Variation in fruit thickness of *M. latifolia*

The fruit thickness of all provenances varies from 2.13 cm-3.21 cm . The fruit thickness varies in ACZ-1 (2.57 cm-3.11 cm) with mean fruit thickness of 2.80 cm , ACZ-2 (2.34 cm-3.10 cm) with mean fruit thickness of 2.66 cm , ACZ3 (2.61 cm-3.15 cm) with mean fruit thickness of 2.80 cm , ACZ-4 (2.44 cm-3.15 cm) with mean fruit thickness of 2.78 cm , ACZ-5 (2.52 cm-3.18 cm) with mean fruit thickness of 2.78 cm , ACZ-6 (2.71 cm-3.21 cm) with mean fruit thickness of 3.02 cm , ACZ-7 (2.13 cm-2.45 cm) with mean fruit thickness of 2.23 cm, ACZ8 (2.24 cm-2.73 cm) with mean fruit thickness of 2.46 cm , ACZ-9 (2.57cm-2.94 cm) with mean fruit thickness of 2.75 cm and ACZ-10 (2.24 cm-3.21 cm) with mean fruit thickness of 2.76 cm (Table 5.1) .The coefficient of variation varies between 2.23-6.67 for all agroclimatic zones with maximum in ACZ-2 (6.67) followed by ACZ-3 (5.66) >ACZ-6(5.24) >ACZ-5(5.20) >ACZ-4(4.62) >ACZ-1(4.51) >ACZ-8(4.45) >ACZ-10(3.87) >ACZ-7(3.02) >ACZ-9(2.23) (Figure 5.3).Similarly, the studies on variation in the fruit thickness of *M. latifolia* collected from agricultural lands of different agroclimatic zones of Odisha were found significant . The fruit thickness of all provenances varies from 2.18 cm-3.90 cm . The fruit thickness varies in ACZ-1 (2.54 cm-2.95 cm) with mean fruit thickness of 2.69 cm , ACZ-2 (2.40 cm-3.37 cm) with mean fruit thickness of 2.67 cm , ACZ-3 (2.85 cm-3.90 cm) with mean fruit thickness of 3.48 cm , ACZ-4 (2.45 cm-2.84 cm) with mean fruit thickness of 2.65 cm , ACZ-5 (2.33 cm-2.84 cm) with mean fruit thickness of 2.60 cm , ACZ-6 (2.27 cm-2.81 cm) with mean fruit thickness of 2.61 cm , ACZ-7 (2.42 cm-3.21 cm) with mean fruit thickness of 2.86 cm , ACZ-8 (2.18 cm-2.95 cm) with mean fruit thickness of 2.52 cm , ACZ-9 (2.51 cm-2.94 cm) with mean fruit thickness of 2.78 cm and ACZ-10 (2.40 cm-2.86 cm) with mean fruit thickness of 2.67 cm (Table5.2) .The result showed low coefficient of variation for fruit thickness in all agroclimatic zones . The coefficient of variation varies between 2.18-9.10 for all agroclimatic zones with maximum in agroclimatic zone–3(9.10) followed by ACZ-7(7.87)>ACZ-8(5.29) >ACZ-6(4.91) >ACZ-4(4.58) >ACZ-2(4.40) > ACZ-5(4.24) >ACZ-9(3.93) >ACZ-1(3.26) >ACZ-10(2.18) (Figure 5.3).

5.4.1.4 Variation in seed length of *M. latifolia*

The studies on variation in the seed length of *Madhuca latifolia* Macb. collected from forest lands of different agroclimatic zones of Odisha were found significant. The seed length of all provenances varies from 2.76 cm-4.10 cm . The seed length varies in ACZ-1 (2.86 cm-3.77 cm) with mean seed length of 3.25 cm , ACZ-2 (3.07 cm-4.10 cm) with mean seed length of 3.47 cm , ACZ-3 (2.95 cm-4.23 cm) with mean seed length of 3.43 cm , ACZ-4 (3.10 cm-3.96 cm) with mean seed length of 3.45 cm , ACZ-5 (

3.14 cm-4.00 cm) with mean seed length of 3.50 cm , ACZ-6 (3.01 cm-3.35 cm) with mean seed length of 3.20 cm , ACZ-7 (2.78 cm-3.32 cm) with mean seed length of 3.05 cm , ACZ-8 (2.96 cm-3.67 cm) with mean seed length of 3.36 cm , ACZ-9 (2.76 cm-3.23 cm) with mean seed length of 3.01cm and ACZ-10 (2.94 cm-3.55 cm) with mean seed length of 3.28 cm (Table 5.1). The coefficient of variation varies between 2.24-9.06 for all agroclimatic zones with maximum in ACZ-3(9.06) followed by ACZ4(6.30) >ACZ-2(6.05) >ACZ-10(3.82) >ACZ-9(3.18) >ACZ-5(3.15) >ACZ-8(3.02) >ACZ-7(2.90) >ACZ-1(2.33) >ACZ-6(2.24) (Figure 5.4).Similarly, the studies on variation in the seed length of *Madhuca latifolia* Macb.collected from agricultural lands of different agroclimatic zones of Odisha were found significant . The seed length of all provenances varies from 2.52 cm-5.24 cm .The seed length varies in ACZ-1 (3.06 cm-3.73 cm) with mean seed length of 3.33 cm , ACZ2 (2.86 cm-5.24 cm) with mean seed length of 2.97 cm , ACZ-3 (3.22 cm-3.47 cm) with mean seed length of 3.34 cm , ACZ-4 (3.10 cm-3.72 cm) with mean seed length of 3.41 cm , ACZ5 (2.98 cm-3.80 cm) with mean seed length of 3.35 cm , ACZ-6 (2.83 cm-4.20 cm) with mean seed length of 3.30 cm , ACZ-7 (2.76 cm-3.79 cm) with mean seed length of 3.08 cm , ACZ-8 (2.52 cm-3.67 cm) with mean seed length of 3.16 cm , ACZ-9 (2.93 cm-3.88 cm) with mean seed length of 3.21 cm and ACZ-10 (2.97 cm-4.15 cm) with mean seed length of 3.36 cm (Table 5.2). The coefficient of variation varies between 1.49-11.21 for all ACZswith maximum in ACZ–6(11.21) followed by ACZ-9(4.04)>ACZ-5(3.93)>ACZ-4(3.66)>ACZ-10(3.32)>ACZ-8(3.16)>ACZ-7(3.04)>ACZ-2(3.03)>ACZ-1(2.27) >ACZ-3(1.49) (Figure 5.4).

5.4.1.5 Variation in seed width of *M. latifolia*

The seed width of all provenances varies from 1.26 cm-1.96 cm . The seed width varies in ACZ1 (1.61 cm-1.81 cm) with mean seed width of 1.71 cm , ACZ-3 (1.63 cm-1.79 cm) with mean seed width of 1.71 cm , ACZ-4 (1.44 cm-1.82 cm) with mean seed width of 1.67 cm , ACZ-5 (1.64 cm-1.96 cm) with mean seed width of 1.77 cm , ACZ-6 (1.59 cm-1.71 cm) with mean seed width of 1.66 cm , ACZ-7 (1.26 cm-1.58 cm) with mean seed width of 1.36 cm , ACZ-8 (1.50 cm-1.78 cm) with mean seed width of 1.62 cm , ACZ-9 (1.45 cm-1.80 cm) with mean seed width of 1.65 cm and ACZ-10 (1.52 cm-1.87 cm) with mean seed width of 1.66 cm (Table 5.1) .The coefficient of variation varies between 2.32-6.34 for all agroclimatic zones with maximum in agroclimatic zone–2(6.34) followed by ACZ–8(5.03) >ACZ–10(4.54) >ACZ–5(4.49) >ACZ–4(3.61) >ACZ–9(3.22) >ACZ–1(2.74) >ACZ–3(2.36) >ACZ–7(2.33) >ACZ–6(2.32) (Figure 5.5).Similarly, the studies on variation in the seed width of *Madhucalatifolia*Macb.collected from agricultural lands of different agroclimatic zones of Odisha were found significant in all agroclimatic zones except ACZ-3 and ACZ-10 . The seed width of all provenances varies from 1.27 cm-1.99 cm . The seed width varies in ACZ-1 (1.69 cm-1.91 cm) with mean seed width of 1.82 cm , ACZ-2 (1.44 cm-1.81 cm) with mean seed width of 1.73 cm,ACZ-4 (1.44 cm-1.81 cm) with mean seed width of 1.72 cm , ACZ-5 (1.52 cm-1.88 cm) with mean seed width of 1.68 cm , ACZ-6 (1.27 cm-1.88 cm) with mean seed width of 1.56 cm,ACZ-7 (1.49 cm-1.73 cm) with mean seed width of 1.64 cm , ACZ-8 (1.37 cm-1.77 cm) with mean seed width of 1.61 cm and ACZ-9 (1.39 cm-1.93 cm) with mean seed width of 1.69 cm (Table 5.2).The result showed low coefficient of variation for seed widths in all agroclimatic zones . The coefficient of variation varies between 1.26-8.08 for all agroclimatic zones with maximum in ACZ-10(8.08) followed by ACZ-6(6.93) >ACZ-5(5.63) >ACZ-2(5.27) >ACZ-8(4.74) >ACZ-7(3.87) >ACZ-9(3.60) and ACZ-4(3.60) >ACZ-1(2.34) >ACZ-3(1.26) (Figure 5.5)..Between different agroclimatic zones for seeds collected from forest areas of all agroclimaticzones , the mean seed width varies from 1.36 cm –1.77 cm with maximum in ACZ-5 and minimum in ACZ-7 . The coefficient of variation between agroclimatic zones for seed width found to be 2.56 (Table 5.1).Similarly, between different agroclimatic zones for seeds collected from agricultural areas of all agroclimaticzones , the mean seed width varies from 1.56 cm –1.82 cm with maximum in ACZ-1 and minimum in ACZ-6 . The coefficient of variation between agroclimatic zones for seed width found to be 2.35 (Table 5.2).

5.4.1.6 Variation in seed thickness of *M. latifolia*

The seed thickness of all provenances varies from 1.13 cm-1.84 cm . The seed thickness varies in ACZ-1 (1.40 cm-1.62 cm) with mean seed thickness of 1.54 cm , ACZ-3 (1.35 cm-1.53 cm) with mean seed thickness of 1.45 cm , ACZ-4 (1.28 cm-1.59 cm) with mean seed thickness of 1.43 cm , ACZ-5 (1.46 cm-1.66 cm) with mean seed thickness of 1.56 cm , ACZ6 (1.64 cm-1.85 cm) with mean seed thickness of 1.75 cm , ACZ-7 (1.13 cm-1.51 cm) with mean seed thickness of 1.27cm , ACZ-8 (1.45 cm-1.61 cm) with mean seed thickness of 1.52 cm , ACZ-9 (1.35 cm-1.64 cm) with mean seed thickness of 1.55 cm and ACZ-10 (1.30 cm-1.84 cm) with mean seed thickness of 1.54 cm (Table 5.1). The result showed low coefficient of variation for seed thickness in all agroclimaticzones . The coefficient of variation varies between 1.99-10.64 for all agroclimatic zones with maximum in ACZ-10(10.64) followed by ACZ-2(8.55) >ACZ-7(5.09) >ACZ-1(4.10) >ACZ-5(4.05) >ACZ-4(3.22) >ACZ-8(3.19) >ACZ-9(3.06) >ACZ-6(2.86) >ACZ-3(1.99) (Figure 5.6).

Similarly, the studies on variation in the seed thickness of *Madhuca latifolia* Macb. collected from agricultural lands of different agroclimatic zones of Odisha were found significant in all agroclimatic zones except ACZ-4. The seed thickness of all provenances varies from 1.14 cm-1.82 cm . The seed thickness varies in ACZ-1 (1.55 cm-1.81 cm) with mean seed thickness of 1.66 cm , ACZ-2 (1.29 cm-1.69 cm) with mean seed thickness of 1.45 cm , ACZ-3 (1.54 cm-1.69 cm) with mean seed thickness of 1.61 cm , ACZ-5 (1.40 cm-1.82 cm) with mean seed thickness of 1.55 cm , ACZ-6 (1.33 cm-1.60 cm) with mean seed thickness of 1.47 cm , ACZ-7 (1.31 cm-1.63 cm) with mean seed thickness of 1.47 cm , ACZ8 (1.14 cm-1.73 cm) with mean seed thickness of 1.44 cm , ACZ-9 (1.30 cm-1.76 cm) with mean seed thickness of 1.58 cm and ACZ-10 (1.34 cm-1.82 cm) with mean seed thickness of 1.57 cm (Table 5.2).The result showed low coefficient of variation for seed thickness in all agroclimatic zones . The coefficient of variation varies between 1.56-6.10 for all agroclimatic zones with maximum in ACZ5(6.10) followed by ACZ-8(5.50) >ACZ-6(5.30) >ACZ-10(4.52)

>ACZ-7(3.83) >ACZ-4(3.50) >ACZ-9(3.38) >ACZ-2(3.77) >ACZ-1(2.45) >ACZ-3(1.56) (Figure 5.6).Between different agroclimatic zones for seeds collected from forest areas of all agroclimatic zones, the mean seed thickness varies from 1.27 cm –1.75 cm with maximum in ACZ-6 and minimum in ACZ-7 . The coefficient of variation between agroclimatic zones for seed thickness found to be 3.31 (Table 5.1). Similarly, for different agroclimatic zones for seeds collected from agricultural areas of all agroclimaticzones , the mean seed thickness varies from 1.44 cm –1.66 cm with maximum in ACZ-1 and minimum in ACZ-8. The coefficient of variation between agroclimatic zones for seed thickness found to be 2.50 (Table5.2).

5.4.1.7 Variation in seed hilum length of *M. latifolia*

The hilum length of all provenances varies from 2.37 cm-3.99 cm . The hilum length varies in ACZ-1 (2.63 cm-3.55 cm) with mean hilum length of 3.01 cm , ACZ-2 (2.45 cm-3.59 cm) with mean hilum length of 3.02 cm , ACZ-3 (2.71 cm-3.99 cm) with mean hilum length of 3.18 cm , ACZ-4 (2.72 cm-3.69 cm) with mean hilum length of 3.15 cm , ACZ-5 (2.66cm-3.78 cm) with mean hilum length of 3.14 cm , ACZ-6 (2.57 cm-2.99 cm) with mean hilum length of 2.79 cm , ACZ-7 (2.48 cm-2.83 cm) with mean hilum length of 2.68 cm , ACZ-8 (2.57 cm-3.45 cm) with mean hilum length of 2.95 cm , ACZ-9 (2.37 cm-2.94 cm) with mean hilum length of 2.73 cm and ACZ-10 (2.58 cm-3.33 cm) with mean hilum length of 2.88 cm (Table 5.1).The result showed low coefficient of variation for hilum lengths in all agroclimatic zones . The coefficient of variation varies between 1.91-10.22 for all agroclimatic zones with maximum in ACZ3(10.22) followed by ACZ-2(7.23) >ACZ-5(6.05) >ACZ-4(4.62) >ACZ-8(4.61) >ACZ--10(4.08) >ACZ-9(3.91) >ACZ-6(3.56) >ACZ-7(2.56) >ACZ-1(1.91) (Figure 5.7).Similarly, the studies on variation in the hilum length of *Madhucalatifolia*Macb.collected from agricultural lands of different agroclimatic zones of Odisha were found significant in all agroclimatic zones except ACZ-3. The hilum length of all provenances varies from 2.06 cm-4.69 cm . The hilum length varies in ACZ1 (2.83 cm-3.34 cm) with mean hilum length of 3.02cm , ACZ-2 (2.58 cm-4.69

cm) with mean hilum length of 2.58 cm , ACZ-4 (2.78 cm-3.45 cm) with mean hilum length of 3.04 cm , ACZ-5 (2.66 cm-3.50 cm) with mean hilum length of 3.01 cm , ACZ-6 (2.52 cm-3.73 cm) with mean hilum length of 2.95 cm , ACZ-7 (2.45 cm-3.54 cm) with mean hilum length of 2.78 cm , ACZ-8 (2.06 cm-3.20 cm) with mean hilum length of 2.76 cm , ACZ-9 (2.67 cm-3.33 cm) with mean hilum length of 2.89 cm and ACZ-10 (2.63 cm-3.83 cm) with mean hilum length of 2.97 cm (Table 5.2).The result showed low coefficient of variation for hilum lengths in all agroclimatic zones . The coefficient of variation varies between 2.87-6.02 for all agroclimatic zones with maximum in ACZ-4(6.02) followed by ACZ-6(5.64) >ACZ-10(4.51) >ACZ-5(5.25) >ACZ-1(4.79) >ACZ-10(4.51) >ACZ-9(4.09) >ACZ-7(3.31) and ACZ-2(3.31) >ACZ-8(2.87) (Figure 5.7).

Between different agroclimatic zones for seeds collected from forest areas of all agroclimaticzones , the mean hilum length varies from 2.68cm –3.18 cm with maximum in ACZ-3 and minimum in ACZ-7. The coefficient of variation between agroclimatic zones for hilum length found to be 1.24 (Table 5.1). Similarly, between different agroclimatic zones for seeds collected from agricultural areas of all agroclimaticzones , the mean hilum length varies from 2.58 cm –3.04 cm with maximum in ACZ-4 and minimum in ACZ-2. The coefficient of variation between agroclimatic zones for hilum length found to be 0.67 (Table 5.2).

5.4.1.8 Variation in kernel length of *M.latifolia*

The kernel length of all provenances varies from 2.34 cm-3.99 cm . The kernel length varies in ACZ-1 (2.46 cm-3.60 cm) with mean kernel length of 2.86 cm , ACZ-2 (2.65 cm-3.99 cm) with mean kernel length of 3.06 cm, ACZ-3 (2.64 cm-3.87 cm) with mean kernel length of 3.12 cm , ACZ-4 (2.69 cm-3.46 cm) with mean kernel length of 3.02 cm , ACZ-5 (2.54 cm-3.28 cm) with mean kernel length of 2.91 cm , ACZ-7 (2.61 cm-3.00 cm) with mean kernel length of 2.80 cm , ACZ-8 (2.36 cm-3.25 cm) with mean kernel length of 2.91 cm , ACZ-9 (2.34 cm-2.86 cm) with mean kernel length of 2.69 cm and ACZ-10 (2.56 cm-3.10 cm) with mean kernel length of 2.83 cm (Table 5.1) .The result showed low coefficient of variation for kernel lengths in all agroclimatic zones . The coefficient of variation varies between 2.69-10.56 for all agroclimatic zones with maximum in ACZ–3(10.56) followed by ACZ–2(10.29) >ACZ–5(6.52) >ACZ–8(5.47) >ACZ–4(5.28) >ACZ–1(4.42) >ACZ–9(4.14) >ACZ–10(3.60) and ACZ–7(3.38) >agroclimatic zone –6(2.69) (Figure 5.8).Similarly, the studies on variation in the kernel length of *Madhuca latifolia* Macb.collected from agricultural lands of different agroclimatic zones of Odisha were found significant in all agroclimatic zones except ACZ-3 . The kernel length of all provenances varies from 2.40 cm-4.02 cm . The kernel length varies in ACZ-1 (2.56 cm-3.21cm) with mean kernel length of 2.92 cm , ACZ-2 (2.72 cm-3.95 cm) with mean kernel length of 2.72 cm , ACZ-4 (2.40 cm-3.12 cm) with mean kernel length of 2.78 cm , ACZ-5 (2.42 cm-3.26 cm) with mean kernel length of 2.81 cm , ACZ-6 (2.60 cm-4.02 cm) with mean kernel length of 3.12 cm , ACZ-7 (2.58 cm-3.62 cm) with mean kernel length of 2.80 cm , ACZ-8 (2.44 cm-3.20 cm) with mean kernel length of 2.80 cm , ACZ-9 (2.46 cm-3.31 cm) with mean kernel length of 2.66 cm and ACZ-10 (2.64 cm-3.76 cm) with mean kernel length of 2.97 cm (Table 5.2) .The result showed low coefficient of variation for kernel lengths in all agroclimatic zones . The coefficient of variation varies between 3.67-11.55 for all agroclimatic zones with maximum in ACZ–6(11.55) followed by ACZ–7(6.00) >ACZ–4(5.69) >ACZ–8(5.64) >ACZ–5(5.63) >ACZ–1(5.61) >ACZ–9(5.23) >ACZ–2(5.21) and ACZ–10(4.26) >ACZ–3(3.67) (Figure 5.8).

Between different agroclimatic zones for kernels collected from forest areas of all agroclimaticzones , the mean kernel length varies from 2.69 cm –3.12 cm with maximum in ACZ-3 and minimum in ACZ-9. The coefficient of variation between agroclimatic zones for kernel length found to be 2.79 (Table 5.1). Similarly, for different agroclimatic zones for kernels collected from agricultural areas of all agroclimaticzones , the mean kernel length varies from 2.66 cm –3.12 cm with maximum in ACZ-6 and minimum in ACZ-9 . The coefficient of variation between agroclimatic zones for kernel length found to be 3.49 (Table 5.2).

5.4.1.9 Variation in kernel width of *M. latifolia*

The kernel width of all provenances varies from 0.97 cm-1.64 cm . The kernel width varies in ACZ-1 (1.25 cm-1.53 cm) with mean kernel width of 1.40 cm , ACZ-2 (1.23 cm-1.46 cm) with mean kernel width of 1.36 cm , ACZ-3 (1.41 cm-1.59 cm) with mean kernelwidth of 1.51 cm , ACZ-4 (1.15 cm-1.58 cm) with mean kernelwidth of 1.40 cm , ACZ-5 (1.36 cm-1.60 cm) with mean kernel width of 1.50 cm , ACZ-7 (0.97 cm-1.18 cm) with mean kernel width of 1.06 cm , ACZ-8 (1.38 cm-1.64 cm) with mean kernel width of 1.51 cm , ACZ-9 (1.37 cm-1.63 cm) with mean kernel width of 1.50 cm and ACZ-10 (1.12 cm-1.54 cm) with mean kernel width of 1.33 cm (Table-5.1) .The result showed low coefficient of variation for kernel width in all agroclimatic zones . The coefficient of variation varies between 3.11-9.07 for all agroclimatic zones with maximum in ACZ–4(9.07) followed by agroclimatic zone–10(5.71) >ACZ–7(5.14) >ACZ–9(4.58) >agroclimatic zone–1(4.51) >ACZ–5(4.22) >ACZ–8(4.19) >ACZ–6(4.17) and ACZ–3(3.34) >ACZ–2(3.11) (Figure 5.9).Similarly, the studies on variation in the kernel width of *M.latifolia* collected from agricultural lands of different agroclimatic zones of Odisha were found significant . The kernel width of all provenances varies from 1.03 cm-1.63 cm . The kernel width varies in ACZ-1 (1.21 cm-1.54 cm) with mean kernel width of 1.39 cm , ACZ2 (1.21 cm-1.51 cm) with mean kernel width of 1.46 cm , ACZ-3 (1.42 cm-1.55 cm) with mean kernel width of 1.49 cm , ACZ-4 (1.21cm-1.54 cm) with mean kernel width of 1.45 cm , ACZ-5 (1.23cm-1.54 cm) with mean kernel width of 1.37 cm , ACZ6 (1.15 cm-1.45 cm) with mean kernel width of 1.26 cm , ACZ-7 (1.03 cm-1.42 cm) with mean kernel width of 1.17 cm , ACZ8 (1.26 cm-1.61 cm) with mean kernel width of 1.49 cm , ACZ-9 (1.29 cm-1.81 cm) with mean kernel width of 1.46 cm and ACZ-10 (1.24 cm-1.63 cm) with mean kernel width of 1.37 cm (Table 5.2) .The result showed low coefficient of variation for kernel width in all agroclimatic zones . The coefficient of variation varies between 2.70-6.94 for all agroclimatic zones with maximum in ACZ5(6.94) followed by ACZ–6(6.87)

>ACZ–4(6.56) >ACZ–7(6.30) >ACZ–9(4.81) >ACZ–10(4.62) >ACZ–2(4.52) >ACZ–7(4.24) and ACZ–1(4.08) >ACZ–3(2.70) (Figure 5.9).Between different agroclimatic zones for kernels collected from forest areas of all agroclimaticzones , the mean kernel width varies from 1.06 cm –1.51 cm with maximum in ACZ-3 and ACZ-8 where as the minimum in ACZ-7 . The coefficient of variation between agroclimatic zones for kernel width found to be 4.46 (Table 5.1). Similarly, between different agroclimatic zones for kernels collected from agricultural areas of all agroclimaticzones , the mean kernel width varies from 1.17 cm –1.49 cm with maximum in ACZ-3 and ACZ-8 where as the minimum in ACZ-7. The coefficient of variation between agroclimatic zones for kernel length found to be 4.75 (Table 5.2).

5.4.1.10 V**ariation in kernel thickness of *M. latifolia***

The kernel thickness of all provenances varies from 0.97 cm-1.62 cm . The kernel thickness varies in ACZ-1(1.07 cm-1.38 cm) with mean kernel thickness of 1.26 cm , ACZ-2(1.21 cm-1.43 cm) with mean kernel thickness of 1.32 cm , ACZ-4 (0.97 cm-1.39 cm) with mean kernel thickness of 1.15 cm , ACZ-5 (1.16 cm-1.37 cm) with mean kernel thickness of 1.27 cm , ACZ-7 (1.11 cm-1.46 cm) with mean kernel thickness of 1.23cm , ACZ-8 (1.24 cm-1.45 cm) with mean kernel thickness of 1.32cm , ACZ-9 (1.15 cm-1.38 cm with mean kernel thickness of 1.25 cm and ACZ-10 (1.14 cm-1.62 cm) with mean kernel thickness of 1.34 cm (Table 5.1) .The result showed low coefficient of variation for kernel thickness in all agroclimatic zones . The coefficient of variation varies between 3.20-6.07 for all agroclimatic zones with maximum in ACZ–4(6.07) followed by ACZ–7(5.98) >ACZ–9(5.06) >ACZ–1(5.03) >ACZ–5 and ACZ-10 (4.98) >ACZ–8(4.78) >ACZ–3(3.93) >ACZ–6(4.36) >ACZ–2(3.20) (Figure 5.10).Similarly, the studies on variation in the kernel thickness of *Madhucalatifolia*Macb.collected from agricultural lands of different agroclimatic zones of Odisha were found significant in all agroclimatic zones except ACZ-1 and ACZ-4 . The kernel thickness of all provenances varies from 0.89 cm-1.63 cm. The kernel thickness varies in ACZ-2 (1.00 cm-1.25 cm) with mean kernel thickness of 1.23 cm , ACZ-3(1.21 cm-1.39 cm) with mean kernel thickness of 1.33cm , ACZ-5(1.12 cm-1.53 cm) with mean kernel thickness of 1.25 cm , ACZ-6 (1.23 cm-1.63 cm) with mean kernel thickness of 1.38 cm , ACZ-7 (1.38 cm-1.61 cm) with mean kernel thickness of 1.51 cm , ACZ-8 (0.89 cm-1.26 cm) with mean kernel thickness of 1.11 cm , ACZ-9 (1.00 cm-1.38 cm) with mean kernel thickness of 1.26 cm and ACZ-10 (1.12 cm-1.58 cm) with mean kernel thickness of 1.37 cm (Table 5.2) .The result showed low coefficient of variation for kernel thickness in all agroclimatic zones. The coefficient of variation varies between 2.86-5.49 for all agroclimatic zones with maximum in ACZ9(5.49) followed by ACZ–7(5.40) >ACZ–5(5.04) >ACZ–6(5.02) >ACZ–4(4.97) >ACZ-1 (4.80) >ACZ–10(4.63) >ACZ–3(3.82) >ACZ–2(3.67) >ACZ–8(2.86) (Figure 5.10).Between different agroclimatic zones for kernels collected from forest areas of all agroclimaticzones , the mean kernel thickness varies from 1.15 cm –1.52 cm with maximum in ACZ-6 and minimum in ACZ-4. The coefficient of variation between agroclimatic zones for kernel thickness found to be 4.31(Table 5.1). Similarly, between different agroclimatic zones for kernels collected from agricultural areas of all agroclimaticzones , the mean kernel thickness varies from 1.11cm –1.51cm with maximum in ACZ-7 and minimum in ACZ-8 . The coefficient of variation between agroclimatic zones for kernel thickness found to be 4.50 (Table 5.2).

5.4.1.11 Variation in 100 fruit weight of *M. latifolia*

The 100 fruit weight of all provenances varies from 801.50g -2253.75g . The 100 fruit weight varies in ACZ-1 (1316.67g-1680.27g) with mean 100 fruit weight of 1441.85g , ACZ-2 (1123g-2023.38g) with mean 100 fruit weight of 1448.78g , ACZ-3 (1210g -1630g) with mean 100 fruit weight of 1424.00g , ACZ-4 (883.67g -2570.00g) with mean 100 fruit weight of 1522.76 g , ACZ-5 (1155.20g-1749.73g) with mean 100 fruit weight of 1405.16 g , ACZ-6 (1132.00 -1758.00g) with mean 100 fruit weight of 1633.40 g , ACZ-7 (801.50 g-907.40g) with mean 100 fruit weight of 855.77 g , ACZ-8 (870.60g-1371.40 g) with mean 100 fruit weight of 1164.57g , ACZ-9 (1014.00g-1660.00g) with mean 100 fruit weight of 1270.02g and ACZ-10 (911.25g-2253.75g) with mean 100 fruit weight of 1711.39g (Table 5.1).

The result showed low coefficient of variation for 100 fruit weight in all agroclimaticzones . The coefficient of variation varies between 2.59-11.25 for all agroclimatic zones with maximum in ACZ–9(11.25) followed by ACZ–1(8.55) >ACZ–5(8.00) >ACZ–4(6.72) >ACZ–6 (5.95) >ACZ–2(4.49) >ACZ–8(4.42) >ACZ–10 (4.28) >ACZ–9(3.63) >ACZ–7(2.59) (Figure 5.11).

Similarly, the studies on variation in the 100 fruit weight of *Madhuca latifolia* Macb. collected from agricultural lands of different agroclimatic zones of Odisha were found significant . The 100 fruit weight of all provenances varies from 835.23g -2310.00g. The 100 fruit weight varies in ACZ-1(1100.93g-1544.00g) with mean 100 fruit weight of 1302.68 g, ACZ-2(1108.33g-2083.38g) with mean 100 fruit weight of 1540.00g, ACZ-3(1380.79g-1640.00g) with mean 100 fruit weight of 1506.47g, ACZ-4(1049.57g-1519.07g)with mean 100 fruit weight of 1296.03g, ACZ-5(951.70g-1452.40g)with mean 100 fruit weight of 1290.51g, ACZ-6(1064.00g-1986.00g)with mean 100 fruit weight of 1319.31g, ACZ-7(1042.80g-2310.00g)with mean 100 fruit weight of 1643.22g, ACZ-8 (835.23g-1838.67g) ith mean 100 fruit weight of 1193.84g, ACZ-9(1231.00g-1652.40g)with mean 100 fruit weight of 1444.45g and ACZ-10(1189.35g-2159.50g) with mean 100 fruit weight of 1674.69g (Table 5.2) .The coefficient of variation varies between 2.80-9.64 for all agroclimatic zones with maximum in ACZ–5(9.64) followed by ACZ–1(5.43) >ACZ–10(5.22) >ACZ–4(6.72) >ACZ–7 (5.16) >ACZ–7(5.14) >ACZ–6(4.60) >ACZ–9 (3.90) >ACZ–2(3.81) >ACZ–3(2.80) (Figure 5.11).

Between different agroclimatic zones for kernels collected from forest areas of all agroclimaticzones , the mean 100 fruit weight varies from 855.77 g - 1711.39 g with maximum in ACZ10 and minimum in ACZ-7. The coefficient of variation between agroclimatic zones for 100 fruit weight found to be 5.28 (Table 5.1). Similarly, for different agroclimatic zones for fruits collected from agricultural areas of all agroclimaticzones , the mean 100 fruit weight varies from 1193.84 g –1674.69 g with maximum in ACZ10 and minimum in ACZ-8 . The coefficient of variation between agroclimatic zones for 100 fruit weight found to be 2.33 (Table 5.2).

5.4.1.12 Variation in 100 seed weight of *M. latifolia*

The 100 seed weight of all provenances varies from 198.40 g to 519.87 g . The 100 seed weightvaries in ACZ1(287.51g-405.33g) with mean 100 seed weight of 342.44 g, ACZ-2(343.36 g-466.25g) with mean 100 seed weight of 395.54 g, ACZ-3 (270.00g -519.87g) with mean 100 seed weight of 394.67 g, ACZ-4 (337.71g -486.40g) with mean 100 seed weight of 375.93 g , ACZ-5 (316.37g-421.11g) with mean 100 seed weight of 376.44 g , ACZ-6 (348.90g-451.20g) with mean 100 seed weight of 392.78 g , ACZ-7 (198.40g-359.60g) with mean 100 seed weight of 266.31g , ACZ-8 (314.50g-461.80g) with mean 100 seed weight of 380.04 g , ACZ-9 (272.53g-434.34g) with mean 100 seed weight of 351.17 g and ACZ-10 (251.30g-468.38 g) with mean 100 seed weight of 355.59 g (Table 5.1) .The result showed low coefficient of variation for 100 seed weight in all agroclimatic zones . The coefficient of variation varies between 4.39-9.32 for all agroclimatic zones with maximum in ACZ–3(9.32) followed by ACZ–10(8.64) >ACZ–1(7.80) >agroclimatic zone–5(7.68) >ACZ–9(6.94) >ACZ–2 (6.44) >ACZ–8(5.20) >ACZ4(4.82) >ACZ–7(4.71) >ACZ–6(4.39) (Figure 5.12).

Similarly, the studies on variation in the 100 seed weight of *Madhuca latifolia* Macb. collected from agricultural lands of different agroclimatic zones of Odisha were found significant . The 100 seed weightof all provenances varies from 230.93 g -583.00 g . The 100 seed weight varies in ACZ-1 (310.93g-508.00g) with mean 100 seed weight of 395.14 g , ACZ-2 (265.67g-583.00 g) with mean 100 seed weight of 265.67 g , ACZ-3 (374.50g -450.00g) with mean 100 seed weight of 410.75g , ACZ-4 (304.85g -407.40g) with mean 100 seed weight of 365.28 g , ACZ-5 (286.09g-508.80 g) with mean 100 seed weight of 366.40 g , ACZ-6 (230.93g-465.29g) with mean 100 seed weight of 342.76 g , ACZ-7 (247.94g-491.07 g) with mean 100 seed weight of 330.43 g , ACZ-8 (248.59 g-442.53 g with mean 100 seed weight of 343.35 g , ACZ-9 (234.02 g-527.50g) with mean 100 seed weight of 363.40 g and ACZ-10 (275.88g-535.83 g) with mean 100 seed weight of 370.54 g (Table 5.2) .The result showed low coefficient of variation for 100 seed weight in all agroclimatic zones . The coefficient of variation varies between 3.05-

9.05 for all agroclimatic zones with maximum in ACZ–6(9.05) followed by ACZ–5(8.92) >ACZ–4(7.57) >ACZ–8(7.38) >ACZ–9(6.77) >ACZ–10 (6.56) >ACZ–7(6.39) >ACZ–1(5.19) >ACZ–2(4.76) >ACZ–3(3.05) (Figure 5.12).

Between different agroclimatic zones for kernels collected from forest areas of all agroclimatic zones, the mean 100 seed weight varies from 266.31 g–395.54 g with maximum in ACZ-2 and minimum in ACZ-7. The coefficient of variation between agroclimatic zones for 100 seed weight found to be 2.00 (Table 5.1).Similarly, for different agroclimatic zones for seeds collected from agricultural areas of all agroclimatic zones , the mean 100 seed weight varies from 265.67 g –410.75 g with maximum in ACZ-3 and minimum in ACZ-2. The coefficient of variation between agroclimatic zones for 100 seed weight found to be 2.99 (Table 5.2).

5.4.1.13 Variation in 100 fresh kernel weight of *M. latifolia*

The 100 fresh kernel weight of all provenances varies from 126.90g -365.93g . The 100 fresh kernel weight varies in ACZ-1(160.78g-284.66g) with mean 100 fresh kernel weight of 217.38 g , ACZ-2(230.40g-314.70g) with mean 100 fresh kernel weight of 267.74g, ACZ-3(180.50g -365.93g) with mean 100 fresh kernel weight of 264.28g, ACZ-4(227.93g -334.20g) with mean 100 fresh kernel weight of 246.73g , ACZ-5(237.40g-318.35g)with mean 100 kernel fresh weight of 283.59g , ACZ-6(223.29g-289.60g)with mean 100 fresh kernel weight of 252.13 g, ACZ-7(126.90g-220.00g)with mean 100 fresh kernel weight of 166.65g , ACZ-8(227.69g-332.40g) with mean 100 fresh kernel weight of 272.05 g , ACZ-9(161.00g-295.40g) with mean 100 fresh kernel weight of 237.26 g and ACZ-10 (178.90g-334.90g) with mean 100 fresh kernel weight of 253.10g (Table 5.1) .The result showed low coefficient of variation for 100 fresh kernel weight in all agroclimatic zones . The coefficient of variation varies between 4.37-12.82 for all agroclimatic zones with maximum in ACZ-4and least was found in ACZ-1(Figure 5.13). Similarly, the studies on variation in the 100 fresh kernel weight of *Madhucalatifolia*Macb. collected from agricultural lands of different agroclimatic zones of Odisha were found significant.The 100 kernel weight of all provenances varies from 139.00 g -397.00 g . The 100 fresh kernel weight varies in ACZ-1(189.78g-305.64g) with mean 100 fresh kernel weight of 243.57 g , ACZ-2(180.83g-397.00 g) with mean 100 fresh kernel weight of 180.90 g , ACZ-3(240.93g -288.60g) with mean 100 fresh kernel weight of 267.47g , ACZ-4(198.18g-268.48g) with mean 100 fresh kernel weight of 237.86g ,ACZ-5(188.80 g-330.72g) with mean 100 fresh kernel weight of 241.28g , ACZ-6(139.00g-286.10g) with mean 100 fresh kernel weight of 207.57g, ACZ-7(167.30g-332.60g) with mean 100 fresh kernel weight of 224.05g , ACZ-8(166.07 g-289.80g) with mean 100 fresh kernel weight of 228.32g , ACZ-9(159.80 g-359.70g) with mean 100 fresh kernel weight of 246.99g and ACZ-10(183.80g-339.10 g) with mean 100 fresh kernel weight of 242.78 g (Table 5.2).The result showed low coefficient of variation for 100 fresh kernel weight in all agroclimatic zones . The coefficient of variation varies between 3.99-13.96 for all agroclimatic zones with maximum in ACZ–1(13.96) followed by ACZ7(8.47) >ACZ–5(7.87) >ACZ–2(5.74) >ACZ–10(5.21) >ACZ–6 (5.20) >ACZ–9(4.40) >ACZ–8(4.16) >ACZ–3(4.11) >ACZ–4(3.99) (Figure 5.13).Between different agroclimatic zones for kernels collected from forest areas of all agroclimaticzones , the mean 100 fresh kernel weight varies from 166.65 g–283.59 g with maximum in ACZ-5 and minimum in ACZ-7. The coefficient of variation between agroclimatic zones for 100 fresh kernel weight found to be 2.60 (Table 5.1).Similarly, for different agroclimatic zones for kernels collected from agricultural areas of all agroclimaticzones , the mean 100 fresh kernel weight varies from 207.57g –272.65 g with maximum in ACZ-2 and minimum in ACZ-6. The coefficient of variation between agroclimatic zones for 100 fresh kernel weight found to be 3.63 (Table 5.2) .

5.4,1,14 Variation in 100 oven dry kernel weight of *M. latifolia*

The 100 oven dry kernel weight of all provenances varies from 85.45g -251.28g . The 100 oven dry kernel weight varies in ACZ-1(111.97g-195.47g) with mean 100 oven dry kernel weight of 150.29 g , ACZ-2(162.12g-218.04g) with mean 100 oven dry kernel weight of 185.12g, ACZ-3(123.34g -251.28g) with mean 100 oven dry kernel weight of

182.71g, ACZ-4(154.29g -227.26g) with mean 100 oven dry kernel weight of 170.39g , ACZ5(162.95g-213.29g) with mean 100 kernel oven dry weight of 195.44g , ACZ-6(151.84g-203.65g) with mean 100 oven dry kernel weight of 173.58 g , ACZ-7(85.45g-153.98g) with mean 100 oven dry kernel weight of 114.80g , ACZ-8(155.12g-230.44g) with mean 100 oven dry kernel weight of 187.29 g , ACZ-9(111.60g-203.69g) with mean 100 oven dry kernel weight of 163.44 g and ACZ-10 (122.20g-234.40g) with mean 100 oven dry kernel weight of 173.94g (Table 5.1) .

The result showed low coefficient of variation for 100 oven dry kernel weight in all agroclimaticzones . The coefficient of variation varies between 2.83-5.33 for all agroclimatic zones with maximum in ACZ–10(5.33) followed by ACZ–3(4.19) >ACZ–7(3.48) >ACZ–8(3.20) >ACZ–5(3.05) >ACZ–6(3.02) >ACZ–1(3.01) >ACZ–4(2.98) >ACZ–2(2.86) >ACZ–9(2.83) (Figure 5.14).Similarly, the studies on variation in the 100 oven dry kernel weight of *Madhucalatifolia*Macb. collected from agricultural lands of different agroclimatic zones of Odisha were found significant . The 100 kernel weight of all provenances varies from 97.16g -273.30 g . The 100 oven dry kernel weight varies in ACZ-1(133.37g-211.80g) with mean 100 oven dry kernel weight of 170.38 g , ACZ-2(126.56g-273.30g) with mean 100 oven dry kernel weight of 192.77 g, ACZ-3(166.46g -201.93g) with mean 100 oven dry kernel weight of 186.76g , ACZ4(139.82g-191.02g) with mean 100 oven dry kernel weight of 165.34g,ACZ-5(127.00 g-232.59g) with mean 100 oven dry kernel weight of 168.87g , ACZ-6(97.16g-201.20g) with mean 100 oven dry kernel weight of 145.13g , ACZ-7(117.47g-232.19g) with mean 100 oven dry kernel weight of 156.30g , ACZ-8(113.43g-200.33g) with mean 100 oven dry kernel weight of 158.50g , ACZ-9(113.81g-260.07g) with mean 100 oven dry kernel weight of 173.34g and ACZ-10(124.24g-232.20g) with mean 100 oven dry kernel weight of 167.68g (Table 5.2).The result showed low coefficient of variation for 100 oven dry kernel weight in all agroclimatic zones . The coefficient of variation varies between 2.60-6.26 for all agroclimatic zones with maximum in ACZ–9(6.26) followed by ACZ–3(5.03) >ACZ–10(4.35) >ACZ–7(3.71) >ACZ–1(3.42) >ACZ–4(3.04) >ACZ–2(2.97) >ACZ–5(2.88) >ACZ–8(2.73) >ACZ–6(2.60) (Figure 5.14).

Between different agroclimatic zones for kernels collected from forest areas of all agroclimaticzones , the mean 100 oven dry kernel weight varies from 114.80g–195.44g with maximum in ACZ-5 and minimum in ACZ-7. The coefficient of variation between agroclimatic zones for 100 oven dry kernel weight found to be 2.74 (Table 5.1).Similarly, for different agroclimatic zones for kernels collected from agricultural areas of all agroclimatic zones , the mean 100 oven dry kernel weight varies from 145.13g –192.77g with maximum in ACZ-2 and minimum in ACZ-6. The coefficient of variation between agroclimatic zones for 100 oven dry kernel weight found to be 3.89 (Table 5.2) .

5.4.2Physico-chemical properties of oil from seeds of *M. latifolia*

In this study of variability in physico-chemical properties of oil from seeds of *Madhuca latifolia* Macb.collected from 10 agroclimatic zones of Odisha , observations were recorded for oil content (%), acid value, saponification value , ester value, FFA (%), iodine value , specific gravity and specific gravity . The variation of the above characters were found out under each agroclimatic zone with in seeds from natural forest, with in seeds from agricultural land and with in the average value of both forest and agricultural land. Similarly , the variation in mean value of the above characters were also studied between different agroclimatic zones for fruits collected from forest lands, between different agroclimatic zones for fruits collected from agricultural land .

5.4.2.1 Variation in Oil content (%) of *M. latifolia*.

The studies on variation in the oil content of *Madhuca latifolia* Macb.collected from forest lands of different agroclimatic zones of Odisha were found significant in all agroclimatic zones except ACZ-3 and ACZ-7. The oil content of all provenances varies from 29.28% -51.84%. The oil content varies in ACZ-1(30.65 %-51.84 %) with mean oil content of 39.15 % , ACZ-2(37.65 %-48.12 %) with mean oil content of 43.25 % , ACZ-4 (39.30 %-49.48 %) with mean oil content of 43.09 % , ACZ-5(32.76 %-46.89 %

) with mean oil content of 40.37 % , ACZ-6(38.52 %-49.93 %) with mean oil content of 42.76 % , ACZ-8(37.66 %-50.72 %) with mean oil content of 43.21 %, ACZ-9(29.28 %-48.97 %) with mean oil content of 40.16 % and ACZ-10(38.98 %-44.65 %) with mean oil content of 41.62 %(Figure 5.24) .

The result showed medium values of coefficient of variation for oil content in all agroclimatic zones . The coefficient of variation varies between 6.02 -7.91 for all agroclimatic zones with maximum in ACZ–3(7.91) followed by ACZ–9(7.87) >ACZ–5(7.83) >ACZ–7(7.67) >ACZ–10(7.60) >ACZ–6 (7.40) >ACZ–4(7.34) >ACZ–8(7.32) >ACZ–2(7.31) >ACZ–1(6.02) (Figure 5.15).

Similarly, the studies on variation in the oil content of *Madhuca latifolia* Macb. collected from agricultural lands of different agroclimatic zones of Odisha were found significant in all agroclimatic zones except ACZ-7. The oil content of all provenances varies from 30.61%-50.63% . The oil content varies inACZ1 (30.61%-44.89%) with mean oil content of 36.68% , ACZ-2(35.21 %-45.78 %) with mean oil content of 40.76% , ACZ-3(37.21%-48.87%) with mean oil content of 42.14 % , ACZ-4 (35.56%-47.58 %) with mean oil content of 40.65 % , ACZ-5(35.67%-46.85 %) with mean oil content of 41.28 % , ACZ-6(33.20 %-45.68 %) with mean oil content of 39.69 % , ACZ-8(34.93%-44.43 %) with mean oil content of 40.28% , ACZ-9 (30.65%-50.63%) with mean oil content of 41.26% and ACZ-10(39.57 %-47.88 %) with mean oil content of 43.84 % (Figure 5.24) .The result showed medium values of coefficient of variation for oil content in all agroclimatic zones . The coefficient of variation varies between 7.21-9.36 for all agroclimatic zones with maximum in ACZ–6(9.36) followed by ACZ–1(8.92) >ACZ–2(8.42) >ACZ–8(7.85) >ACZ–4(7.78) >ACZ–7 (7.72) >ACZ–5 and 9(7.66) >ACZ–3(7.51) >ACZ–10(7.21) (Figure 5.15).

Between different agroclimatic zones for fruits collected from forest areas of all agroclimatic zones , the mean oil content varies from 39.14 % - 43.25 % with maximum in ACZ-2 and minimum in ACZ-1. The coefficient of variation between agroclimatic zones for oil content found to be 3.90 (Figure 5.33).Similarly, between different agroclimatic zones for fruits collected from agricultural areas of all agroclimatic zones , the mean oil content varies from 36.68 % - 43.84 % with maximum in ACZ-10 and minimum in ACZ-1. The coefficient of variation between agroclimatic zones for oil content found to be 7.92 (Figure 5.33) .

5.4.2.2 Variation in Oil yield (g) of *M. latifolia*

The studies on variation in the oil yield of *Madhuca latifolia* Macb.collected from forest lands of different agroclimatic zones of Odisha were found significant in all agroclimatic zones. The oil yield of all provenances varies from 32.70g-112.51g. The oil yield varies in ACZ-1(38.36g-78.50g) with mean oil yield of 58.85g , ACZ-2(62.66g-95.76g) with mean oil yield of 80.01g , ACZ-3(45.97g-99.35g) with mean oil yield of 73.17g , ACZ-4 (61.22g-112.51g) with mean oil yield of 74.00g , ACZ-5(61.62g-100.02g) with mean oil yield of 78.88g , agroclimatic zone -6(61.21g-93.14g) with mean oil yield of 74.52g , ACZ-7 (36.89g-63.92g) with mean oil yield of 47.31g , ACZ-8(59.84g-100.72g) with mean oil yield of 80.91g , ACZ-9(32.70g-86.28g) with mean oil yield of 66.24g and ACZ-10(49.34g-91.39g) with mean oil yield of 72.07g (Figure 5.25) .

The result showed medium values of coefficient of variation for oil yield in all agroclimatic zones . The coefficient of variation varies between 2.75-5.33 for all agroclimatic zones with maximum in ACZ–10(5.33) followed by ACZ–3(4.12) >ACZ–7(3.46) >ACZ–8(3.33) >ACZ–5(3.13) >ACZ–4(3.12) >ACZ–6(2.94) >ACZ–2(2.85) and ACZ–1(2.85) >ACZ–9(2.75) (Figure 31).

Similarly, the studies on variation in the oil yield of *Madhuca latifolia* Macb. collected from agricultural lands of different agroclimatic zones of Odisha were found significant in all agroclimatic zones except ACZ-7. The oil yield of all provenances varies from 33.75g-125.08g . The oil yield varies in ACZ-1 (41.76g-83.28g) with mean oil yield of 62.46g , ACZ2(50.76g-125.08g) with mean oil yield of 78.98g , ACZ-3(71.56g-92.14g) with mean oil yield of 78.53g , ACZ-4 (55.39g-84.77g) with mean oil yield of 67.44g , ACZ-5(51.63g-83.61g) with mean oil yield of 69.15g , ACZ-6(33.75g-84.20g) with mean oil yield of 57.94g , ACZ-7(50.48g-91.11g) with mean oil yield of 63.58g, ACZ-8 (40.73g-81.16g) with mean oil yield of 63.84g , ACZ-9 (37.40g-104.70g) with mean oil yield of 71.51g and ACZ-10(56.16g-106.00g) with mean oil yield of 73.70g (Figure 5.25) .

The result showed medium values of coefficient of variation for oil yield in all agroclimatic zones . The coefficient of variation varies between 2.72-5.56 for all agroclimatic zones with maximum in ACZ–9(5.56) followed by ACZ–3(5.39) >ACZ–10(4.40) >ACZ–7(3.64) >agroclimatic zone –1(3.24) >ACZ2 (2.86) >ACZ–4(2.77)>ACZ–5(2.76) >ACZ–6(2.73) >ACZ–8(2.72) (Figure 5.16).Between different agroclimatic zones for fruits collected from forest areas of all agroclimaticzones , the mean oil yield varies from 47.31g- 80.91g with maximum in ACZ-8 and minimum in ACZ-7. The coefficient of variation between agroclimatic zones for oil yield found to be 3.08 (Figure 5.33).Similarly, between different agroclimatic zones for fruits collected from agricultural areas of all agroclimatic zones , the mean oil yield varies from 57.94g – 78.98g with maximum in ACZ-2 and minimum in ACZ-6. The coefficient of variation between agroclimatic zones for oil yield found to be 4.11 (48) .

5.4.2.3 Variation in Acid value of *M. latifolia*

The studies on variation in the acid value of *Madhuca latifolia* Macb.collected from forest lands of different agroclimatic zones of Odisha were found significant. The acid value of all provenances varies from 0.71-104.32. The acid value varies in ACZ-1(7.52-9.83) with mean acid value of 8.97 , ACZ-2(3.84-6.92) with mean acid value of 4.84 , ACZ-3(3.81-6.11) with mean acid value of 4.95 , ACZ-4 (3.74-6.73) with mean acid value of 5.07, ACZ5(0.71-4.61) with mean acid value of 3.06 , ACZ-6(0.76-104.32) with mean acid value of 29,06 , ACZ-7(1.85-16.65) with mean acid value of 5.36 , ACZ-8(1.40-5.68) with mean acid value of 3.81, ACZ-9(0.94-1.87) with mean acid value of 1.17 and ACZ-10(2.39-4.78) with mean acid value of 3.22(Figure 5.26) .The result showed medium values of coefficient of variation for acid value in all agroclimatic zones . The coefficient of variation varies between 4.11-10.88 for all agroclimatic zones with maximum in ACZ–6(10.88) followed by ACZ–5(10.35) >ACZ–10(9.78) >ACZ–8(8.29) >ACZ–1(6.67) >ACZ–2 (6.53) >ACZ–4(6.46) >ACZ–3(6.38) >ACZ7(5.86) >ACZ–9(4.11) (Figure 5.17).

Similarly, the studies on variation in the acid value of *Madhuca latifolia* Macb. collected from agricultural lands of different agroclimatic zones of Odisha were found significant.The acid value of all provenances varies from 0.67-56.65 . The acid value varies in ACZ-1 (1.81-5.43) with mean acid value of 3.26 , ACZ-2(7.35-10.02) with mean acid value of 8.55 , ACZ-3(1.03-3.94) with mean acid value of 2.05 , ACZ-4 (1.91-3.83) with mean acid value of 2.55, ACZ-5(1.63-3.64) with mean acid value of 2.77 , ACZ-6(5.86-56.65) with mean acid value of 21.84 , ACZ-7(0.70-4.21) with mean acid value of 2.99 , ACZ-8(1.34-3.42) with mean acid value of 2.10 , ACZ-9 (1.06-4.40) with mean acid value of 2.22 and ACZ-10(0.67-2.00) with mean acid value of 1.34 (Figure 5.26) .

The result showed medium values of coefficient of variation for acid value in all agroclimatic zones . The coefficient of variation varies between 3.15-15.43 for all agroclimatic zones with maximum in ACZ–3(15.43) followed by ACZ–8(15.04) >ACZ–6(14.48) >ACZ–4(12.22) >ACZ–10(11.90) >ACZ–5 (11.42) >ACZ–2(11.10) >ACZ–7(10.56) >ACZ–1(9.71) >ACZ–9(3.15) (Figure 5.17).Between different agroclimatic zones for fruits collected from forest areas of all agroclimaticzones , the mean acid value varies from 1.17 - 29.06 with maximum in ACZ6 and minimum in ACZ-9 . The coefficient of variation between agroclimatic zones for acid value found to be 13.72 (Figure 5.33).Similarly, between different agroclimatic zones for fruits collected from agricultural areas of all agroclimatic zones , the mean acid value varies from 1.34-21.84 with maximum in ACZ-6 and minimum in ACZ-10 . The coefficient of variation between agroclimatic zones for acid value found to be 3.19 (Figure 5.33) .

5.4.2.4 Variation in Saponification value of *M. latifolia*

The studies on variation in the saponification value of *M.latifolia* collected from forest lands of different agroclimatic zones of Odisha were found significant. The saponification value of all provenances varies from 108.60-235.30. The saponification value varies in ACZ-1(181.00-235.30) with mean saponification value of 204.53 , ACZ-2(108.60-153.85) with mean saponification value of 127.61, ACZ-3(160.31-224.44) with mean saponification value of 191.58, ACZ-4 (166.58-210.41) with mean saponification value of 182.36 , ACZ-5(165.03-215.09) with mean saponification value of 190.17 , ACZ6(176.35-216.42) with mean saponification value of 193.98 , ACZ-7(110.52-153.03) with mean saponification value of 130.92, ACZ-8(192.88-227.95) with mean saponification value of 212.17 , ACZ-9(126.70-181.00)with mean saponification value of 151.14 and ACZ-10(136.27-184.36)with mean saponification value of 164.32 (Figure 5.27) .

The result showed medium values of coefficient of variation for saponification value in all agroclimaticzones . The coefficient of variation varies between 3.26-8.47 for all agroclimatic zones with maximum in ACZ–3(8.47) followed by ACZ–8(7.45) >ACZ–7(7.32) >ACZ–10(5.77) >ACZ –4(5.20) >ACZ–5(4.99) >ACZ–9(4.18) >ACZ–1(4.10) >ACZ–2(3.60) >ACZ–6(3.26) (Figure 5.18).Similarly, the studies on variation in the saponification value of*Madhucalatifolia*Macb. collected from agricultural lands of different agroclimatic zones of Odisha were found significant.The saponification value of all provenances varies from 93.52-271.20 . The saponification value varies in ACZ--1 (171.95-226.25) with mean saponification value of 196.39 , ACZ-2(108.60-144.80) with mean saponification value of 123.99, ACZ-3(93.52-134.66) with mean saponification value of 113.46, ACZ-4 (175.34-227.95) with mean saponification value of 202.52 , ACZ-5(187.03-271.20) with mean saponification value of 224.44 , ACZ-6(152.30-200.39) with mean saponification value of 176.35 , ACZ-7(140.28-205.74) with mean saponification value of 174.88 , ACZ-8(125.76-203.16) with mean saponification value of 161.56, ACZ-9(135.75-190.05) with mean saponification value of 162.90 and ACZ-10(128.25-176.35) with mean saponification value of 149.89 (Figure 42) .The result showed medium values of coefficient of variation for saponification value in all agroclimatic zones . The coefficient of variation varies between 3.12-10.55 for all agroclimatic zones with maximum in agroclimatic zone–10(10.55) followed by ACZ–5(7.41) >ACZ–9(5.82) >ACZ–3(5.58) >ACZ–7(5.43) >ACZ–6 (5.38) >ACZ–1(5.01) >ACZ–8(3.92) ACZ–2(3.51) >ACZ–4(3.12) (Figure 5.18).Between different agroclimatic zones for fruits collected from forest areas of all agroclimaticzones , the mean saponification value varies from 127.61-212.17 with maximum in ACZ8 and minimum in ACZ-2. The coefficient of variation between agroclimatic zones for saponification value found to be 5.49 (Figure 48). Similarly, for different agroclimatic zones for fruits collected from agricultural areas of all agroclimatic zones, the mean saponification value varies from 113.46-224.44 with maximum in ACZ-5 and minimum in ACZ-3. The coefficient of variation between agroclimatic zones for saponification value found to be 5.71 (Figure 5.33) .

5.4.2.5 Variation in Ester value of *M. latifolia*

The studies on variation in the ester value of *Madhuca latifolia* Macb. collected from forest lands of different agroclimatic zones of Odisha were found significant. The ester value of all provenances varies from 72.03-226.62. The ester value varies in ACZ-1(171.17-226.62) with mean ester value of 195.56, ACZ-2(103.99-148.47) with mean ester value of 122.76 , ACZ3(155.41-218.88) with mean ester value of 186.62 , ACZ-4 (160.28-205.18) with mean ester value of 177.29 , ACZ-5(161.29-214.38) with mean ester value of 187.11 , ACZ6(72.03-195.09) with mean ester value of 164.92, ACZ-7(104.35-147.48) with mean ester value of 125.56 , ACZ-8(187.91-225.14) with mean ester value of 208.35 , ACZ-9(125.17-179.13)with mean ester value of 149.96 and ACZ-10(133.88-181.97)with mean ester value of 161.10 (Figure 5.28) .

The result showed medium values of coefficient of variation for ester value in all agroclimatic zones. The coefficient of variation varies between 0.76-2.58 for all agroclimatic zones with maximum in ACZ–2(2.58) followed by ACZ–7(2.52) >ACZ–9(2.11) >ACZ–10(1.96) >agroclimatic zone –6(1.92) >ACZ–4(1.78) >ACZ–3(1.69) and ACZ–5(1.69) >ACZ–8(1.52) >ACZ–1(0.76) (Figure 34).Similarly, the studies on variation in the ester value of*Madhuca latifolia* Macb. collected from agricultural lands of different agroclimatic zones of Odisha were found significant.The ester value of all provenances varies from 91.46-268.12 . The ester value varies inACZ-1 (168.33-222.63) with mean ester value of 193.13 , ACZ-2(99.25-136.78) with mean ester value of 115.43, ACZ-3(91.46-133.63) with mean ester value of 111.41 , ACZ-4(173.43-226.03) with mean ester value of 199.97 , ACZ-5 (183.96-268.12) with mean ester value of 221.67 , ACZ-6(103.66-184.47) with mean ester value of 154.51 , ACZ-7(138.17-202.14) with mean ester value of 171.88 , ACZ-8(124.43-201.10) with mean ester value of 159.46 , ACZ-9(134.16-187.85) with mean ester value of 160.68 and ACZ-10 (126.92-174.34) with mean ester value of 148.56 (Figure 5.28)

The result showed medium values of coefficient of variation for ester value in all agroclimatic zones. The coefficient of variation varies between 1.43-2.84 for all agroclimatic zones with maximum in ACZ–3(2.84) followed by ACZ–2(2.74) >agroclimatic zone–10(2.13) >ACZ–6(2.05) >ACZ–8(1.98) >ACZ–9(1.97) >ACZ–7(1.84) >agroclimatic zone–1(1.64) >ACZ–4(1.58) >ACZ–5(1.43) (Figure 5.19).Between different agroclimatic zones for fruits collected from forest areas of all agroclimatic zones, the mean ester value varies from 122.76-208.35 with maximum in ACZ-8 and minimum in ACZ-2 . The coefficient of variation between agroclimatic zones for saponification value found to be 0.27 (Figure 5.33). Similarly, for different agroclimatic zones for fruits collected from agricultural areas of all agroclimatic zones, the mean ester value varies from 111.41-221.67 with maximum in ACZ-5 and minimum in ACZ-3. The coefficient of variation between agroclimatic zones for saponification value found to be 1.93 (Figure 5.33) .

5.4.2.6 Variation in Free fatty acid content of *M. latifolia*

The free fatty acid content of all provenances varies from 0.36%-52.42%. The free fatty acid content varies in ACZ-1(3.78% -4.94%) with mean free fatty acid content of 4.51% , ACZ-2(1.93%-3.48%) with mean free fatty acid content of 2.43%, ACZ-3(1.92%-3.07%) with mean free fatty acid content of 2.49% , ACZ-4 (1.88%-3.38%) with mean free fatty acid content of 2.55% , ACZ5(0.36 %-2.32%) with mean free fatty acid content of 1.54 % , ACZ-6(0.38 %-52.42 %) with mean free fatty acid content of 14.60 % , ACZ-7(0.93 %-8.37 %) with mean free fatty acid content of 2.70 % , ACZ-8(0.70%-2.86 %) with mean free fatty acid content of 1.92% , ACZ-9(0.47%-0.94%)with mean free fatty acid content of 0.59% and ACZ-10(1.20 %-2.40%)with mean free fatty acid content of 1.62 % (Figure 5.29) .

The result showed medium values of coefficient of variation for free fatty acid content in all agroclimaticzones . The coefficient of variation varies between 4.10 – 21.66 for all agroclimatic zones with maximum in ACZ–6(21.66) followed by ACZ–8(16.49) >ACZ–4(12.87) >ACZ–3(12.69) >agroclimatic zone –7(11.72) >ACZ–1 (7.16) >ACZ–2(6.45) >ACZ–9(5.37) >ACZ–10(5.21) >ACZ–5(4.10) (Figure 35).Similarly, the studies on variation in the free fatty acid content of*Madhucalatifolia*Macb. collected from agricultural lands of different agroclimatic zones of Odisha were found significant.The free fatty acid content of all provenances varies from 0.34%-28.47% . The free fatty acid content varies inACZ1 (0.91%-2.73%) with mean free fatty acid content of 1.64 % , ACZ-2(3.69 %-5.03 %) with mean free fatty acid content of 4.30 % , ACZ-3(0.52 %-1.98 %) with mean free fatty acid content of 1.03% , ACZ-4(0.96%-1.92%) with mean free fatty acid content of 1.28% , ACZ-5(0.82%-1.83%) with mean free fatty acid content of 1.39 % , ACZ-6(2.95 %-28.47%) with mean free fatty acid content of 10.97 % , ACZ-7(0.35%-2.11%) with mean free fatty acid content of 1.50% , ACZ-8(0.67%-1.72%) with mean free fatty acid content of 1.06%, ACZ-9(0.53%-2.21%) with mean free fatty acid content of 1.11% and ACZ-10(0.34%-1.01%) with mean free fatty acid content of 0.67% (Figure 5.29) .

The result showed medium values of coefficient of variation for free fatty acid content in all agroclimaticzones . The coefficient of variation varies between 4.67-28.82 for all agroclimatic zones with maximum in ACZ–6(28.82) followed by agroclimatic zone–4(8.40) >ACZ–2(7.38) >ACZ–5(6.92) >agroclimatic zone –1(6.59) >ACZ–8 (6.35) >ACZ–7(6.31) >agroclimatic zone–3(6.13) >ACZ–9(6.05) >ACZ–10(4.67) (Figure 5.20).Between different agroclimaticzones for fruits collected from forest areas of all agroclimatic zones , the mean free fatty acid content varies from 0.59% - 14.6% with maximum in ACZ-6 and minimum in ACZ-9 . The coefficient of variation between agroclimatic zones for saponification value found to be 9.09 (Figure 5.33). Similarly, for different agroclimatic zones for fruits collected from agricultural areas of all agroclimatic zones , the mean free fatty acid content varies from 0.67% - 10.97% with maximum in ACZ-6 and minimum in ACZ-10. The coefficient of variation between agroclimatic zones for saponification value found to be 12.71 (Figure 5.33) .

5.4.2.7 Variation in Iodine value of *M. latifolia*

The iodine value of all provenances varies from 54.10-67.82. The iodine value varies in ACZ-1(54.10-61.21) with mean iodine value of 57.56 , ACZ-3(54.61-63.50) with mean iodine value of 58.75 , ACZ-4 (55.37-63.50) with mean iodine value of 59.87 and ACZ-6(54.86-62.99) with mean iodine value of 59.03 (Figure 5.30) .The result showed medium values of coefficient of variation for iodine value in all agroclimatic zones . The coefficient of variation varies between 4.26-5.71 for all agroclimatic zones with maximum in ACZ–8(5.71) followed by ACZ–5(5.50) >ACZ–3(5.38) >ACZ–6(5.36) >ACZ–4(5.28) >ACZ–10 (5.13) >ACZ–9(5.06) >ACZ–2(4.96) >ACZ–7(4.90) >ACZ–1(4.26) (Figure 5.21).Similarly, the studies on variation in the iodine value of*Madhucalatifolia*Macb. collected from agricultural lands of different agroclimatic zones of Odisha were found significant in ACZ-1 , ACZ-4 and ACZ-8 . The iodine value of all provenances varies from 52.83.-68.07. The iodine value varies in ACZ-1 (54.36-62.99) with mean iodine value of 58.80 , ACZ-4 (54.61-60.20) with mean iodine value of 56.69 and ACZ-8(56.13-67.31) with mean iodine value of 62.84 (Figure 5.30) .

The result showed medium values of coefficient of variation for iodine value in all agroclimatic zones. The coefficient of variation varies between 2.79-5.75 for all agroclimatic zones with maximum in ACZ–5(5.75) followed by ACZ–1(5.38) >ACZ–7(5.28) >ACZ–6(5.24) >ACZ–8(5.03) >ACZ–9 and 10 (5.02) >ACZ–2(4.93) >ACZ–3(4.85) >ACZ–4(2.79) (Figure 36).Between different agroclimatic zones for fruits collected from forest areas of all agroclimaticzones , the mean iodine value varies from 55.42-64.52 with maximum in ACZ-7 and minimum in ACZ-8. The coefficient of variation between agroclimatic zones for iodine value found to be 5.27 (Figure 5.33). Similarly, for different agroclimatic zones for fruits collected from agricultural areas of all agroclimaticzones , the mean iodine value varies from 54.99-65.20 with maximum in ACZ-3 and minimum in ACZ-5. The coefficient of variation between agroclimatic zones for iodine value found to be 5.20 (Figure 5.33) .

5.4.2.8 V**ariation in Density of oil of *M. latifolia***

The specific gravity of all provenances varies from 0.863-0.901. The coefficient of variation varies between 1.13-5.30 for all agroclimatic zones with maximum in ACZ–1(5.30) followed by ACZ–2(3.73)>ACZ–10(3.64) >ACZ–7(3.63) >ACZ–9(3.62) >ACZ–3 and 5(3.57) >ACZ–6(3.56) >ACZ–8(3.52) >ACZ4(1.13) (Figure 5.22).Similarly, the studies on variation in the density of oil of *Madhuca latifolia* Macb. collected from agricultural lands of different agroclimatic zones of Odisha were found non significant. The density of oil of all provenances varies from 0.853-0.904 .The coefficient of variation varies between 1.78-3.64 for all agroclimatic zones with maximum in ACZ–2, 3 and 10 (3.64) followed by ACZ–8 and 9 (3.62) >ACZ–6 and 7(3.59) >ACZ–4(3.57) >agroclimatic zone –5(3.52) >ACZ–1 (1.78) (Figure 5.22).Between different agroclimatic zones for fruits collected from forest areas of all agroclimaticzones , the mean density of oil varies from 0.871-0.898 with maximum in ACZ-8 and minimum in ACZ-7. The coefficient of variation between agroclimatic zones for density of oil found to be 3.58 (Figure 5.33). Similarly, for different agroclimatic zones for fruits collected from agricultural areas of all agroclimaticzones , the mean density of oil varies from 0.868-0.899 with maximum in ACZ-5 and minimum in ACZ-3 . The coefficient of variation between agroclimatic zones for density of oil found to be 3.60 (Figure 5.33) .

5.4.2.9 V**ariation in Specific gravity of oil of *M. latifolia***

The specific gravity of all provenances varies from 0.865-0.903.The coefficient of variation varies between 3.51-3.62 for all agroclimatic zones with maximum in agroclimatic zone–2 and 7(3.62) followed by ACZ–9(3.61)>ACZ–10(3.59) >ACZ–4(3.58) >ACZ–3,5 and 6(3.56) >ACZ–1 (3.55) >ACZ–8(3.51) (Figure 5.23).Similarly, the studies on variation in the specific gravity of oil of *Madhuca latifolia* Macb.collected from agricultural lands of different agroclimatic zones of Odisha were found non significant.The specific gravity of oil of all provenances varies from 0.855-0.906 .The coefficient of variation varies between 3.51-3.63 for all agroclimatic zones with maximum in agroclimatic zone–2 and 3(3.63) followed by ACZ–9(3.62)>ACZ8 and 10(3.61) >ACZ–6 and 7(3.58) >ACZ–1and 4(3.56) >ACZ–5 (3.51) (Figure 5.23).Between different agroclimatic zones for fruits collected from forest areas of all agroclimaticzones , the mean specific gravity of oil varies from 0.872-0.900 with maximum in ACZ-8 and minimum in ACZ-7. The coefficient of variation between agroclimatic zones for specific gravity of oil found to be 3.58 (Figure 5.55). Similarly, for different agroclimatic zones for fruits collected from agricultural areas of all agroclimaticzones , the mean specific gravity of oil varies from 0.870-0.901 with maximum in ACZ-5 and minimum in ACZ-3. The coefficient of variation between agroclimatic zones for specific gravity of oil found to be 3.59 (Figure 5.33) .

5.4.3 Correlation between morphometric characters of fruits, physico-chemical properties of oil, ecological and soil characters and seedling characters

5.4.3.1 Correlation of various traits for seeds collected from *M. latifolia* trees present in forest lands

The correlations with in the morphological characters of seeds is given in the Table 5.3 . The 100 kernel ovendry weight responsible for oil yield from kernels of *Madhuca latifolia* has significant positive correlation with fruit width , seed length, seed width, kernel width, 100 seed Fresh weight and 100 fresh kernel weight . The correlations with in the oil characters of seeds is given in the Table 5.4 . The oil content and oil yield showed no significant correlation with any of the other oil characters . However, acid value found to be significantly positively correlated with free fatty acid content and ester value of oil positively correlated with saponification value. The correlations among the morphological and oil characters of seeds is given in the Table 5.5. The oil content has no significant correlation with any of the morphological traits , however, the oil yield showed significant correlation with seed length, seed width, kernel width, kernel thickness, 100 seed Fresh weight,100 fresh kernel weight and 100 oven dry kernel weight .

None of the soil parameters showed significant positive correlation with any of the seed morphological traits or oil traits. Similarly, neither the seed morphological traits nor the oil traitsshowed significant positive correlation with the ecological characters.The correlations of the morphological traits of seeds with the climatic parameters of the forest lands ispresented in the Table 5.6. Morphological characters like fruit width , showed significant positive correlation with maximum temperature, minimum temperature and average temperature, fruit thickness with minimum temperature and average temperature, seed width with average temperature, 100 fresh fruit weight with minimum temperature, kernel length significantly positively correlated with average humidity and significantly negatively correlated with difference of maximum and minimum temperature . However, the Oil traitsshowed no significant positive correlation with the climatic parameters.The correlations with in the germination-seedling characters of seeds is given in the Table 5.12 . Germination percentage showed significant positive correlation with mean daily germination, peak value, germination value , collar diameter, fresh seedling biomass and oven dry seedling biomass . Peak value showed significant positive correlation with mean daily germination and germination value where as collar diameter showed significant positive correlation with seedling length , fresh seedling biomass and oven dry seedling biomass.The correlations among the morphological characters of seeds and germination-seedling characters found only seed length to be significantly positively correlated with fresh seedling biomass where as other traits to be non significant. In addition the correlations among the oil characters of seeds and germination-seedling characters found only moisture content of seeds to be significantly positively correlated with acid value and free fatty acid content of oil where as other traits to be non significant.

5.4.3.2 Correlation of various traits for seeds collected from *M. latifolia* trees present in agricultural lands

The correlation study was carried out among morphological and oil characters of seeds collected from agricultural lands along with the ecological , soil and climatic parameters of the habitat.The correlations with in the morphological characters of seeds is given in the Table 5.7 . The 100 kernel oven dry weight responsible for oil yield from kernels of *Madhuca latifolia* has significant positive correlation with seed length, seed thickness, hilum length and 100 seed Fresh weight.The correlations with in the oil characters of seeds is given in the Table 5.8 .Similarly like forest lands, in case of seeds from agricultural lands ,the oil content and oil yield showed no significant correlation with any of the other oil characters . However, acid value found to be significantly positively correlated with free fatty acid content and ester value of oil positively correlated with saponification value. The correlations among the morphological and oil characters of seeds is given in the Table 5.5 . The oil content has no significant correlation with any of the morphological or oil traits , however, the oil yield showed only positive significant correlation with 100 oven dry kernel weight .The correlations of the morphological traits of seeds with the soil characters of the agricultural lands are presented in the Table 5.9 . None of the soil parameters showed significant positive correlation with any of the seed morphological traits or oil traits.The correlations of the oil traits of seeds with the soil characters of the agricultural lands are presented in the Table 5.10 .Oil content found to have significant positive correlation with soil pH, soil EC where as ester value, density and specific gravity of oil with soil available nitrogen.The correlations of the morphological traits of seeds with the climatic parameters of the forest lands are presented in the Table 5.11 . Morphological characters like fruit length showed significant positive correlation with minimum temperature and average temperature, seed thickness with maximum temperature and average temperature , fruit width, fruit thickness and kernel thickness with total rainfall .Similarly like the forest lands, the oil traits of the seeds from agricultural lands showed no significant positive correlation with the climatic parameters.The correlations with in the germination-seedling characters of seeds is given in the Table 5.12. Germination percentage showed significant positive correlation with mean daily germination, peak value and germination value . Peak value showed significant positive correlation with mean daily germination and germination value where as seedling length showed significant positive correlation with fresh seedling biomass and oven dry seedling biomass . Collar diameter showed significant positive correlation with moisture content and fresh seedling biomass with oven dry seedling biomass.The correlations among the morphological characters of seeds and germination-seedling characters found only seed width to be significantly positively correlated with seedling shoot length and fresh seedling biomass.The correlations among the oil characters of seeds and germination-seedling characters found non of the characters are significantly correlated.

5.5 DISCUSSION

5.5.1Variation of morphological characters with in each agroclimatic zone

Limited studies have been carried out regarding variation of seed morphological characters for the genus Madhuca .The variation was studied separately in fruits collected from forest land and agricultural land for anagroclimatic zone. The morphological characters of fruit for sample trees with in each agroclimatic zone is presented in Table 5.1 and 5.2 .The coefficient of variation with in each agroclimatic zone for different morphological parameters of seeds collected from forest and agricultural lands are presented in the Fig.5.1- 5.14 . This indicates there is variation of a morphological character with in a agroclimatic zone which may be due to genotypic factor of sample trees , to certain extent of environmental factors like microclimatic and microedaphicprevailing within the agroclimatic zone and interaction of genotypic and environmental factors .Higher level of polymorphism has been reported in *Madhuca indica* (Nimbalkar, 2018) and another species from the same genus *Madhuca hainanensis* (96.9%) (Dai et al. 2013) .Mitchell et al. (2017) described variability exists at the intrapopulation level, where the individuals within the same population show differences in behaviour or responses . This variability may be because of an evolutionary process called bet-hedging which produces a range of phenotypes for the next generation which has increased chances of generational survivality in an uncertain or changing environment (Slatkin, 1974). This reduces the risk of a population becoming extinct in different environmental conditions and alsoensures the success of the future generation where large numbers of progeny are generated. Scotti et al. (2015) also described that microgeographic variation can be a reason for variation with in a population of a species.

Nimbalkaret. al(2018) in a similar study found that 15% genetic variation occurs among regions and 85% within individuals of *Madhuca indica* which was even higher than *Madhuca hainanensis* where among-population and within-population variance was 12 and 71% (Dai et al. 2013). Mehedi et al. (2014) reported in his study for Inter and

Intrapopulation variations in *Stachys inflata* that habitat of a population may be consisting of different microhabitats and different ecological condition prevailing on them and these conditions can yield different morphological characters within a population . He also discussed that the individual–environment interactions might be more complex than was previously thought. Polymorphism has also been reported in other genera such as Eurya (Bahulikar et al. , 2004) and Terminalia (Sarwat et al., 2011).

Although works has not been reported regarding the intrapopulation variation with in the provenances for *Madhuca latifolia* , however, very few works are reported on other tree species. Gera et al. (2001) studied on Intra-population variation in *Albizzia procera* relation to seed characters among the 33 trees in Jabalpurand found that large amount of variation was recorded seed length (8.78%) .Chezhin et al. (2010) in his study on genetic diversity analysis in a seed orchard of *Eucalyptus tereticornis* found that the variation due tointra population component accounted for 46.3% .The maximum coefficient of variation for each of the morphological characters of fruits collected from both forest and agricultural lands under different agroclimatic zones are presented in Fig. 5.1-5.14.In case of fruits collected from forest lands, themorphological characters like fruit length , seed helium length , kernel length and 100 seed weight has maximum variation in ACZ-3 and characters like kernel width , kernel thickness and 100 fresh kernel weight showed maximum variation in ACZ-4 . However, other morphological characters showed its maximum variation in different agroclimaticzones . Similarly, in case of fruits collected from agricultural lands themorphologicalcharacters like fruit length , seed length , kernel length and 100 seed weight has maximum variation in ACZ-6 , characters like seed thickness, kernel width , 100 fruit weight showed maximum variation in ACZ-5 and characters like fruit width, fruit thickness has maximum variation in ACZ-3 . However, other morphological characters showed its maximum variation in different agroclimaticzones . These might be due to higher number of better genotypes , effect of environmental characteristics of the agroclimatic zone and their interaction contributing to maximum variation of the particular character in that agroclimatic zone.

The morphological characters showing higher maximum value of coefficient of variations like seed length (11.21), seed thickness (10.64) , seed helium length (10.22) , kernel length (10.56) , 100 fruit weight (11.25) 100 kernel weight (12.82) can be considered for selection purposes in their respective agroclimatic zone in forest lands for further improvement studies of the species . Similarly, from agricultural lands also morphological characters showing higher maximum value of coefficient of variations like seed length(11.21), kernel length(11.55) , kernel width(11.55), and 100 fresh kernel weight (13.96) can be considered for selection purposes in their respective agroclimatic zone for further improvement studies of the species.The maximum values of different traits are found in different sample trees (i.e maximum value of most of the traits are not found in a single sample tree) with in a agroclimatic zone . This also shows that the different morphological characters of fruits with in a tree also may not be interdependent to each other to a higher degree and are may be more influenced by genetic control than the environmental factors. Morphological characters of fruits showed significant differences of their mean in forest lands and agricultural land undersomeagroclimaticzones.The significant difference of mean of a trait between forest and agricultural land occurring in certainagroclimatic zones and not in others may be due to microclimatic and edaphic conditions of forest and agricultural lands , genotypic factors of sample trees present in it andtheir interactions.

Besides that it was also found that even fora particular character in all agroclimatic zones, the higher mean valuesare not confined either completely to forest lands or to agricultural lands. The highest mean value of a character is mainly because of contribution of better genotypes present in that area (either forest land or agriculture land) and also the response of those genotypes to the local environment favoring the character .Similar type of variation study carried out by Nimbalkar (2018) in trees from forest areas and agricultural field bunds for *Madhuca indica* .

The coefficient of variation of each morphological character of fruit among all agroclimatic zones is given by Table 5.1 and 5.2. These variation may be due to the fact that this species grows over a wide range of climate as well as edaphic conditions in forests of different agroclimaticzone . Similar findings were revealed by Wani and Ahmad (2013), Wani and Wani (2013) in case of *Madhuca indica* and Abraham *et al*. (2010) in case of *Madhuca longifolia*. Variability of seed characteristics were also studied by Police *et al*. (2013),Vasanth Reddy *et al*. (2007) in *Pongamia pinnata* and Gairola*et al*. (2011), Sudhirkumar (2003).The seed characteristics of *Madhuca indica* Gmel like fruit length, 100 fruit weight , kernel width and kernel thickness are having higher variation among the agroclimatic zones and may be taken up for selection of trees from different agroclimatic zones for further study and improvement of the species. Similar types of findings were also reported by Prabhkaran*et al.* (2019) ,Gingwal*et al*. (2005), Kaushik*et al*. (2007), Mahapatra and Panda (2010) in *Jatropha curcas*.

Higher value of coefficient of variation were found for morphological characters of the fruits collected from forest lands like 100 fruit weight (5.28) , fruit length (4.77) , kernel width (4.46) and kernel thickness (4.31). Similarly, Higher value of coefficient of variation were found for morphological characters of the fruits collected from agricultural lands likekernelwidth (4.75), kernel thickness (4.50) , 100 kernel weight (3.63) and kernel length .These characters can be taken up respectively in forest and agricultural lands for selection among all the agroclimatic zones for further tree improvement programmes .

The mean morphological characters of fruits collected from forest lands and agricultural lands under different agroclimatic zones are presented in Table 5.1 and 5.2 . In case of seeds collected from forest lands, the mean fruit thickness, seed thickness and kernel thickness found to be maximum in ACZ-6, the mean fruit width , hilum length , kernel length and kernel width found maximum in ACZ-3, mean seed length, seed width , mean 100 fresh kernel weight and 100 oven dry kernel weight found to be maximum in ACZ-5,mean 100 fruit weight maximum in ACZ-10 and mean 100 seed weight maximum in

ACZ-2. Similarly, for seeds collected from agricultural lands the meanfruitwidth ,kernelwidthand 100 seed weight found maximum in ACZ-3, mean seed length and hilum length found maximum in ACZ-4 , mean fruit thickness and kernel length found maximum in agroclimatic zone 6 , mean fruit length ,100 fresh kernel weight and 100 ovendry kernel weight in ACZ-2, mean seed width in ACZ-1 , mean kernel thickness in ACZ-7 and mean 100 fruit weight in ACZ-10. The shows that the climate and edaphic condition of the agroclimatic zones are favorable for the genotypes of the respective zones in promoting the seed characters.

Among all the sample trees under different agroclimaticzones , the best genotype showing maximum values for important morpholohical characters like maximum fruit length (8.14cm) ,maximum seed length (5.24cm), maximum 100 seed weight (583g), maximum 100 fresh kernel weight (397g) and maximum 100 oven dry kernel weight (273.30g)wassample tree-STMBA 8 .The highest values expressed for the traits is due to its genotypic characters and environmental interaction as explained above.

5.5.2Studies on variation in physico-chemical properties of oil from seeds of *M. latifolia*

The oil content of seeds and its physico-chemical characters for sample trees with in each agroclimatic zone is presented in Fig. 5.24 to 5.32 . The coefficient of variation various oil traits in the seeds collected from forest and agricultural lands under different agroclimatic zones presented in Fig. 5.33.This indicates there is variation in oil characters with in agroclimatic zone from lower to higher range . The variation is mainly due to different genotypes present with in each agroclimatic zones and impact of the microclimatic, microedaphic and geographic variation with in each zones on its genotypes . Besides the role of different genotypes present with in agroclimatic zone which contributes to the intra population variation, Scotti et al. (2015) and Mehedi et al. (2014) described that microgeographicand micro habitat conditions can be a reason for variationin oil content .Nimbalkar et.al (2018) and Dai et. al (2013)also reportedthatgenetic variance exists within-population of *Madhuca indica* even to an extent of 85% in and 71%in *Madhuca hainanensis*.

The maximum coefficient of variation found for oil contentand other oil traits in forest and agricultural lands with in each agroclimatic zone is expressed in Fig. 5.33. The maximum variationswere observed in oil characters of seeds collected from forest land in different agroclimatic zones like FFA in ACZ-6(21.66), acid valueinACZ-6(10.88) , saponification valueinagroclimatic zone–3 (8.47) and Oil content in ACZ-3 (7.91).Similarly, maximum variations were also observed in agricultural lands in different agroclimatic zones for FFA in ACZ-6(28.82), acid valueinACZ-3(15.43) , Saponification valueinACZ-10(10.55) and oil content in ACZ-6 (9.36). These oil traits showing higher variation in agricultural and forest lands can be considered for selection of the species in the respective zones for further research and improvement progammesOil content and its physico-chemical properties for forest area and agricultural area under each agroclimatic zone are presented respectively in Fig. 5.24 to 5.32. It reflectedthat even with in a agroclimatic zone, the maximum values for different traits are not found on a same sample tree (germplasm) rather on different sample trees .This also showed that the oil content and most of the physico-chemical properties of oil extracted from seeds of a particular tree (germplasm) also may not be interdependent to each other and may be more influenced by the environmental factors and interaction of the genotype with the environment it grows. Under each agroclimatic zone , mean value individual oil character of seeds collected from *Madhuca latifolia* trees located in forest areas and that collected from trees located in agricultural lands were also compared. The findings revealed for each of the oil character that , significant difference between forest and agricultural land occurs only in some of the agroclimatic zones. For a particular trait, significant difference between forest and agricultural land occurring in some agroclimatic zones and not in others may be due to microclimatic and edaphic conditions of forest and agricultural lands , genotypic factors of sample trees and interaction of the genotypic and micro environmental factors.Nimbalkar (2018) carried out similar type of studies for *Madhuca indica* and also reported the variation in oil content of seeds collected from forest areas and from agricultural field bunds.

Even the higher (among forest and agricultural land) mean values for the oil characters of a particular zone were not always expressedeither only to forest land or only to agricultural land rather one oil character showed its higher value in seeds collected from forest land where as other oil character showed the higher value in agricultural land. This is mainly because of contribution of better genotypes present in that area (either forest land or agriculture land) and also the response of those genotypes to the local environment favoring that character.

The coefficient of variation of oil content of seeds collected from forest and agricultural lands and its pysico-chemical properties among all the agroclimatic zones is given by Fig. 5.33. These variation may be due to the fact that this species grows over a wide range of climate as well as edaphic conditions in forests of different agroclimatic zone. MunasingheandWansapala (2015) studied variation in oil content and fatty acid profile in different agroclimatic zones of Sri Lanka for *Madhuca longifolia* . He suggested Oil content and the Fatty acid composition are not correlated with the geographical factors but, there can be the impact of other environmental conditions. The fatty acid biosynthesis pathway are linked to physiological processes of plants which are somewhat regulated by genotype- environment interaction during seed development (Aabd et al., 2013). Hegde et al. (2018) reported significant variation in oil yield of *Madhuca indica* with range from 115.04 g to 283.84 g oil yield per kg of kernel collected from different provenances of Gujrat and mentioned variation in seed oil content and oil yield is attributed to genetic makeup and geographic situation.Similarstudies were reported in Mahua among 37 accessions from Tamil Nadu showing wide variation in oil content ranged from 44.40 to 61.50 per cent (SangitaYadav et al. 2011) and also by Diwakara and Das (2014) where oil content in Mahua ranged from 38.3 to 50.2 per cent among 20 genotypes in Jharkhand. Such variation were also reported in other Tree Borne Oil seeds such as *Pongamia pinnata*

(Raut et al., 2010) and *Calophyllum inophyllum* (Rahul, 2016 and Shinde et al., 2012) . Very less work has been carried out on variation of seed oil content and its physico-chemical properties with agroclimatic zones or provenances of Mahua, however, this study shows the existence of variation of oil characters in intra as well as inter population of *Madhuca latifolia* in all ten agroclimatic zones of odisha . These information may be useful collection of *Madhuca latifolia* seed in Odisha for extraction of oil to be used for food , fuel and industrial value .Most of the traits can be used for further improvement of this species for production of better quality and quantity yield of seed oil as per the utilisation purposes.

Higher to moderate values of coefficient of variation were found foroil characters from the seeds collected from forest lands among all agroclimatic zones in acid value (13.72) , free fatty acid content (9.09) , saponification value (5.49) , Iodine value (5.27) and oil content (3.90) . Similarly, in seeds collected from agricultural lands recorded higher to moderate values of coefficient of variation were found for oil characters like free fatty acid content (12.71) , oil content (7.92) , saponification value (5.71) and iodine value (5.20) . This indicates the above oil characters from forest and agricultural lands can be taken up for selection of the species in further improvement programmes.The mean oil content for seeds collected from forest lands was found maximum in ACZ2 ,mean oil yield , mean saponification value and mean ester value found maximum in ACZ-8 , mean acid value and mean free fatty acid content found maximum in ACZ6 and mean iodine value found maximum in ACZ-7. However, the mean oil content for seeds collected from agricultural lands was found maximum in ACZ-10 , mean oil yield in ACZ-9 , mean saponification value and mean ester value in ACZ-5, mean acid value and mean free fatty acid content in ACZ-6 and mean iodine value in ACZ-3.This shows that the climate and edaphic conditions of the agroclimatic zones are favorable for the genotypes of the respective zones in promoting the respective oil characters .

Seeds may be collected for food value of oil higher oil yield, less free fatty acids and less iodine value where as seeds may be collected for industrial uses like biodiesel production and soap industry with low free fatty acid content and higher saponification value . Basing on this seeds from forest land under ACZ-8 may be collected for both food and industrial value as it has higher oil content (43.21%) , oil yield (80.91g), saponification value (212.17) and lesser free fatty acid content (1.92) and iodine value (55.42).Among all the sample trees under different agroclimatic zones , the seeds collected from treesrecorded for maximum Oil content (51.84) was sample tree-STSGA 7, maximum oil yield (125.08g) was sample tree-STMBA 8, maximum saponification value (271.20) , maximum ester value (268.12) and minimum iodine value (52.83) was sample tree-9 under agricultural land of ACZ5, minimum acid value (0.67) and minimum FFA (0.34%)was sample tree-STAGA4. The highest values expressed for the traits is due to its genotypic characters and environmental interaction as explained above.

5.5.3Correlation between morphometric characters of fruits ,Physico-chemical properties of oil , ecological and soil characters and seedling characters

The correlations with in the morphological characters of seeds is given in the Table 5.3 and Table 5.7. Similar type of correlation of morphometric characters has been done in other species previously by Bagchi and Dobriyal (1990) in *Acacia nilotica*, in *Dalbergia sissoo* (Gera et al., 2000; Singh and Pokhriyal, 2001), in *Pinus roxburghii* (Ghildiyal et al., 2009) ,Singh and Sofi (2011) in different plus trees of *Cordia africana*, Rawat and Bakshi (2011) in *Pinus wallichiana* and Sudrajat (2016) in *Anthocephalus cadamba* indicating that the traits are interdependent on each other. Significant correlation among traits aretaken into consideration in the improvement study of the species as the improvement of one trait may cause simultaneous effects in the other trait (Divakara et al. 2010).The oil content and oil yield showed no significant positive correlation with any of the other oil characters (Table 5.4 and Table 5.8) .Munasinghe and Wansapala (2015) reported no significant positive correlation occurs oil content and fatty acids content in *Madhuca longifolia*. Similarly, Sudrajat et al. (2018) found oil content has no significant correlation with biochemical traits of seeds of *Sterculia foetida* . However, acid value found to be significantly positively correlated with free fatty acid content as free fatty acid content was a derived mathematical value of acid value . Ester value of oil positively correlated with saponification value due to low content of free fatty acids.The correlations among the morphological and oil characters of seeds is given in the Table 5.5 . The oil content has no significant correlation with any of the morphological traits/ Similar type trend also appears in case of *Sterculia foetida* as reported by Sudrajat et al. (2018) . However, oil yield has found to have significant correlation with seed traits like oven dry kernel weight as oil yield directly depends on oven dry kernel weight and oil content on oven dry basis. The other seed traits which are contributing to the oven dry kernel weight like fresh kernel weight , seed weight , seed length, seed width, kernel width, kernel thickness therefore also showed significant correlations.The correlation of the morphological traits of seeds with the soil characters and oil traits with the soil characters of the forest lands presented in the Table 5.9 and Table 5.10 showed no significant positive correlation of soil characters with any of the seed morphological traits or oil traits. This may be due to the range of soil characters among different agroclimatic zones did not influenced much to have substantial variation in the morphological characters of seed and oil characters .Climatic factors found positively correlated to some of the morphological traits of seeds in both the agricultural lands and forest lands which indicates climatic conditions in agricultural lands as well as the moderation of climatic conditions done by the forest giving rise to microclimatic conditions plays a greater role in influencing these seed characters.

The differences of ecological parameters among the zones for such parameters are not so high and the limit in which they falls did not affected to the morphological and oil characters of seeds to that extent that its can be significant.The correlations with in the germination-seedling characters of seeds are given in the Table 5.12 . Similar type of correlation study was carried out by Jayasankar et al. (1998) in *Tectona grandis*, Ginwal et al. (2005) and Ghosh and Singh (2011) in *Jatropha curcas*, Gupta et al.(2016) in *Pongamia pinnata*, Wani and Wani (2017) in *Madhuca indica* and Fornah et al. (2017) in *Gmelina arborea* .

Table 5.1: Variation in the morphological parameters of fruits of *M. latifolia* from forest land between different agroclimatic zones (ACZ)

Agroclimatic Zone	Fruit length (cm)	Fruit width (cm)	Fruit thickness (cm)	Seed length (cm)	Seed width (cm)	Seed thickness (cm)	Hilum length (cm)	Kernel length (cm)	Kernel width (cm)	Kernel thickness (cm)	100 Fresh fruit weight (g)	100 Fresh seed weight (g)	100 kernel Fresh weight (g)	100 kernel oven dry weight (g)
ACZ-1	5.32	2.88	2.80	3.25	1.71	1.54	3.01	2.86	1.40	1.26	1441.85	342.44	217.38	150.29
ACZ-2	4.94	2.81	2.66	3.47	1.61	1.57	3.02	3.06	1.36	1.32	1448.78	395.54	267.74	185.12
ACZ-3	4.31	2.97	2.80	3.43	1.71	1.45	3.18	3.12	1.51	1.23	1424.00	394.67	264.28	182.71
ACZ-4	5.16	2.87	2.78	3.45	1.67	1.43	3.15	3.02	1.40	1.15	1522.76	375.93	246.73	170.39
ACZ-5	4.70	2.96	2.78	3.50	1.77	1.56	3.14	2.91	1.50	1.27	1405.16	376.44	283.59	195.44
ACZ-6	4.36	2.86	3.02	3.20	1.66	1.75	2.79	2.97	1.45	1.52	1633.40	392.78	252.13	173.58
ACZ-7	4.29	2.22	2.23	3.05	1.36	1.27	2.68	2.8	1.06	1.23	855.77	266.31	166.65	114.80
ACZ-8	4.59	2.60	2.46	3.36	1.62	1.52	2.95	2.91	1.51	1.32	1164.57	380.04	272.05	187.29
ACZ-9	3.98	2.88	2.75	3.01	1.65	1.55	2.73	2.69	1.50	1.25	1270.02	351.17	237.26	163.44
ACZ-10	4.45	2.90	2.76	3.28	1.66	1.54	2.88	2.83	1.33	1.34	1711.39	355.59	253.10	173.94
Mean	**4.61**	**2.80**	**2.70**	**3.30**	**1.64**	**1.52**	**2.95**	**2.92**	**1.40**	**1.29**	**1387.77**	**363.09**	**246.09**	**169.70**
CV	**4.66**	**3.00**	**1.99**	**1.47**	**2.56**	**3.31**	**1.24**	**2.79**	**4.46**	**4.31**	**5.28**	**2.00**	**2.60**	**2.74**
CD	**0.37**	**0.15**	**0.09**	**0.08**	**0.07**	**0.09**	**0.06**	**0.14**	**0.11**	**0.09**	**126.94**	**12.57**	**11.04**	**8.04**

Table 5.2: Variation in the morphological parameters of fruits of *M. latifolia* from agricultural land across different agroclimatic zones

Agroclimatic Zone	Fruit length (cm)	Fruit width	Fruit thickness	Seed length	Seed width	Seed thickness	Hilum length	Kernel length	Kernel width	Kernel thickness	100 fruit weight	100 seed weight	100 kernel weight	100 kernel oven dry weight
ACZ-1	4.40	2.85	2.69	3.33	1.82	1.66	3.02	2.92	1.39	1.32	1302.68	395.14	243.57	170.38
ACZ-2	4.41	2.79	2.67	2.97	1.73	1.45	2.58	2.72	1.46	1.23	1540.00	265.67	272.65	192.77
ACZ-3	4.74	3.55	3.48	3.34	1.72	1.61	2.97	2.93	1.49	1.33	1506.47	410.75	267.47	186.76
ACZ-4	4.69	2.81	2.65	3.41	1.72	1.50	3.04	2.78	1.45	1.27	1296.03	365.28	237.86	165.34
ACZ-5	4.48	2.82	2.60	3.35	1.69	1.56	3.01	2.81	1.37	1.26	1290.58	366.40	241.23	168.87
ACZ-6	4.37	2.77	2.61	3.30	1.56	1.47	2.95	3.12	1.26	1.38	1319.31	342.76	207.57	145.13
ACZ-7	4.28	3.25	2.86	3.08	1.64	1.47	2.78	2.80	1.17	1.51	1643.22	330.43	224.05	156.30
ACZ-8	4.17	2.71	2.52	3.16	1.61	1.44	2.76	2.80	1.49	1.11	1193.84	343.35	228.32	158.50
ACZ-9	4.65	2.89	2.78	3.21	1.69	1.58	2.89	2.66	1.46	1.26	1444.45	363.40	246.99	173.34
ACZ-10	4.74	2.79	2.67	3.36	1.71	1.57	2.97	2.97	1.37	1.37	1674.69	370.54	242.78	167.68
Mean	**4.49**	**2.92**	**2.75**	**3.25**	**1.69**	**1.53**	**2.90**	**2.85**	**1.39**	**1.30**	**1421.13**	**355.37**	**232.07**	**176.07**
CV	**1.85**	**1.36**	**2.65**	**0.58**	**2.35**	**2.50**	**0.67**	**3.49**	**4.75**	**4.50**	**2.33**	**2.99**	**3.63**	**3.89**
CD	**0.15**	**0.07**	**0.13**	**0.03**	**0.07**	**0.07**	**0.03**	**0.17**	**0.12**	**0.10**	**57.21**	**19.10**	**15.79**	**11.81**

Table 5.3: Correlation with inSeed morphological characters from Forest land

Seed Characters	Fruit length	Fruit width	Fruit thickness	Seed length	Seed width	Seed thickness	Hilum length	Kernel length	Kernel width	Kernel thickness	100 Fresh fruit weight	100 Fresh seed weight	100 kernel Fresh weight	100 kernel ovendry weight
Fruit length	1.000													
Fruit width	0.198^{NS}	1.000												
Fruit thickness	0.138^{NS}	0.891**	1.000											
Seed length	0.564^{NS}	0.463^{NS}	0.250^{NS}	1.000										
Seed width	0.294^{NS}	0.942**	0.808**	0.552^{NS}	1.000									
Seed thickness	0.013^{NS}	0.616^{NS}	0.769**	0.122^{NS}	0.605^{NS}	1.000								
Hilum length	0.588^{NS}	0.579^{NS}	0.337^{NS}	0.912**	0.665*	0.005^{NS}	1.000							
Kernel length	0.372^{NS}	0.314^{NS}	0.292^{NS}	0.783**	0.298^{NS}	0.106^{NS}	0.725*	1.000						
Kernel width	0.010^{NS}	0.765**	0.640*	0.404^{NS}	0.855**	0.614^{NS}	0.489^{NS}	0.256^{NS}	1.000					
Kernel thickness	-0.252^{NS}	0.095^{NS}	0.380^{NS}	-0.142^{NS}	0.077^{NS}	0.783**	-0.382^{NS}	0.029^{NS}	0.148^{NS}	1.000				
100 Fresh fruit weight	0.279^{NS}	0.831**	0.871**	0.416^{NS}	0.723*	0.679*	0.390^{NS}	0.358^{NS}	0.456^{NS}	0.376^{NS}	1.000			
100 Fresh seed weight	0.182^{NS}	0.757*	0.685*	0.678*	0.757*	0.678*	0.606^{NS}	0.654*	0.818**	0.317^{NS}	0.678*	1.000		
100 kernel Fresh weight	0.101^{NS}	0.704*	0.522^{NS}	0.729*	0.766**	0.590^{NS}	0.611^{NS}	0.486^{NS}	0.813**	0.243^{NS}	0.573^{NS}	0.914**	1.000	
100 kernel ovendry weight	0.109^{NS}	0.707*	0.523^{NS}	0.735*	0.768**	0.587^{NS}	0.620^{NS}	0.495^{NS}	0.814**	0.235^{NS}	0.573^{NS}	0.918**	1.000**	1.000

Table 5.4: Correlation with in Oil characters of seeds from Forest lands

Oil Characters	Oil content	Oil yield (g)	Acid value	Saponification value	Ester value	FFA%	Iodine value	Density	Specific gravity
Oil content	1.000								
Oil yield (g)	0.489^{NS}	1.000							
Acid value	0.237^{NS}	0.031^{NS}	1.000						
Saponification value	-0.130^{NS}	0.343^{NS}	0.280^{NS}	1.000					
Ester value	-0.201^{NS}	0.349^{NS}	0.012^{NS}	0.963^{**}	1.000				
FFA%	0.236^{NS}	0.031^{NS}	1.000^{**}	0.280^{NS}	0.012^{NS}	1.000			
Iodine value	0.083^{NS}	-0.445^{NS}	-0.165^{NS}	-0.971^{**}	-0.965^{**}	-0.165^{NS}	1.000		
Density	0.015^{NS}	0.419^{NS}	0.267^{NS}	0.961^{**}	0.926^{**}	0.268^{NS}	-0.977^{**}	1.000	
Specific gravity	0.033^{NS}	0.430^{NS}	0.242^{NS}	0.960^{**}	0.932^{**}	0.242^{NS}	-0.974^{**}	0.998^{**}	1.000

Table 5.5: Correlation among Seed characters and Oil characters of seeds from Forest lands

Seed Characters → / **Oil Characters↓**	Fruit length	Fruit width	Fruit thickness	Seed length	Seed width	Seed thickness	Hilum length	Kernel length	Kernel width	Kernel thickness	100 Fresh fruit weight	100 Fresh seed weight	100 kernel Fresh weight	100 kernel oven dry weight
Oil content	0.118^{NS}	-0.227^{NS}	-0.122^{NS}	0.276^{NS}	-0.245^{NS}	0.163^{NS}	-0.044^{NS}	0.352^{NS}	-0.080^{NS}	0.318^{NS}	0.113^{NS}	0.317^{NS}	0.264^{NS}	0.261^{NS}
Oil yield (g)	0.135^{NS}	0.588^{NS}	0.450^{NS}	0.727*	0.638*	0.579^{NS}	0.548^{NS}	0.533^{NS}	0.728*	0.289^{NS}	0.547^{NS}	0.916**	0.969**	0.989**
Acid value	-0.025^{NS}	0.066^{NS}	0.492^{NS}	-0.162^{NS}	0.040^{NS}	0.604^{NS}	-0.245^{NS}	0.217^{NS}	0.046^{NS}	0.770**	0.342^{NS}	0.216^{NS}	-0.035^{NS}	-0.036^{NS}
Saponification value	0.274^{NS}	0.393^{NS}	0.418^{NS}	0.326^{NS}	0.623^{NS}	0.349^{NS}	0.445^{NS}	0.224^{NS}	0.641*	0.148^{NS}	0.300^{NS}	0.431^{NS}	0.411^{NS}	0.410^{NS}
Ester value	0.293^{NS}	0.390^{NS}	0.298^{NS}	0.385^{NS}	0.637*	0.194^{NS}	0.533^{NS}	0.173^{NS}	0.655*	-0.061^{NS}	0.217^{NS}	0.388^{NS}	0.438^{NS}	0.437^{NS}
FFA%	-0.025^{NS}	0.066^{NS}	0.492^{NS}	-0.162^{NS}	0.040^{NS}	0.603^{NS}	-0.246^{NS}	0.216^{NS}	0.046^{NS}	0.770**	0.341^{NS}	0.215^{NS}	-0.035^{NS}	-0.037^{NS}
Iodine value	-0.299^{NS}	-0.360^{NS}	-0.319^{NS}	-0.429^{NS}	-0.627^{NS}	-0.340^{NS}	-0.502^{NS}	-0.241^{NS}	-0.681*	-0.123^{NS}	-0.215^{NS}	-0.472^{NS}	-0.512^{NS}	-0.511^{NS}
Density	0.264^{NS}	0.267^{NS}	0.278^{NS}	0.348^{NS}	0.524^{NS}	0.374^{NS}	0.387^{NS}	0.242^{NS}	0.624^{NS}	0.245^{NS}	0.199^{NS}	0.455^{NS}	0.456^{NS}	0.454^{NS}
Specific gravity	0.254^{NS}	0.269^{NS}	0.272^{NS}	0.338^{NS}	0.524^{NS}	0.368^{NS}	0.377^{NS}	0.219^{NS}	0.633*	0.231^{NS}	0.204^{NS}	0.456^{NS}	0.462^{NS}	0.461^{NS}

Table 5.6: Correlation between morphological characters of seed from Forest lands and weather data

	Fruit length	Fruit width	Fruit thickness	Seed length	Seed width	Seed thickness	Hilum length	Kernel length	Kernel width	Kernel thickness	100 Fresh fruit weight	100 Fresh seed weight	100 kernel Fresh weight	100 kernel ovendry weight
Temp.(max)	0.009 NS	0.656	0.508 NS	-0.039 NS	0.603 NS	0.221 NS	0.168 NS	-0.367 NS	0.331 NS	-0.208 NS	0.395 NS	0.053 NS	0.163 NS	0.163 NS
Temp. (min)	0.192 NS	0.695	0.695	0.372 NS	0.502 NS	0.161 NS	0.531 NS	0.540 NS	0.270 NS	-0.182 NS	0.641	0.467 NS	0.265 NS	0.273 NS
Temp. (avg)	0.132 NS	0.796	0.721	0.221 NS	0.638	0.206 NS	0.440 NS	0.166 NS	0.341 NS	-0.247 NS	0.618 NS	0.325 NS	0.246 NS	0.252 NS
Temp (diff)	-0.189 NS	-0.226 NS	-0.331 NS	-0.411 NS	-0.069 NS	0.008 NS	-0.424 NS	-0.823	-0.035 NS	0.044 NS	-0.358 NS	-0.437 NS	-0.150 NS	-0.159 NS
Total Rainfall	-0.316 NS	-0.098 NS	0.077 NS	-0.111 NS	-0.259 NS	-0.096 NS	-0.090 NS	0.347 NS	-0.337 NS	0.185 NS	-0.050 NS	-0.121 NS	-0.278 NS	-0.273 NS
Avg. Humidity	0.002 NS	0.056 NS	0.123 NS	0.361 NS	-0.103 NS	-0.113 NS	0.258 NS	0.671	-0.115 NS	0.014 NS	0.339 NS	0.331 NS	0.166 NS	0.168 NS

Table 5.7: Correlation with inSeed morphological characters from Agricultural land

	Fruit length	Fruit width	Fruit thickness	Seed length	Seed width	Seed thickness	Hilum length	Kernel length	Kernel width	Kernel thickness	100 Fresh fruit weight	100 Fresh seed weight	100 kernel Fresh weight	100 kernel ovendry weight
Fruit length	1.000													
Fruit width	0.273^{NS}	1.000												
Fruit thickness	0.461^{NS}	0.946^{**}	1.000											
Seed length	0.575^{NS}	0.006^{NS}	0.107^{NS}	1.000										
Seed width	0.424^{NS}	0.108^{NS}	0.213^{NS}	0.197^{NS}	1.000									
Seed thickness	0.549^{NS}	0.297^{NS}	0.414^{NS}	0.581^{NS}	0.699^{*}	1.000								
Hilum length	0.521^{NS}	0.070^{NS}	0.125^{NS}	0.970^{**}	0.222^{NS}	0.653^{*}	1.000							
Kernel length	0.017^{NS}	0.055^{NS}	0.092^{NS}	0.472^{NS}	-0.253^{NS}	0.147^{NS}	0.439^{NS}	1.000						
Kernel width	0.354^{NS}	-0.097^{NS}	0.152^{NS}	0.103^{NS}	0.399^{NS}	0.206^{NS}	-0.039^{NS}	-0.387^{NS}	1.000					
Kernel thickness	0.123^{NS}	0.485^{NS}	0.322^{NS}	0.072^{NS}	-0.065^{NS}	0.150^{NS}	0.207^{NS}	0.413^{NS}	-0.823^{**}	1.000				
100 Fresh fruit weight	0.348^{NS}	0.447^{NS}	0.405^{NS}	-0.302^{NS}	0.127^{NS}	0.057^{NS}	-0.278^{NS}	-0.021^{NS}	-0.320^{NS}	0.630^{NS}	1.000			
100 Fresh seed weight	0.486^{NS}	0.375^{NS}	0.447^{NS}	0.829^{**}	0.300^{NS}	0.789^{**}	0.857^{**}	0.343^{NS}	0.155^{NS}	0.126^{NS}	-0.184^{NS}	1.000		
100 kernel Fresh weight	0.550^{NS}	0.466^{NS}	0.517^{NS}	0.698^{*}	0.310^{NS}	0.741^{*}	0.724^{*}	0.067^{NS}	0.244^{NS}	0.068^{NS}	-0.048^{NS}	0.939^{**}	1.000	
100 kernel ovendry weight	0.439^{NS}	0.118^{NS}	0.265^{NS}	-0.193^{NS}	0.346^{NS}	0.351^{NS}	-0.152^{NS}	-0.627^{NS}	0.507^{NS}	-0.262^{NS}	0.197^{NS}	0.019^{NS}	0.207^{NS}	1.000

Table5.8: Correlation with in Oil characters of seeds from Agricultural lands

	Oil content	Oil yield (g)	Acid value	Saponification value	Ester value	FFA%	Iodine value	Density	Specific gravity
Oil content	1.000								
Oil yield (g)	0.419^{NS}	1.000							
Acid value	-0.268^{NS}	-0.353^{NS}	1.000						
Saponification value	-0.405^{NS}	-0.414^{NS}	-0.015^{NS}	1.000					
Ester value	-0.349^{NS}	-0.343^{NS}	-0.194^{NS}	0.984**	1.000				
FFA%	-0.269^{NS}	-0.353^{NS}	1.000**	-0.015^{NS}	-0.194^{NS}	1.000			
FFA%	0.345^{NS}	0.463^{NS}	-0.003^{NS}	-0.960**	-0.941**	-0.003^{NS}	1.000		
Iodinevalue	-0.345^{NS}	-0.477^{NS}	0.030^{NS}	0.947**	0.924**	0.030^{NS}	-0.964**	1.000	
Density	-0.345^{NS}	-0.500^{NS}	0.035^{NS}	0.941**	0.917**	0.035^{NS}	-0.963**	0.999**	1.000

Table 5.9: Correlation among Seed characters and soil characters of seeds from Agricultural lands

	Fruit length	Fruit width	Fruit thickness	Seed length	Seed width	Seed thickness	Hilum length	Kernel length	Kernel width	Kernel thickness	100 Fresh fruit weight	100 Fresh seed weight	100 kernel Fresh weight	100 kernel ovendry weight
pH	0.545^{NS}	0.519^{NS}	0.602^{NS}	0.196^{NS}	0.081^{NS}	0.309^{NS}	0.109^{NS}	0.288^{NS}	0.091^{NS}	0.283^{NS}	0.662*	0.351^{NS}	0.447^{NS}	0.069^{NS}
EC	0.406^{NS}	0.244^{NS}	0.319^{NS}	0.351^{NS}	-0.117^{NS}	0.228^{NS}	0.242^{NS}	0.459^{NS}	0.031^{NS}	0.188^{NS}	0.434^{NS}	0.420^{NS}	0.457^{NS}	-0.140^{NS}
Organic Carbon	0.256^{NS}	-0.270^{NS}	-0.301^{NS}	0.506^{NS}	-0.089^{NS}	0.171^{NS}	0.459^{NS}	0.184^{NS}	-0.166^{NS}	0.062^{NS}	0.071^{NS}	0.301^{NS}	0.347^{NS}	-0.240^{NS}
Available Nitrogen	-0.321^{NS}	-0.566^{NS}	-0.675*	0.210^{NS}	-0.496^{NS}	-0.227^{NS}	0.228^{NS}	0.080^{NS}	-0.329^{NS}	-0.132^{NS}	-0.424^{NS}	-0.040^{NS}	-0.065^{NS}	-0.309^{NS}
Available Phosphorus	-0.240^{NS}	-0.377^{NS}	-0.365^{NS}	-0.019^{NS}	-0.237^{NS}	-0.200^{NS}	-0.154^{NS}	0.137^{NS}	0.149^{NS}	-0.352^{NS}	-0.034^{NS}	-0.020^{NS}	0.024^{NS}	-0.297^{NS}
Available Potassium	-0.761*	-0.330^{NS}	-0.411^{NS}	-0.246^{NS}	-0.358^{NS}	-0.541^{NS}	-0.294^{NS}	-0.093^{NS}	0.137^{NS}	-0.536^{NS}	-0.703*	-0.235^{NS}	-0.286^{NS}	-0.428^{NS}
Available Sulphur	0.016^{NS}	-0.178^{NS}	-0.063^{NS}	-0.243^{NS}	-0.337^{NS}	-0.443^{NS}	-0.342^{NS}	-0.291^{NS}	0.471^{NS}	-0.470^{NS}	-0.161^{NS}	-0.235^{NS}	-0.150^{NS}	0.324^{NS}

Table 5.10: Correlation among Oil characters of seeds from Agricultural lands and its soil characters

	Oil content	Oil yield (g)	Acid value	Saponification value	Ester value	FFA%	Iodine value	Density	Specific gravity	pH
pH	0.741^{*}	0.255^{NS}	-0.317^{NS}	-0.608^{NS}	-0.539^{NS}	-0.317^{NS}	0.566^{NS}	-0.478^{NS}	-0.471^{NS}	1.000
EC	0.666^{*}	0.043^{NS}	-0.224^{NS}	-0.406^{NS}	-0.358^{NS}	-0.225^{NS}	0.440^{NS}	-0.335^{NS}	-0.327^{NS}	0.907^{**}
Organic Carbon	0.505^{NS}	-0.104^{NS}	-0.286^{NS}	0.417^{NS}	0.461^{NS}	-0.287^{NS}	-0.380^{NS}	0.476^{NS}	0.476^{NS}	0.356^{NS}
Available Nitrogen	0.023^{NS}	-0.292^{NS}	0.163^{NS}	0.715^{*}	0.672^{*}	0.162^{NS}	-0.615^{NS}	0.693^{*}	0.687^{*}	-0.334^{NS}
Available Phosphorus	0.297^{NS}	-0.198^{NS}	-0.243^{NS}	-0.123^{NS}	-0.078^{NS}	-0.243^{NS}	0.249^{NS}	-0.160^{NS}	-0.151^{NS}	0.353^{NS}
Available Potassium	-0.487^{NS}	-0.519^{NS}	0.098^{NS}	0.203^{NS}	0.181^{NS}	0.099^{NS}	-0.136^{NS}	0.087^{NS}	0.096^{NS}	-0.549^{NS}
Available Sulphur	0.122^{NS}	0.346^{NS}	0.068^{NS}	-0.410^{NS}	-0.415^{NS}	0.068^{NS}	0.507^{NS}	-0.650^{*}	-0.658^{*}	-0.093^{NS}

Table 5.11 : Correlation among morphological characters of seeds from Agricultural land and weather data

	Fruit length	Fruit width	Fruit thickness	Seed length	Seed width	Seed thickness	Hilum length	Kernel length	Kernel width	Kernel thickness	100 Fresh fruit weight	100 Fresh seed weight	100 kernel Fresh weight	100 kernel ovendry weight
Temp.(max)	0.610^{NS}	-0.093^{NS}	0.027^{NS}	0.522^{NS}	0.540^{NS}	0.786	0.583^{NS}	-0.087^{NS}	0.176^{NS}	0.015^{NS}	0.034^{NS}	0.489^{NS}	0.286^{NS}	0.280^{NS}
Temp. (min)	0.783	0.259^{NS}	0.443^{NS}	0.494^{NS}	0.397^{NS}	0.380^{NS}	0.451^{NS}	0.182^{NS}	0.272^{NS}	0.132^{NS}	0.104^{NS}	0.289^{NS}	0.434^{NS}	0.431^{NS}
Temp. (avg)	0.842	0.135^{NS}	0.315^{NS}	0.601^{NS}	0.547^{NS}	0.662	0.609^{NS}	0.063^{NS}	0.263^{NS}	0.108^{NS}	0.088^{NS}	0.447^{NS}	0.436^{NS}	0.431^{NS}
Temp (diff)	-0.354^{NS}	-0.339^{NS}	-0.439^{NS}	-0.126^{NS}	-0.010^{NS}	0.187^{NS}	-0.037^{NS}	-0.246^{NS}	-0.154^{NS}	-0.121^{NS}	-0.078^{NS}	0.055^{NS}	-0.234^{NS}	-0.235^{NS}
Total Rainfall	0.108^{NS}	0.709	0.653	-0.139^{NS}	-0.106^{NS}	0.058^{NS}	-0.064^{NS}	0.379	-0.469^{NS}	0.701	0.516^{NS}	-0.028^{NS}	0.119^{NS}	0.141^{NS}
Avg. Humidity	0.376^{NS}	0.239^{NS}	0.309^{NS}	0.098^{NS}	-0.193^{NS}	-0.383^{NS}	-0.048^{NS}	0.251^{NS}	0.089^{NS}	0.140^{NS}	0.279^{NS}	-0.133^{NS}	0.109^{NS}	0.086^{NS}

Table 5.12: Correlation within seedling traits

	Germination percentage	Mean daily germination	Peak value	Germination Value	Seedling length (cm)	Collar diameter (cm)	Fresh seedling biomass(g)	Oven dry seedling Biomass(g)	moisture content (%)
Germination percentage	1.000								
Mean daily germination	1.000**	1.000							
Peak value	0.987**	0.987**	1.000						
Germination Value	0.989**	0.990**	0.993**	1.000					
Seedling length (cm)	-0.590NS	-0.596NS	-0.620NS	-0.628NS	1.000				
Collar diameter (cm)	-0.660*	-0.665*	-0.703*	-0.643*	0.667*	1.000			
Fresh seedling biomass(g)	-0.721*	-0.725*	-0.727*	-0.725*	0.907**	0.708*	1.000		
Oven dry seedling Biomass(g)	-0.749*	-0.752*	-0.765**	-0.753*	0.791**	0.699*	0.954**	1.000	
moisture content (%)	0.358NS	0.356NS	0.396NS	0.361NS	0.012NS	-0.248NS	-0.236NS	-0.515NS	1.000

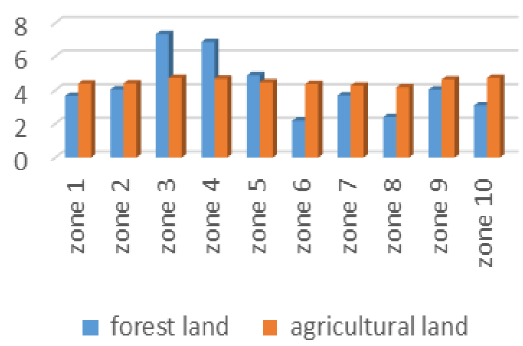


Fig.5.1: Coefficient of variation of fruit length (cm) of *Madhuca latifolia* under different agro

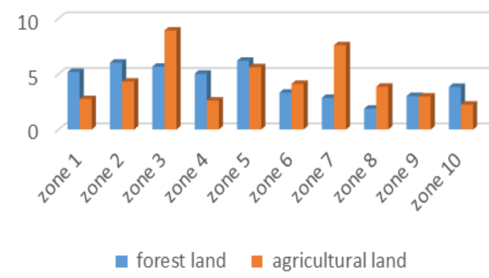


Fig.5.2: Coefficient of variation of fruit width of *Madhuca latifolia* under different agro climatic zones

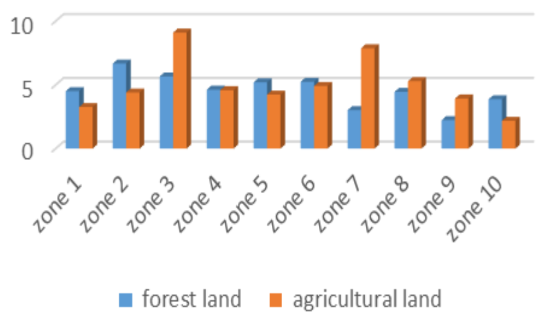


Fig.5.3: Coefficient of variation of fruit thickness of *Madhuca latifolia* under different agroclimatic zones

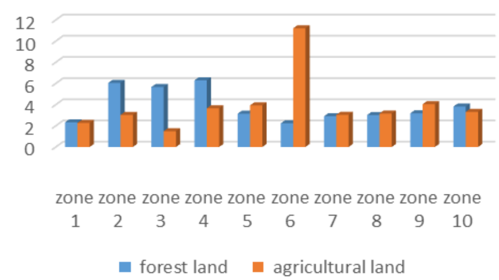


Fig.5.4: Coefficient of variation of seed length of *Madhuca latifolia* under different agroclimatic zones

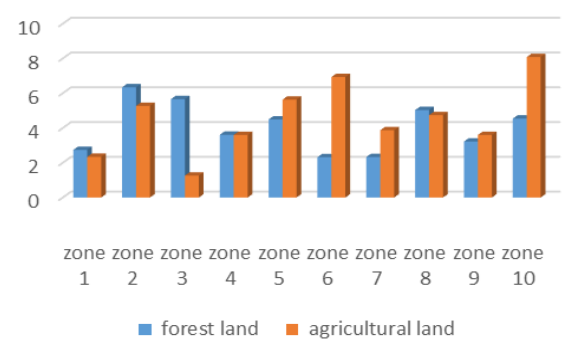


Fig.5.5: Coefficient of variation of seed width of *Madhuca latifolia* under different agroclimatic zones

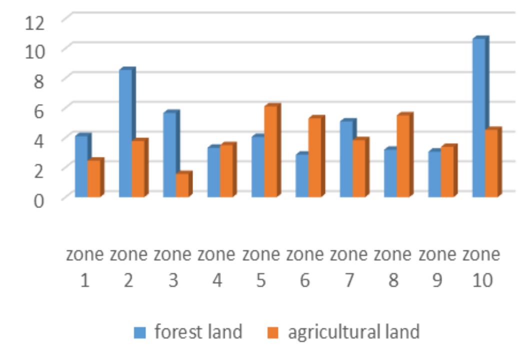


Fig.5.6: Coefficient of variation of seed thickness of *Madhuca latifolia* under different agroclimatic zones

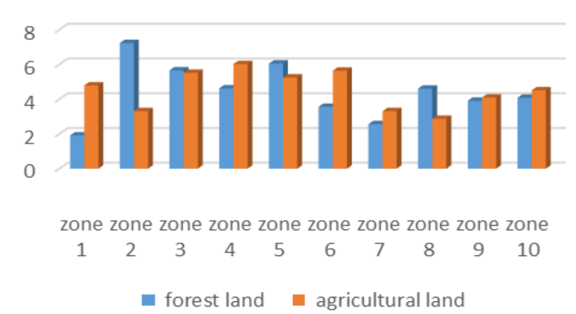


Fig.5.7: Coefficient of variation of seed hilum of *Madhuca latifolia* under different agroclimatic zones

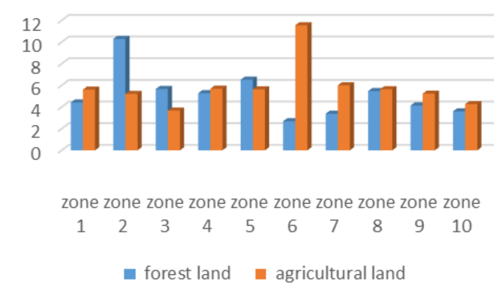


Fig.5.8: Coefficient of variation of kernel length of *Madhuca latifolia* under different agro climatic zones

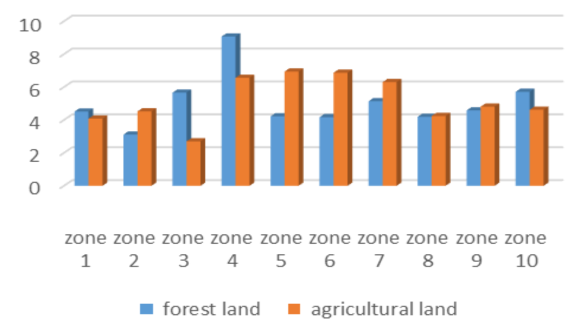


Fig.5.9: Coefficient of variation of kernel width of *Madhuca latifolia* under different agro climatic

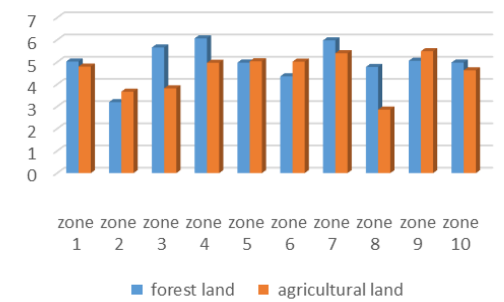


Fig.5.10: Coefficient of variation of kernel thickness of *Madhuca latifolia* under

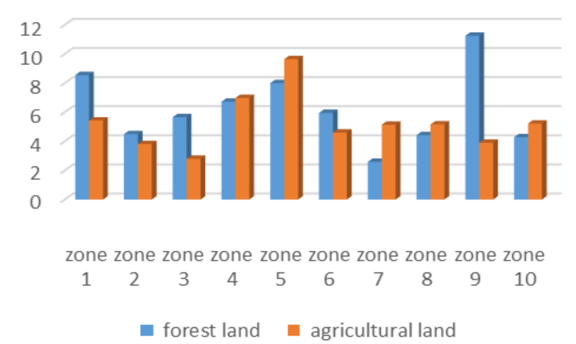


Fig.5.11: Coefficient of variation of 100 fruit weight of *Madhuca latifolia* under different agro climatic zones

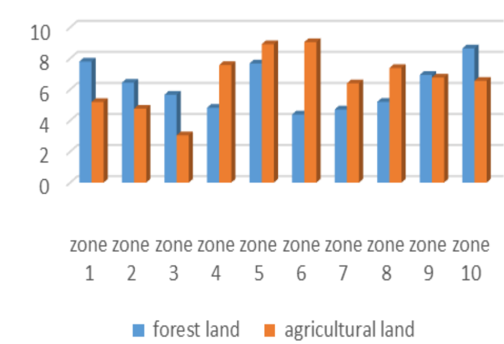


Fig.5.12: Coefficient of variation of 100 seed weight of *Madhuca latifolia* under different agro climatic zones

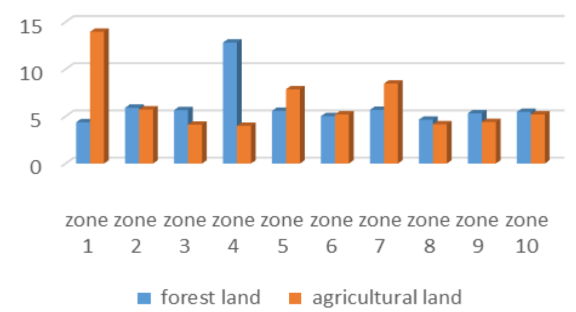


Fig.5.13: Coefficient of variation of 100 fresh kernel weight of *Madhuca latifolia* under different agroclimatic zones

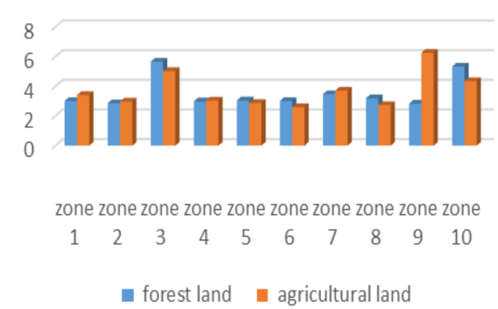


Fig.5.14: Coefficient of variation of 100 ovendry kernel weight of *Madhuca latifolia* under different agroclimatic zones

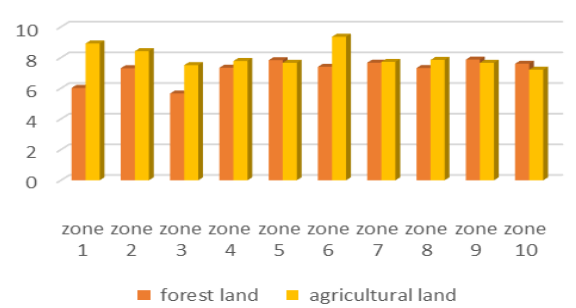


Fig.5.15: Coefficient of variation of oil content (%) of *Madhuca latifolia* under different agroclimatic zones

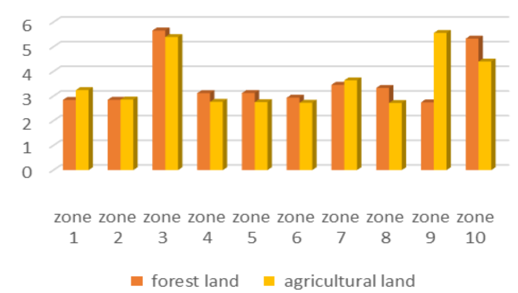


Fig.5.16: Coefficient of variation of oil yield (g) of *Madhuca latifolia* under different agroclimatic zones

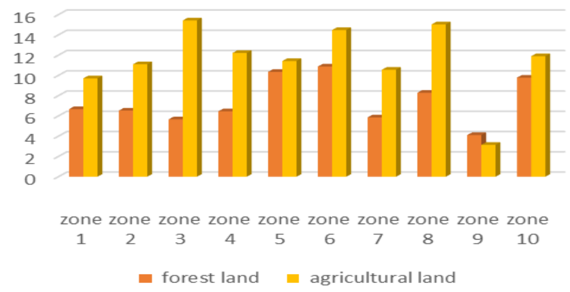


Fig.5.17: Coefficient of variation of Acid Value of oil from *Madhuca latifolia* under different agroclimatic zones

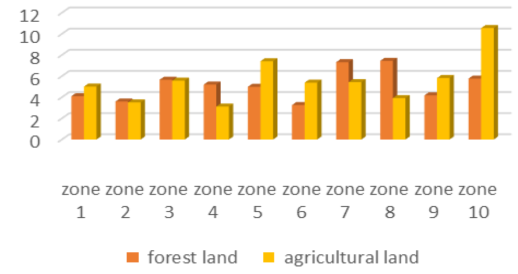


Fig.5.18: Coefficient of variation of Saponification Value of oil from *Madhuca latifolia* under different agroclimatic zones

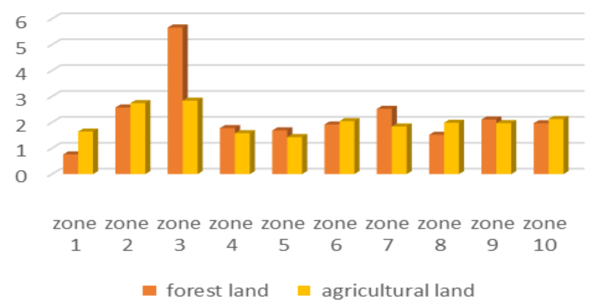


Fig.5.19: Coefficient of variation of Ester Value of oil from *Madhuca latifolia* under different agroclimatic zones

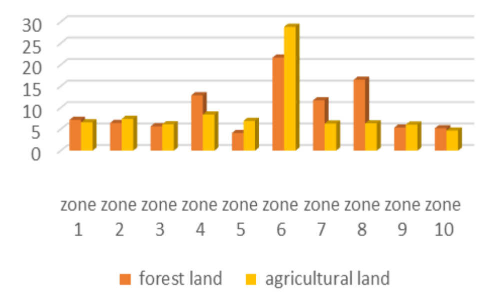


Fig.5.20: Coefficient of variation of Free Fatty Acid content of oil from *Madhuca latifolia* under different agroclimatic zones

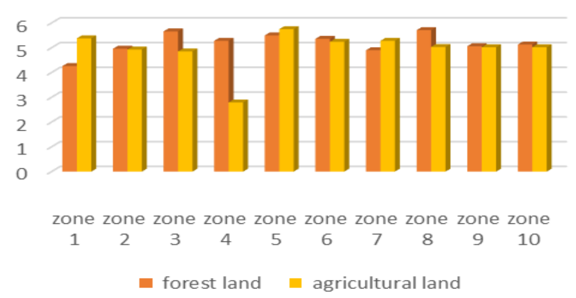


Fig.5.21: Coefficient of variation of Iodine Value of oil from *Madhuca latifolia* under different agroclimatic zones

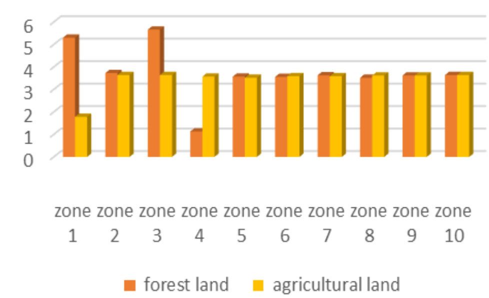


Fig.5.22: Coefficient of variation of Density of oil from *Madhuca latifolia* under different agroclimatic zones

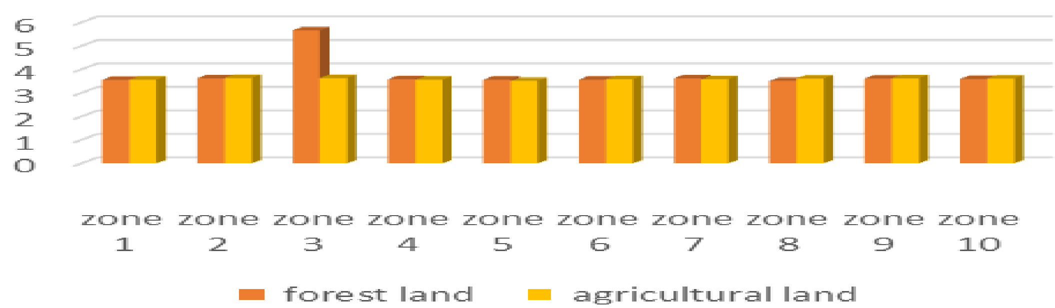


Fig.5.23: Coefficient of variation of Specific gravity of oil from *Madhuca latifolia* under different agroclimatic zones

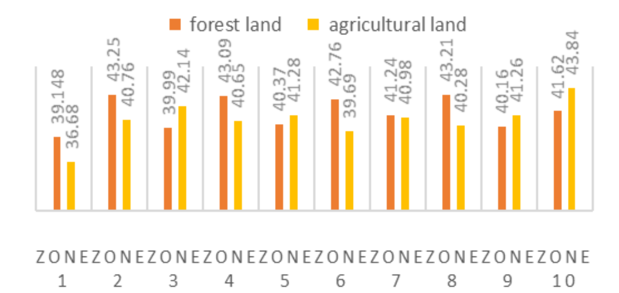


Fig.5.24: Mean oil content (%) of *Madhuca latifolia* under different agroclimatic zones

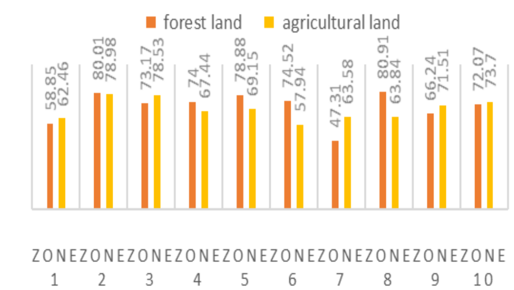


Fig.5.25: Mean oil yield (g) of *Madhuca latifolia* under different agroclimatic zones

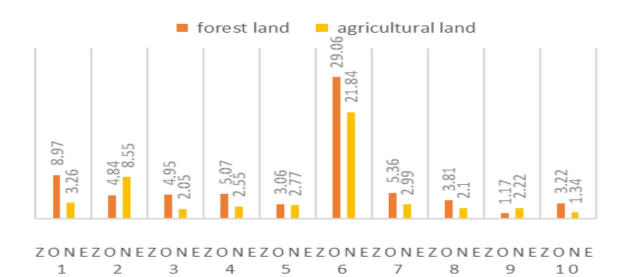


Fig.5.26: Mean Acid Value of oil from *Madhuca latifolia* under different agroclimatic zones

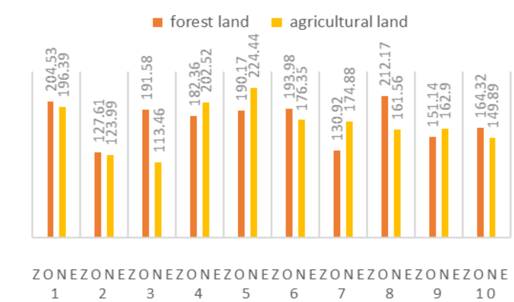


Fig.5.27: Mean Saponification Value of oil from *Madhuca latifolia* under different agroclimatic zones

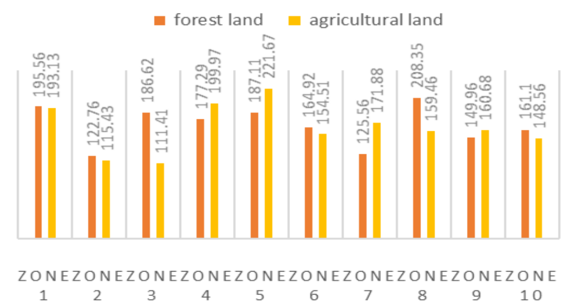


Fig.5.28: Mean Ester Value of oil from *Madhuca latifolia* under different agroclimatic zones

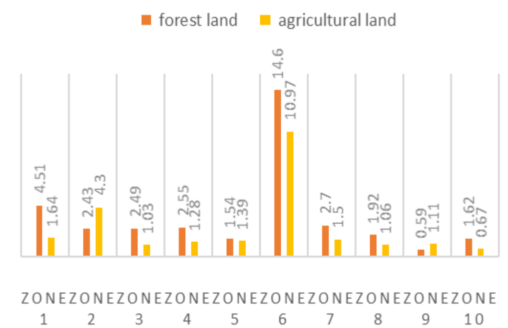


Fig.5.29: Mean Free Fatty Acid content of oil from *Madhuca latifolia* under different agroclimatic zones

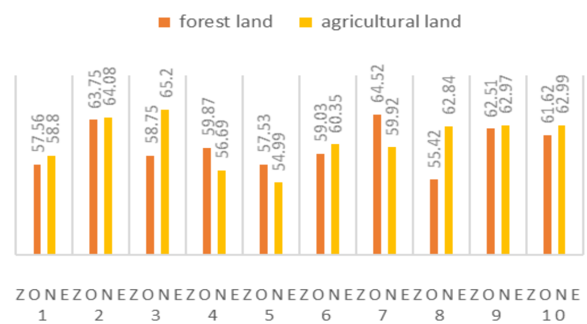


Fig.5.30: mean Iodine Value of oil from *Madhuca latifolia* under different agroclimatic zones

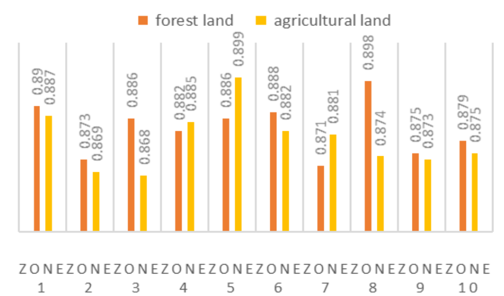


Fig.5.31: Mean density of oil from *Madhuca latifolia* under different agroclimatic zones

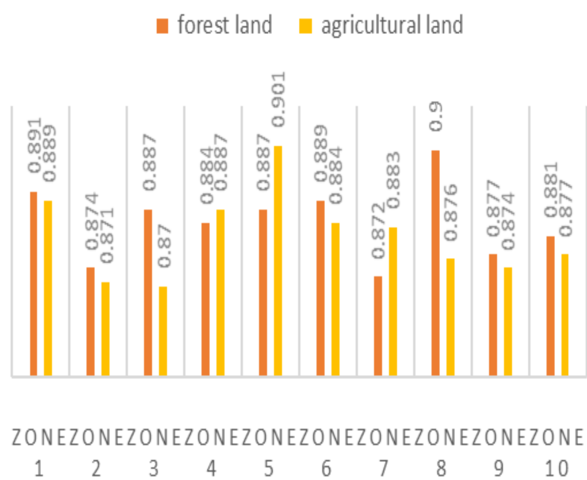


Fig.5.32: Mean Specific gravity of oil from *Madhuca latifolia* under different agroclimatic zones

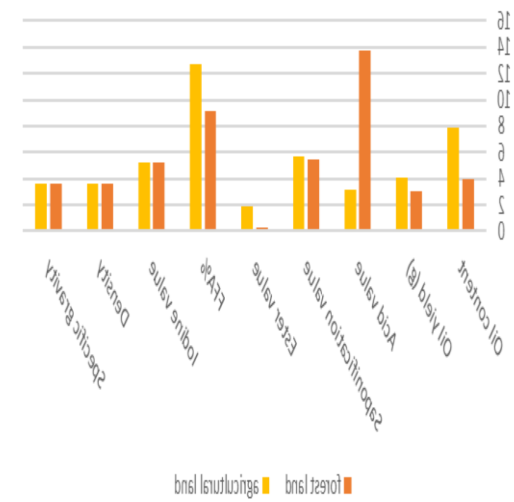


Fig.5.33: Coefficient of Variation of oil traits among all agroclimatic zones

Plate 5.1 Variation in fruit sizes of *Madhuca latifolia* with in a agroclimatic zone

Plate 5.2 Maximum Fruit Length in STMBA – 8 **Plate 5.3** Maximum Seed Length in STMBA – 8

CHAPTER- 6

EFFECT OF SEED SOURCE ON SEED GERMINATION AND INITIAL GROWTH BEHAVIOUR OF *Madhuca latifolia* SEEDLINGS

6.1 Introduction

Seed source forms a very important element in the quality of seedlings produced in the nursery, since the quality of the seedlings is determined by the genotype of the seed from which it originates. Therefore, it is essential to assess the early morphological and seedling vigor studies and to understand the effect of seed sizes and provenance in determining these seedling traits. Seed size is important physical indicator of seed quality that affects vegetation growth and field performance. Seed mass of species represent a complex adaptive compromises (Harper, 1977) and plays a vital role in the establishment of the juvenile phase of a plant's growth curve. Different species give different results (Owoh et al. 2011, Kapatsa et al. 2014, Maru and Bo, 2015) on the effect of seed size on germination.

Seed oils primarily accumulate neutral oils (Lersten et al. 2006) which are composed of triacyglycerols (TAGs). Storage of energy rich TAG likely determines the fitness of most plants as it is an immediate energy source for seed germination and plant establishment for 80 % of the plants which rely on TAGs in their seeds (Harwood, 1980) while fewer plant species rely on starches and proteins. Earliness of germination was positively correlated with seed lipid content and the seed area to mass ratio (Gardin et al. 2011). Thus, seed traits like seed size, weight and endosperm content determines to a great extent the reproductive success of plants. Studying seed oil content (total content and quality), a trait which is predicted to be under natural selection as it influences initial rapid growth will help us understand the evolutionary significance of seed oil content and will also be of great interest from an economical point of view as it will help in the breeding and cultivation of oil seed crops.

The present chapter deals with the effect of seed source on seed germination and seedling growth attributes of *M. latifolia*. The results are expected to prescribe the best seed source for seedling vigour and better field performance of the species.

6.2 Materials and Methods

6.2.1 Lay out experiment

The seeds from sample trees of each agroclimatic zone were sown in polybags kept in nursery of College of Forestry, OUAT. Each sample tree was considered as a treatment within each agroclimatic zone for which 3 replications were laid under RBD .Under each replication 10 polypots were sown with one seed per poly pot. The germinating characters like germination percentage, mean daily germination, peak value and germination value for the germinated seeds of sample trees were evaluated . After 90 days from sowing of seeds, seedlings characters like shoot length, collar diameter, fresh seedling biomass, oven dry seedling biomass, moisture content oven dry basis and shoot vigour index were recorded. From each sample Tree randomly 3 samples with 100 fresh and fully matured fruits per sample were collected. The fruits were kept in water for 1 hour,de-pulped and then seeds were extracted. The extracted Seeds were treated with water for 12 hours . Then the seeds were mixed with Dithane M-45 @3g/kg of seed and sown in the nursery bed .

6.2.2 Observations recorded

The number of seed germinated daily upto 40 Days after sowing on which germinating characters were recorded . Seedling length (cm), collar diameter (cm), Fresh seedling biomass(g), Oven dry seedling Biomass(g) were recorded after 90 days of sowing. Based on the number of seeds germinated, Germination percent (%), Mean daily germination (MDG), Peak Value (PV) and Germination Value (GV) were calculated following Czabatore (1962).

Peak value was calculated as the maximum MDG reached at any time during the period of the test (Czeabatore, 1962)

$$PV = \frac{\text{Final germination percentage}}{\text{No. of days required to reach the peak value of germination}}$$

Germination value is an index combining speed and completeness of seed germination. Daily germination counts were recorded and GV was calculated as per (Czeabatore, 1962).

GV= PV×MDG

PV=Peak value of germination.

MDG= Mean daily germination.

GV= Germination value.

Besides, morphological and biomass characters like Seedling shoot length (cm), Collar diameter (cm) Fresh seedling biomass(g), Oven dry seedling Biomass(gm) recorded after 90. Seedling (Shoot) vigour Index was calculated by multiplying seedling length (shoot length) with the corresponding germination percentage and the values were recorded.

Shoot vigour Index = Germination percentage x Shoot length

6.2.3 Statistical Analysis

The recorded observations were subjected to analysis of variance (ANOVA) as described by Snedecor and Cochran (1980) 2nd Edition to understand the significance of differences among sample trees progenies with in each agroclimatic zone and also among the zones. Critical difference (CD) studied for different traits traitswas calculated to evaluate differences between treatments. Various genetic parameters like Genotypic Coefficient of Variance (GCV), Phenotypic Coefficient of Variance (PCV), Coefficient of variation (CV) or Environmental coefficient of variation (ECV) were also determined by using software “Agrigene” to study the variations within agroclimatic zone and among the agroclimatic zones. Besides, **c**orrelation was carried out within and among the morphological characters, oil characters, germination and seedling characters, ecological, edaphic and climatic factors of the different agroclimatic zones

6.3 RESULTS

6.3.1 Germination percentage (%)

The germination of all provenances varies from 27 % -100 % .The germination varies in ACZ-1(39 % - 92%) with mean germination of 77.10% , ACZ-2(28 % - 94%) with mean germination of 70.90% , ACZ-3(55 % -100 %) with mean germination of 82.6% , ACZ-4 (56% -100 %) with mean germination of 82.7% , ACZ-5(27 % -100 %) with mean germination of 76% , ACZ-6(65% -100 %) with mean germination percentage of 87.7% , ACZ-7(55% -100 %) with mean germination percentage of 78.9% , ACZ-8(86% -100 %) with mean germination percentage of 93.8% , ACZ-9(66% -100 %) with mean germination percentage of 88.6% and ACZ-10(66% -100 %) with mean germination percentage of 53.00% (Figure 6.1).

The coefficient of variation ranges between 6.53-7.39 for all ACZs with maximum in ACZ–10 (7.39) and minimum in ACZ–8 (6.53) .The extent of variability is also accessed by genotypic and phenotypic variances and genotypic and phenotypic coefficient of variation. All agroclimatic zone showed higher values of phenotypic coefficient of variation than Genotypic coefficient of variation. Maximum Phenotypic coefficient of variation (49.57) and genotypic coefficient of variation (49.02) recorded in ACZ- 10 (Table 6.3).

The germination of all provenances varies from 37 % -100 % .The germination varies in ACZ-1(68 % - 94%) with mean germination of 83.60% , ACZ -2(46 % - 100%) with mean germination of 75.40% , ACZ-3(39 % -100 %) with mean germination of 75.00% , ACZ-4 (38% -100 %) with mean germination of 75.20% , ACZ-5(46 % -100 %) with mean germination of 78.60% , ACZ-6(37% -100%) with mean germination percentage of 79.10% , ACZ-7(37% -84 %) with mean germination percentage of 63.00% , ACZ-8(73% -100 %) with mean germination percentage of 89.30% , ACZ-9(80% -100 %) with mean germination percentage of 92.70% and ACZ-10(80% -100 %) with mean germination percentage of 72.50% (Figure 6.1). The result also showed medium range of coefficient of variations for germination percentage in all ACZs. The coefficient of variation ranges between 6.58 – 7.09 for all agroclimatic zones with maximum in ACZ–7 (7.09) and minimum in agroclimatic zone –9 (1.08). All agroclimatic zone showed higher values of phenotypic coefficient of variation than Genotypic coefficient of variation. Maximum Phenotypic coefficient of variation (28.40) and genotypic coefficient of variation (27.57) recorded in ACZ- 3 (Table 6.3). Between different agroclimatic zones, for seeds collected from the forest areas, the mean germination percentage varies from 53.00% –93.80%with maximum in agroclimatic zone -8 and minimum in ACZ-10 (Table 6.1). The coefficient of variation (6.76) , phenotypic coefficient of variation (15.89) and genotypic coefficient of variation (14.38) were found for germination percentage between the agroclimatic zones (Table 6.13). Similarly, between different agroclimatic zones for seeds collected from agricultural areas, the mean germination percentage varies from 63.00% –92.70% with maximum in ACZ-9 and minimum in ACZ-7 (Table 6.2). The coefficient of variation (6.77) , phenotypic coefficient of variation (12.78) and genotypic coefficient of variation (10.84) were found for germination percentage between the agroclimatic zones (Table 6.146.14) .

Correlation analysis found significant relationship of germination percentage with seed kernel thickness and fresh fruit weight (Table 6.15).

6.3.2 Mean Daily Germination

The mean daily germination varies in agroclimatic zone -1(0.98-2.30) with average mean daily germination of 1.93 , ACZ-2 (0.70-2.35) with average mean daily germination of 1.77 , ACZ-3(1.38-2.50) with average mean daily germination of 2.07 , ACZ-4 (1.40-2.50) with average mean daily germination of 2.07 , agroclimatic zone -5(0.68-2.50) with average mean daily germination of 1.90 , ACZ -6(1.65-2.53) with average mean daily germination of 2.19 , ACZ-7(1.38-2.50) with average mean daily germination of 1.97 , ACZ-8 (2.15-2.50) with average mean daily germination of 2.35 , ACZ-9(1.65-2.50) with average mean daily germination of 2.22 and ACZ-10(0.65-2.50) with average mean daily germination of 1.33 (Figure 6.1). The result showed low range of coefficient of variations for mean daily germination in all agroclimatic zones . The coefficient of variation ranges between 3.58-5.22 for all agroclimatic zones with maximum in ACZ –10 (5.22) and minimum in ACZ–8 (3.58). The extent of variability is also accessed by genotypic and phenotypic variances and genotypic and phenotypic coefficient of variation. All agroclimatic zone showed higher values of phenotypic coefficient of variation than Genotypic coefficient of variation. Maximum Phenotypic coefficient of variation (49.06) and genotypic coefficient of variation (48.91) recorded in ACZ- 10(Table 6.4).

The mean daily germination of all provenances varies from 0.93-2.50 .The mean daily germination varies in ACZ-1(1.70-2.35) with average mean daily germination of 2.09 , ACZ -2(1.15-2.50) with average mean daily germination of 1.89 , ACZ-3(0.98-2.50) with average mean daily germination of 1.88 , ACZ-4 (0.95-2.50) with average mean daily germination of 1.88 , ACZ-5(1.15-2.50) with average mean daily germination of 1.97 , ACZ -6(0.93-2.50) with average mean daily germination of 1.98 , ACZ -7(0.93-2.10) with average mean daily germination of 1.58 , ACZ -8(1.83-2.50) with average mean daily germination of 2.23 , ACZ-9(2.00-2.50) with average mean daily germination of 2.32 and ACZ-10(1.15-2.50) with average mean daily germination of 1.81 (Figure 6.1).

The result showed low range of coefficient of variations for mean daily germination in all agroclimatic zones . The coefficient of variation ranges between 3.61-4.62 for all agroclimatic zones with maximum in ACZ–7 (4.62) and minimum in ACZ–9 (3.61). All agroclimatic zone showed higher values of phenotypic coefficient of variation than genotypic coefficient of variation. Maximum Phenotypic coefficient of variation (27.79) and genotypic coefficient of variation (27.52)recorded in agroclimatic zone- 3 (Table 6.4).The average mean daily germination of *Madhuca latifolia* Macb. seeds collected from forest land and agricultural land showed significant difference between them only in ACZ-7 (T value of Figure 6.1). Between different agroclimatic zones, for seeds collected from the forest areas, the mean daily germination varies from 1.33-2.35 with maximum in ACZ-8 and minimum in ACZ-10 (Table 6.1). The coefficient of variation (3.98) , phenotypic coefficient of variation (14.83) and genotypic coefficient of variation (14.31) were found for mean daily germination between the ACZs (Table 6.13). Similarly, between different agroclimatic zones for seeds collected from agricultural areas, the mean daily germination varies from 1.58-2.32 with maximum in ACZ-9 and minimum in ACZ-7 (Table 6.2). The coefficient of variation (4.00) , phenotypic coefficient of variation (11.37) and genotypic coefficient of variation (10.70) were found for mean daily germination between the ACZs (Table 6.14) .

Correlation analysis found significant relationship of mean daily germination with seed kernel thickness and fresh fruit weight (Table 6.15).

6.3.3 Peak Value

The peak value of all provenances varies from 0.93-4.76 . The peak value varies in ACZ-1(1.44-4.41) with mean peak value of 3.32 , ACZ-2(1.04-4.09) with mean peak value of 2.91, ACZ-3(2.44-4.65) with mean peak value of 3.48 , ACZ-4 (2.15-4.76) with mean peak value of 3.58 , ACZ-5(0.93-4.35) with mean peak value of 3.09, ACZ-6(2.54-4.65) with mean peak value of 3.78, ACZ-7(2.20-4.00) with mean peak value of 3.23, ACZ-8(3.14-4.76) with mean peak value of 4.04 , ACZ-9(2.54-4.43) with mean peak value of 3.71 and ACZ-10(1.13-3.95) with mean peak value of 2.30 (Figure 6.1). The result showed low range of coefficient of variations for peak value in all agroclimatic zones . The coefficient of variation ranges between 3.74-4.68 for all agroclimatic zones with maximum in ACZ–10 (4.68) and minimum in ACZ–8 (3.74). The extent of variability is also accessed by genotypic and phenotypic variances and genotypic and phenotypic coefficient of variation. All agroclimatic zone showed higher values of phenotypic coefficient of variation than Genotypic coefficient of variation. Maximum Phenotypic coefficient of variation (46.54) and genotypic coefficient of variation (46.37) recorded in ACZ- 10(Table 6.5). The peak value ofall provenances varies from 1.31-5.56. The peak value varies in ACZ-1(2.81-4.09) with mean peak of 3.33 , ACZ-2(1.59-3.57) with mean peak value of 2.76 , ACZ-3(1.39-4.17) with mean peak value of 3.13 , ACZ-4 (1.31-4.65) with mean peak value of 3.07 , ACZ-5(1.74-4.17) with mean peak value of 3.20 , ACZ-6(1.48-4.35) with mean peak value of 3.07 , ACZ-7(1.48-3.65) with mean peak value of 2.62 , ACZ-8(3.13-4.35) with mean peak value of 3.71 , ACZ-9(3.46-5.00) with mean peak value of 4.00 and ACZ-10(2.42-5.56) with mean peak value of 3.43 (Figure 6.1).

The coefficient of variation ranges between 3.75 – 4.41 for all ACZswith maximum in ACZ–7 (4.41) and minimum in agroclimatic zone –9 (3.75). All agroclimatic zone showed higher values of phenotypic coefficient of variation than genotypic coefficient of variation. Maximum Phenotypic coefficient of variation (29.76) and genotypic coefficient of variation (29.47)recorded in ACZ- 3 (Table 6.5). Between different ACZs, for seeds collected from the forest areas, the peak value varies from 2.30-4.04 with maximum in ACZ-8 and minimum in ACZ-10 (Table 6.1). The coefficient of variation (4.00) , phenotypic coefficient of variation (15.44) and genotypic coefficient of variation (14.89) were found for peak value between the ACZs (Table 6.13). Similarly, between different agroclimatic zones for seeds collected from agricultural areas, the peak value varies from 2.62-4.00 with maximum in ACZ-9 and minimum in ACZ-7 (Table 6.2). The coefficient of variation (4.05) , phenotypic coefficient of variation (13.32) and genotypic coefficient of variation (12.72) were found for peak value between the ACZs (Table 6.14) .

6.3.4 Germination value

The germination value of all provenances varies from 0.63-11.90 .The germination value varies in ACZ-1(1.41-8.80) with mean germination value of 6.70 , ACZ-2(0.73-9.60) with mean germination value of 5.63 , ACZ-3(3.60-11.36) with mean germination value of 7.46 , ACZ-4 (3.02-11.90) with mean germination value of 7.60 , ACZ-5(0.63-10.87) with mean germination value of 6.63 , ACZ-6(4.19-10.87) with mean germination value of 8.40 , ACZ-7(3.03-10.00) with mean germination value of 6.55 , ACZ-8(6.91-11.90) with mean germination value of 9.47 , ACZ-9(4.19-10.87) with mean germination value of 8.35 and ACZ-10(0.73-9.62) with mean germination value of 3.65 (Figure 6.1).

The result showed medium range of coefficient of variations for germination value in all agroclimatic zones. The coefficient of variation ranges between 5.31 – 6.99 for all agroclimatic zones with maximum in ACZ–10 (6.99) and minimum in agroclimatic zone –8 (5.31). The extent of variability is also accessed by genotypic and phenotypic variances and genotypic and phenotypic coefficient of variation. All agroclimatic zone showed higher values of phenotypic coefficient of variation than Genotypic coefficient of variation. Maximum Phenotypic coefficient of variation (88.29) and genotypic coefficient of variation (87.97)recorded in ACZ- 10(Table 6.6).. The germination value of all provenances varies from 1.24-13.89 .The germination value varies in ACZ-1(4.82-9.60) with mean germination value of 7.04 , ACZ-2(1.82-8.93) with mean germination value of 5.42 , ACZ-3(1.36-10.42) with mean germination value of 6.26 , ACZ-4 (1.24-10.81) with mean germination value of 6.10 , ACZ-5(2.05-10.42) with mean germination value of 6.71 , ACZ-6(1.37-10.87) with mean germination value of 6.42 , ACZ-7(1.37-7.67) with mean germination value of 4.38, ACZ-8(5.86-10.87) with mean germination value of 8.37 , ACZ-9(7.18-11.25) with mean germination value of 9.27 and ACZ-10(2.78-13.89) with mean germination value of 6.55 (Figure 6.1).

The result showed medium range of coefficient of variations for germination value in all agroclimatic zones . The coefficient of variation ranges between 5.33 – 6.54for all agroclimatic zones with maximum in ACZ–7 (6.54) and minimum in ACZ–9 (5.33). All agroclimatic zone showed higher values of phenotypic coefficient of variation than genotypic coefficient of variation. Maximum Phenotypic coefficient of variation (51.51) and genotypic coefficient of variation (51.19)recorded in ACZ- 10 (Table 6.6). Between different agroclimatic zones, for seeds collected from the forest areas, the germination value varies from 3.65-9.47 with maximum in agroclimatic zone -8 and minimum in ACZ-10 (Table 6.1). The coefficient of variation (5.67) , phenotypic coefficient of variation (23.85) and genotypic coefficient of variation (23.15) were found for germination value between the agroclimatic zones (Table 6.13). Similarly, between different agroclimatic zones for seeds collected from agricultural areas, the germination value varies from 4.38-9.27 with maximum in agroclimatic zone -9 and minimum in ACZ-7 (Table 6.2). The coefficient of variation (5.75) , phenotypic coefficient of variation (21.33) and genotypic coefficient of variation (20.74) were found for germination value between the ACZs (Table 6.14) .

Correlation analysis found significant relationship between germination value and seed kernel thickness (Table 6.15).

6.3.5 Seedling Length

The studies on variation in the length of seedlings raised from *M. latifolia* Seeds collected from forest lands of different agroclimatic zones of Odisha were found significant. The germination ofall provenances varies from 11.35cm - 33.21cm .The seedling length varies in ACZ-1(11.35cm – 25.04cm) with mean seedling length of 19.64cm , agroclimatic zone -2(20.22cm-33.21cm) with seedling length of 23.39cm , ACZ-3(17.65cm-21.46cm) with mean seedling length of 20.21cm , ACZ-4 (16.88cm-22.43cm) with mean seedling length of 19.68cm , ACZ-5(14.60cm-29.62cm) with mean seedling length of 20.85cm , ACZ-6(16.98cm-22.71cm) with mean seedling length of 19.94cm , ACZ-7(17.34cm-21.87cm) with mean seedling length of 19.51cm , ACZ-8(12.86cm-21.62cm) with mean seedling length of 17.33cm , ACZ-9(11.86cm-

20.34cm) with mean seedling length of 16.17cm and ACZ-10(14.65cm-25.30cm) with mean seedling length of 20.43cm (Figure 6.2).

The result showed higher coefficient of variations for seedling length in all agroclimatic zones . The coefficient of variation ranges between 12.39-13.34for all agroclimatic zones with maximum in ACZ–8 (13.34) and minimum in ACZ–2 (12.39) .The extent of variability is also accessed by genotypic and phenotypic variances and genotypic and phenotypic coefficient of variation. All ACZs showed higher values of phenotypic coefficient of variation than Genotypic coefficient of variation. Maximum Phenotypic coefficient of variation (25.86) and genotypic coefficient of variation (22.47)recorded in ACZ- 1(Table 6.7).

Similarly, the studies on variation in the length of seedlings raised from from *M. latifolia*. Seeds collected from agricultural lands of different agroclimatic zones of Odisha were found significant. The seedling length of all provenances varies from 8.07cm-31.50cm . The seedling length varies in ACZ-1(16.78cm-26.46cm) with mean seedling length of 23.26cm , ACZ -2(18.14cm-29.91cm) with mean seedling length of 22.95cm , ACZ-3(17.89cm-23.27cm) with mean seedling length of 21.03cm , ACZ-4 (17.65cm-22.67cm) with mean seedling length of 19.74cm , ACZ-5(8.07cm-23.66cm) with mean seedling length of 18.59cm, agroclimatic zone -6(13.03cm-21.67cm) with mean seedling length of 18.56cm , ACZ -7(14.50cm-21.32cm) with mean seedling length of 16.80cm , agroclimatic zone -8(13.82cm-21.34cm) with mean seedling length of 18.53cm , ACZ -9(8.16cm-31.50cm) with mean seedling length of 19.47cm and agroclimatic zone -10(17.33cm-28.18cm) with mean seedling length of 21.76cm (Figure 6.2).

The result showed higher coefficient of variations for seedling length in all agroclimatic zones . The coefficient of variation ranges between 12.4-13.23 for all agroclimatic zones with maximum in ACZ–7 (13.23) and minimum in ACZ–1 (12.40) .All ACZ showed higher values of phenotypic coefficient of variation than genotypic coefficient of variation. Maximum Phenotypic coefficient of variation (36.52) and genotypic coefficient of variation (34.19)recorded in ACZ- 9 (Table 6.7).The mean value of length of seedling raised from *Madhuca latifolia* Macb. seeds collected from forest land and agricultural land showed significant difference between them only in agroclimatic zone – 7 (T value of Figure 6.2).Between different agroclimatic zones, for seeds collected from the forest areas, the seedling length varies from 16.17cm-23.39cm with maximum in agroclimatic zone -2 and minimum in ACZ-9 (Table 6.1). The coefficient of variation (12.79) , phenotypic coefficient of variation (16.07) and genotypic coefficient of variation (9.74) were found for seedling length between the ACZs (Table 6.13). Similarly, between different agroclimatic zones for seeds collected from agricultural areas, the seedling length varies from 16.80cm-23.26cm with maximum in ACZ-1 and minimum in ACZ-7(Table 6.2). The coefficient of variation (12.74) , phenotypic coefficient of variation (16.51) and genotypic coefficient of variation (10.44) were found for seedling length between the ACZ (Table 6.14) .

6.3.6 Collar Diameter

The studies on variation in the collar diameter of seedlings raised from *M. latifolia*. seeds collected from forest lands of different agroclimatic zones of Odisha were found significant. The germination of all provenances varies from 0.2cm-0.55cm .The collar diameter varies in ACZ-1(0.25cm-0.38cm) with mean collar diameter of 0.32cm , ACZ-2(0.34cm-0.55cm) with mean collar diameter of 0.43cm , ACZ-3(0.27cm-0.38cm) with mean collar diameter of 0.32cm , ACZ-4 (0.23cm-0.37cm) with mean collar diameter of 0.31cm , ACZ-5(0.25cm-0.55cm) with mean collar diameter of 0.45cm , ACZ -6(0.32cm-0.42cm) with mean collar diameter of 0.37cm , ACZ-7(0.32cm-0.41cm) with mean collar diameter of 0.37cm , ACZ-8(0.28cm-0.42cm) with mean collar diameter of 0.35cm , ACZ-9(0.20cm-0.35cm) with mean collar diameter of 0.29cm and ACZ-10(0.34cm-0.54cm) with mean collar diameter of 0.44cm (Figure 6.2). The result showed low coefficient of variations for collar diameter in all ACZs. The coefficient of variation ranges between 3.53-4.75 for all ACZs with maximum in agroclimatic zone –5

(4.75) and minimum in agroclimatic zone –9 (3.53). The extent of variability is also accessed by genotypic and phenotypic variances and genotypic and phenotypic coefficient of variation. All ACZs showed higher values of phenotypic coefficient of variation than Genotypic coefficient of variation. Maximum Phenotypic coefficient of variation (20.31) and genotypic coefficient of variation (20.08)recorded in ACZ- 5 (Table 6.8).Similarly, the studies on variation in the collar diameter of seedlings raised from *M. latifolia* seeds collected from agricultural lands of different agroclimatic zones of Odisha were found significant. The collar diameter of all provenances varies from 0.20cm-0.59cm .The collar diameter varies in ACZ-1(0.23cm-0.44cm) with mean collar diameter of 0.35cm, agroclimatic zone -2(0.33cm-0.59cm with mean collar diameter of 0.46cm , ACZ-3(0.27cm-0.40cm) with mean collar diameter of 0.35cm , ACZ-4 (0.26cm-0.35cm) with mean collar diameter of 0.31cm , ACZ-5(0.32cm-0.58cm) with mean collar diameter of 0.43cm ,agroclimatic zone -6(0.26cm-0.40cm) with mean collar diameter of 0.34cm , ACZ-7(0.30cm-0.47cm) with mean collar diameter of 0.37cm, ACZ-8(0.20cm-0.42cm) with mean collar diameter of 0.30cm , ACZ-9(0.20cm-0.35cm) with mean collar diameter of 0.31cm and agroclimatic zone -10(0.34cm-0.49cm) with mean collar diameter of 0.43cm (Figure 6.2).

The result showed low coefficient of variations for collar diameter in all agroclimatic zones . The coefficient of variation ranges between 3.46-4.64 for all agroclimatic zones with maximum in ACZ–8 (4.64) and minimum in ACZ–2 (3.64) .All agroclimatic zone showed higher values of phenotypic coefficient of variation than genotypic coefficient of variation. Maximum Phenotypic coefficient of variation (21.84) and genotypic coefficient of variation (21.32)recorded in ACZ- 8 (Table 6.8).The mean value of collar diameter of seedlings raised from *Madhuca latifolia* Macb seeds collected from forest land and agricultural land showed significant difference between them in agroclimatic zone - 6 and 8 (T value of Figure 6.2). Between different agroclimatic zones, for seeds collected from the forest areas, the collar diameter varies from 0.29cm-0.45cm with maximum in ACZ-5 and minimum in ACZ-9 (Table 6.1) . The coefficient of variation (4.04) , phenotypic coefficient of variation (16.46) and genotypic coefficient of variation

(15.75) were found for collar diameter between the ACZs (Table 6.13). Similarly, between different ACZsfor seeds collected from agricultural areas, the collar diameter varies from 0.30cm-0.46cm with maximum in ACZ-2 and minimum in agroclimatic zone -8(Table 6.2). The coefficient of variation (4.04) , phenotypic coefficient of variation (15.81) and genotypic coefficient of variation (15.43) were found for collar diameter between the ACZs (Table 6.14) .

6.3.7 Seedling Fresh Biomass

The studies on variation in the fresh biomass of seedling raised from *Madhuca latifolia* Macb. Seeds collected from forest lands of different agroclimatic zones of Odisha were found significant. The seedling fresh biomass of all provenances varies from 8.97g-14.87g .The seedling fresh biomass varies in ACZ-1(9.12g-13.21g) with mean seedling fresh biomass of 11.40g , ACZ-2(10.21g-14.28g) with mean seedling fresh biomass of 12.09g , ACZ-3(10.23g-11.78g) with mean seedling fresh biomass of 11.06g , ACZ-4 (10.75g-12.28g) with mean seedling fresh biomass of 11.44g , ACZ-5(9.68g-14.87g) with mean seedling fresh biomass of 11.73g,, ACZ-6(8.97g-12.13g) with mean seedling fresh biomass of 11.00g , ACZ-7(10.17g-11.63g) with mean seedling fresh biomass of 10.95g , ACZ-8(9.23g-11.34g) with mean seedling fresh biomass of 10.72g , ACZ-9(9.57g-11.59g) with mean seedling fresh biomass of 10.34g and ACZ-10(10.08g-13.68g) with mean seedling fresh biomass of 11.70g (Figure 6.2). The result showed higher coefficient of variations for seedling fresh biomass in all ACZs. The coefficient of variation ranges between 9.77-10.12 for all agroclimatic zones with maximum in ACZ–9 (10.12) and minimum in ACZ–2 (9.77) .The extent of variability is also accessed by genotypic and phenotypic variances and genotypic and phenotypic coefficient of variation. All agroclimatic zone showed higher values of phenotypic coefficient of variation than Genotypic coefficient of variation. Maximum Phenotypic coefficient of variation (17.18) and genotypic coefficient of variation (1410)recorded in ACZ- 5 (Table 6.9).

Similarly, the studies on variation in the fresh biomass of seedling raised from *M. latifolia*. seeds collected from agricultural lands of different agroclimatic zones of Odisha were found significant. The seedling fresh biomass of all provenances varies from 5.83g-15.34g .The seedling fresh biomass varies in ACZ-1(11.21g-14.46g) with mean fresh seedling biomass of 12.81g , ACZ-2(10.21g-13.83g) with mean seedling fresh biomass of 11.81g , ACZ-3(10.01g-12.43g) with mean seedling fresh biomass of 11.12g , ACZ-4 (10.36g-12.50g) with mean seedling fresh biomass of 11.22g , ACZ-5(6.36g-12.65g) with mean seedling fresh biomass of 10.77g, ACZ-6(9.28g-11.87g) with mean seedling fresh biomass of 10.79g , agroclimatic zone -7(8.92g-11.49g) with mean seedling fresh biomass of 10.17g , ACZ -8(9.87g-11.87g) with mean seedling fresh biomass of 10.90g , ACZ-9(5.83g-14.76g) with mean seedling fresh biomass of 11.34g and ACZ-10(10.02g-15.34g) with mean seedling fresh biomass of 12.08g (Figure 6.2).

The result showed higher coefficient of variations for seedling fresh biomass in all agroclimatic zones . The coefficient of variation ranges between 9.65-10.16 for all agroclimatic zones with maximum in ACZ–7 (10.16) and minimum in ACZ–1 (9.65) .All ACZs showed higher values of phenotypic coefficient of variation than genotypic coefficient of variation. Maximum Phenotypic coefficient of variation (24.86) and genotypic coefficient of variation (22.81)recorded in ACZ- 9(Table 6.9).The mean value of fresh biomass of seedling raised from *M. latifolia* seeds collected from forest land and agricultural land showed significant difference between them in ACZ-1 and 8 (T value of Figure 6.2).Between different agroclimatic zones, for seeds collected from the forest areas, the seedling fresh biomass varies from 10.34g- 12.09gwith maximum in ACZ-2 and minimum in ACZ-9 (Table 6.1). The coefficient of variation (9.72) , phenotypic coefficient of variation (10.73) and genotypic coefficient of variation (4.50) were found for seedling fresh biomass between the agroclimatic zones (Table 6.13). Similarly, between different agroclimatic zones for seeds collected from agricultural areas, the seedling fresh biomass varies from 10.17g-12.81g with maximum in ACZ-1 and minimum in ACZ-7(Table 6.2). The coefficient of variation (9.71) , phenotypic coefficient of variation (11.74) and genotypic coefficient of variation (6.58) were found for seedling fresh biomass between the ACZs (Table 6.14) .

6.3.8 Seedling Oven dry biomass

The studies on variation in the oven dry biomass of the seedling raised from *M. latifolia* seeds collected from forest lands of different agroclimatic zones of Odisha were found significant. The seedling oven dry biomass of all provenances varies from 2.57g-4.83g .The seedling oven dry biomass varies in ACZ-1(2.82g-3.97g) with mean seedling oven dry biomass of 3.51g , ACZ-2(3.31g-4.36g) with mean seedling oven dry biomass of 3.77g , ACZ-3(3.01g-3.62g) with mean seedling oven dry biomass of 3.29g , ACZ-4 (2.86g-3.87g) with mean seedling oven dry biomass of 3.48g , ACZ-5(2.99g-4.83g) with mean seedling oven dry biomass of 3.61g , ACZe-6(2.57g-3.68g) with mean seedling oven dry biomass of 3.26g , ACZ-7(2.98g-3.83g) with mean seedling oven dry biomass of 3.33g , ACZ-8(2.97g-3.47g) with mean seedling oven dry biomass of 3.28g , ACZ9(2.91g-3.73g) with mean seedling oven dry biomass of 3.22g and ACZ-10(3.13g-4.03g) with mean seedling oven dry biomass of 3.62g (Figure 6.2).

The result showed medium coefficient of variations for seedling oven dry biomass in all agroclimatic zones . The coefficient of variation ranges between 7.53-7.75 for all agroclimatic zones with maximum in ACZ–9 (7.75) and minimum in ACZ–2(7.53). The extent of variability is also accessed by genotypic and phenotypic variances and genotypic and phenotypic coefficient of variation. All agroclimatic zone showed higher values of phenotypic coefficient of variation than Genotypic coefficient of variation. Maximum Phenotypic coefficient of variation (17.39) and genotypic coefficient of variation (15.67)recorded in ACZ- 5 (Table 6.10).

Similarly, the studies on variation in the oven dry biomass of the seedlings raised from *M. latifolia*. Seeds collected from agricultural lands of different agroclimatic zones of Odisha were found significant. The seedling oven dry biomass of all provenances varies from 1.88g-4.81g .The seedling oven dry biomass varies in ACZ-1(3.35g-4.28g) with mean seedling oven dry biomass of 3.86g , agroclimatic zone -2(3.11g-4.03g) with mean seedling oven dry biomass of 3.53g , ACZ-3(3.04g-3.92g) with mean seedling oven dry biomass of 3.33g, ACZ-4 (2.98g-4.01g) with mean seedling oven dry biomass of 3.44g, ACZ-5(1.98g-3.73g) with mean seedling oven dry biomass of 3.21g, , ACZ-6(3.02g-3.74g) with mean seedling oven dry biomass of 3.31g , ACZ-7(2.57g-3.61g) with mean seedling oven dry biomass of 3.09g , ACZ-8(3.09g-3.78g) with mean seedling oven dry biomass of 3.41g , ACZ-9(1.88g-4.68g) with mean seedling oven dry biomass of 3.49g and ACZ-10(2.89g-4.81g) with mean seedling oven dry biomass of 3.69g (Figure 6.2).

The result showed medium coefficient of variations for seedling oven dry biomass in all agroclimatic zones . The coefficient of variation ranges between 7.49-7.82 for all agroclimatic zones with maximum in agroclimatic zone –7 (7.82) and minimum in ACZ–1 (7.49). All agroclimatic zone showed higher values of phenotypic coefficient of variation than genotypic coefficient of variation. Maximum Phenotypic coefficient of variation (24.02) and genotypic coefficient of variation (22.78)recorded in ACZ- 9 (Table 6.10).

The mean value of seedling oven dry biomass of *M. latifolia* seeds collected from forest land and agricultural land showed significant difference between them only in agroclimatic zone-1(T value of Figure 6.2).Between different agroclimatic zones, for seeds collected from the forest areas, the seedling oven dry biomass varies from 3.22g-3.77g with maximum in ACZ-2 and minimum in ACZ-9 (Table 6.1). The coefficient of variation (7.65) , phenotypic coefficient of variation (9.35) and genotypic coefficient of variation (5.40) were found for seedling oven dry biomass between the ACZs (Table 6.13).

Similarly, between different agroclimatic zones for seeds collected from agricultural areas, the seedling oven dry biomass varies from 3.09g-3.86g with maximum in ACZ-1 and minimum in ACZ-7(Table 6.2). The coefficient of variation (7.66) , phenotypic coefficient of variation (10.08) and genotypic coefficient of variation (6.49) were found for seedling oven dry biomass between the agroclimatic zones (Table 6.14) .

6.3 .9 Moisture content

The studies on variation in the moisture content of seedlings raised from *M. latifolia* seeds collected from forest lands of different agroclimatic zones of Odisha were found significant. The moisture content of all provenances varies from 179.90%-282.87%. The moisture content varies in ACZ-1(209.97%-240.46%) with mean moisture content of 225.42%, ACZ-2(179.90%-246.63%) with mean moisture content of 220.62% , ACZ-3(223.52%-255.05%) with mean moisture content of 236.23%, ACZ-4(202.37%-282.87%) with mean moisture content of 230.79%, ACZ-5(207.87%-244.95%) with mean moisture content of 225.93%,ACZ-6(222.51%-263.91%) with mean moisture content of 238.44%, ACZ-7(203.66%-244.90%) with mean moisture content of 229.84%, ACZ-8(210.77%-252.08%) with mean moisture content of 226.63%, ACZ-9(201.54%-245.36%) with moisture content of 221.20% and ACZ-10(204.51% - 277.90%) with mean moisture content of 224.10% (Figure 6.2).

The result showed low coefficient of variations for moisture content in all agroclimatic zones . The coefficient of variation ranges between 4.15 – 4.36 for all agroclimatic zones with maximum in ACZ–9 (4.36) and minimum in ACZ–4 and 6 (4.15). The extent of variability is also accessed by genotypic and phenotypic variances and genotypic and phenotypic coefficient of variation. All agroclimatic zone showed higher values of phenotypic coefficient of variation than Genotypic coefficient of variation. Maximum Phenotypic coefficient of variation (11.96) and genotypic coefficient of variation (11.21)recorded in ACZ- 4 (Table 6.11).

Similarly, the studies on variation in the moisture content of seedlings raised from *M. latifolia* seeds collected from agricultural lands of different agroclimatic zones of Odisha were found significant. The moisture content of all provenances varies from 204.44% -

273.15% . The moisture content varies in ACZ-1(216.58% - 245.22%) with mean moisture content of 231.65% , agroclimatic zone-2(212.68% - 254.02%) with mean moisture content of 234.52% , ACZ-3(211.82% -253.29%) with mean moisture content of 234.44 % , ACZ-4(211.72%-273.15%) with mean moisture content of 228.32%, ACZ-5(217.34%-256.96%) with mean moisture content of 235.39%,ACZ-6(206.27%-238.74%) with mean moisture content of 225.99%, ACZ-7(204.44%-264.98%) with mean moisture content of 229.87%, ACZ-8(207.48%-232.04%) with mean moisture content of 220.29% , ACZ-9(210.11%-248.61%) with mean moisture content of 224.99% and ACZ-10(216.34% -246.71%) with mean moisture content of 228.24% (Figure 6.2).

The result showed low coefficient of variations for moisture content in all agroclimatic zones . The coefficient of variation ranges between 4.05-4.35 for all agroclimatic zones with maximum in ACZ–9 (4.35) and minimum in ACZ–1(4.05). All ACZs showed higher values of phenotypic coefficient of variation than genotypic coefficient of variation. Maximum Phenotypic coefficient of variation (10.71) and genotypic coefficient of variation (9.85)recorded in ACZ- 4 (Table 6.11).

The mean value of moisture content of seedlings raised from *M. latifolia* seeds collected from forest land and agricultural land showed significant difference between them in agroclimatic zone -5 and 6 (T value of Figure 6.2).Between different agroclimatic zones, for seeds collected from the forest areas, the moisture content varies from 220.62% – 238.44%with maximum in agroclimatic zone -6and minimum in ACZ-2 (Table 6.1) . The coefficient of variation (4.23) , phenotypic coefficient of variation (4.89) and genotypic coefficient of variation (2.46) were found for moisture content between the agroclimatic zones (Table 6.13). Similarly, between different agroclimatic zones for seeds collected from agricultural areas, the moisture content varies from 220.29% – 235.39% with maximum in agroclimatic zone -4 and 5 and minimum in ACZ-8 (Table 6.2). The coefficient of variation (4.20) , phenotypic coefficient of variation (4.65) and genotypic coefficient of variation (2.00) were found for moisture content between the ACZs(Table 6.14) .

6.3.10 Shoot Vigour Index

The studies on variation in the shoot vigour index of *M. latifolia* seedlings raised from seeds collected from forest lands of different agroclimatic zones of Odisha were found significant. The shoot vigour index of all provenances varies from 394.2-2962.0 .The shoot vigour index varies in ACZ-1(442.65-2278.64) with mean shoot vigour index of 1562.67 , ACZ-2(587.16-2523.96) with mean shoot vigour index of 1682.61, ACZ-3(1179.75-2146.00) with mean shoot vigour index of 1670.50 , ACZ-4 (1134.00-2134.00) with mean shoot vigour index of 1628.01 , ACZ-5(394.20-2962.00) with mean shoot vigour index of 1658.79 , ACZ-6(1203.18-2150.00) with mean shoot vigour index of 1750.12 , ACZ-7(1156.10-1976.00) with mean shoot vigour index of 1538.67, ACZ -8(1131.68-2162.00) with mean shoot vigour index of 1632.98 , agroclimatic zone -9(782.76-1733.40) with mean shoot vigour index of 1434.09 and agroclimatic zone -10(400.40-1641.74) with mean shoot vigour index of 1045.84 (Figure 6.2).

The result showed low coefficient of variations for shoot vigour index in all agroclimatic zones . The coefficient of variation ranges between 3.57-4.61 for all agroclimatic zones with maximum in ACZ–10 (4.61) and minimum in agroclimatic zone –2 (3.57). The extent of variability is also accessed by genotypic and phenotypic variances and genotypic and phenotypic coefficient of variation. All agroclimatic zone showed higher values of phenotypic coefficient of variation than Genotypic coefficient of variation. Maximum Phenotypic coefficient of variation (50.57) and genotypic coefficient of variation (50.44recorded in ACZ- 5 (Table 6.12).

Similarly, the studies on variation in the shoot vigour index of *M. latifolia* seedlings raised from seeds collected from agricultural lands of different agroclimatic zones of Odisha were found significant. The shoot vigour index of all provenances varies from

379.29 – 2961.00 .The shoot vigour index varies in ACZ-1(1375.96-2214.64) with mean shoot vigour index of 1935.10 , ACZ-2(1037.30-2593.00) with mean shoot vigour index of 1740.10 , ACZ-3(831.48-2105.20) with mean shoot vigour index of 1570.67 , ACZ-4 (777.10-2055.30) with mean shoot vigour index of 1474.29 , ACZ-5(379.29-2126.00) with mean shoot vigour index of 1531.05 ,agroclimatic zone -6(482.11-2167.00) with mean shoot vigour index of 1483.90 , ACZ -7(637.51-1230.78) with mean shoot vigour index of 1047.99 , ACZ-8(1382.00-1984.62) with mean shoot vigour index of 1642.04 , ACZ-9(677.28-2961.00) with mean shoot vigour index of 1799.20 and ACZ10(980.89-2024.00) with mean shoot vigour index of 1550.47 (Figure 6.2).

The result showed low coefficient of variations for shoot vigour index in all agroclimatic zones . The coefficient of variation ranges between 3.37-4.65 for all agroclimatic zones with maximum in agroclimatic zone –7 (4.65) and minimum in ACZ–1 (3.37) .All ACZs showed higher values of phenotypic coefficient of variation than genotypic coefficient of variation. Maximum Phenotypic coefficient of variation (41.82) and genotypic coefficient of variation (41.64)recorded in ACZ- 5(Table 6.12).

The mean value of shoot vigour index of *M. latifolia* seedlings raised from seeds collected from forest lands and agricultural lands showed significant difference between them in ACZ-6,7 and 10 (T value of Figure 6.2).

Between different agroclimatic zones, for seeds collected from the forest areas, the shoot vigour index varies from 1045.84-1750.12 with maximum in agroclimatic zone -6 and minimum in ACZ-10 (Table 6.1). The coefficient of variation (4.00) , phenotypic coefficient of variation (12.71) and genotypic coefficient of variation (12.06) were found for shoot vigour index between the ACZs (Table 6.13). Similarly, between different agroclimatic zones for seeds collected from agricultural areas, the shoot vigour index varies from 1047.99-1935.10 with maximum in ACZ-1 and minimum in ACZ-7 (Table 6.2) . The coefficient of variation (3.77) , phenotypic coefficient of variation (15.40) and genotypic coefficient of variation (14.93) were found for shoot vigour index between the ACZs (Table 6.14) .

6.4 DISCUSSION

Performance of trees with respect to provenance trials becomes somewhat difficult as the tree has a long gestation period, therefore the study of their growth and development during juvenile age is required to determine the relative performance of the different genotypes (Chaturvedi and Pandey, 2005). The higher and lower values for germinating trait like germination percentage, mean daily germination, peak value and germination value for the seeds from sample trees under each agroclimatic zone may be due to the synergic effect of rate of biochemical and physiological changes within each seed to break its dormancy , amount of stored food material in seed and nursery environmental conditions with in which it is germinating. However, the variation in quantity and quality of stored food materials and other biochemicals in sample tree seeds of a agroclimatic zone are mainly attributed to their genetic makeup , microenvironmental variation with in the agroclimatic zone it grows and their interaction. Similarly, the higher and lower values of seedling traits like seedling length, collar diameter, fresh seedling biomass ,oven dry seedling biomass , moisture content and shoot vigour index found for sample tree seeds with in a agroclimatic zone . This is also due to genotypic factors controlling both seed and seedling traits and their interaction with the nursery environment which affects the growth and development of seedlings at different rates.

In all agroclimatic zone phenotypic coefficient of variation found higher than genotypic coefficient of variation for all the germination and seedling characters (Fig.59-68) which indicates environmental factors has also a role in expression of the characters (Mohamed et al. , 2015). Higher PCV , GCV and CV values in an agroclimatic zone indicates higher variation of the trait in that zone (Wani and Wani , 2017). Again , higher the difference between the PCV and GCV value and higher the CV value indicates more influence of environmental factors for expression of the character in the particular agroclimatic zone (Reddy et al., 2011) .

The phenotypic coefficient of variation and genotypic coefficient of variation in present study for all traits with in each agroclimatic zone found to have lower to higher variation of characters (Fig.59-68) . In the above study also the differences observed for most of the germination and seedling parameters are genetic in nature because the environmental deviations were found less for the experimental site, while the randomization and replication might have further reduced the chances of site effects. This also explains the variation in observed phenotypic values (Vakshasya et al., 1992). However, characters like seedling length and fresh seedling biomass showed higher environmental variation than other characters.

For the seedlings raised from the seeds collected from forest lands , higher variations with in each zone were found for all the germination traits with highest in germination value (Fig. 62). Agroclimatic zone -10 showed maximum variations with in the agroclimatic zone for the germination traits (Table:60-63) like germination value (PCV-88.29 , GCV-87.97 and CV-6.99), germination percentage (PCV-49.57 , GCV-49.02 and CV-7.39) , mean daily germination (PCV-49.06 , GCV-48.91 and CV-5.22) and peak value (PCV-46.54 , GCV-46.37 and CV-4.68). So, these germinating traits has a scope for further assessment of genetic variability in agroclimatic zone -10 that to be helpful for improvement of the species. Seedling traits like shoot vigour index, seedling length, fresh seedling biomass and oven dry seedling biomass showed higher variations with highest in shoot vigour index. Agroclimatic zone-5 showed maximum variations within the agroclimatic zone for the seedling traits (Fig.66,67 and 69) like shoot vigour index (PCV-50.57 , GCV-50.44 and CV-3.68), oven dry seedling biomass (PCV-17.39 , GCV-15.67 and CV-7.59) and fresh seedling biomass (PCV-17.18 , GCV-14.10 and CV-9.83). Seedling length although showed second highest variation in agroclimatic zone-5 which is very close to the highest variation showed in agroclimatic zone -1. So, these germinating traits has a scope for further assessment of genetic variability in agroclimatic zone -5 that to be helpful for improvement of the species.

Similar types of studies on the variability parameter estimates considering genetic parameters were carried out in *Azadirachta indica* (Dhillon et al., 2003), *Pongamia pinnata* (Kumaran, 1991) and *Dalbergia sissoo* (Dogra et al., 2005) . Variations in germination traits of seeds in relation to provenances have also been reported in many other forest tree species like *Albizia lebbek* (Kumar and Toky 1993), *Pinus pinaster* (Falleri 1994), *Acacia nilotica* (Ginwal et al. 1995) and *Jatropha curcas* (Ginwal et al., 2005) .

Similarly, in case of seedlings raised from the seeds collected from trees on agricultural lands, agroclimatic zone -3 showed maximum variations (PCV, GCV and CV values) with in the agroclimatic zone (Fig. 59-61) for most of the germination traits except germination value which has second highest variation after agroclimatic zone -10 . Seedling traits showed maximum variation in for most of the traits in agroclimatic zone -8 except shoot vigour index which found second highest after agroclimatic zone -5 (Fig.63-67) . So, for agricultural lands, these agroclimatic zones may be taken up for the different germination and seedling traits as mentioned above for further assessment of genetic variability which may be helpful for improvement programme of the species.

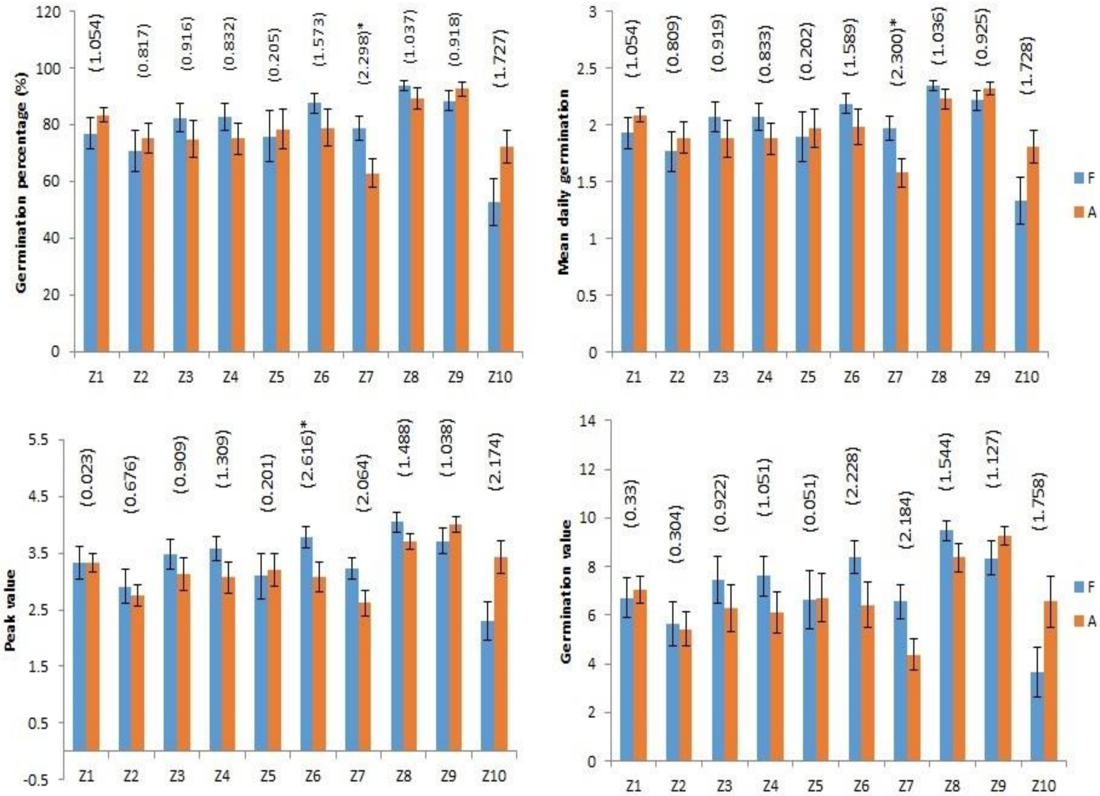
Variation among the agroclimatic zones revealed that , germination traits like germination percentage, peak value and germination value had moderate level of variations (PCV , GCV and CV) with maximum variation in germination value in the seedlings raised from both forest lands and agricultural lands (Fig. 79) . Seedling characters like seedling length, collar diameter, fresh seedling biomass and shoot vigour index also revealed moderate level of variation with maximum variation in collar diameter in the seedlings raised from both forest lands and agricultural lands (Fig. 79). However, seedling length and fresh seedling biomass showed comparatively more influenced by environmental factors for their phenotypic expression than other characters. So, the above mentioned germinating and seedling characters can be taken up for further improvement study of the species.

Similar type of findings were revealed by Wani and Ahmad (2013), Wani and Wani (2013) , Wani and Wani (2017) in case of *Madhuca indica* and Abraham *et al*. (2010) in case of *Madhuca longifolia*. Variability of seed characteristics were also studied by Police *et al*. (2013),Vasanth Reddy *et al*. (2007) in *Pongamia pinnata* , Gosh andSingh(2011) in *Jatropha curcas* , Ramachandra (1996) in *Acacia catechu* , Devagiri *et al*. (1997) in *Heracleum candicans* , Sharma and Sharma (1995) in *Grewia optiva*, Subramanium *et al*. (1995) in *Eucalyptus grandis* and Srivastava et al. (1993) in *Terminalia arjuna.*

Besides further improvement of the species, this agroclimatic zone based seedling evaluation study of *Madhuca latifolia* can be helpful for production of quality planting material for each zone and also in making decision for afforestation and reforestation programmes for the locality.

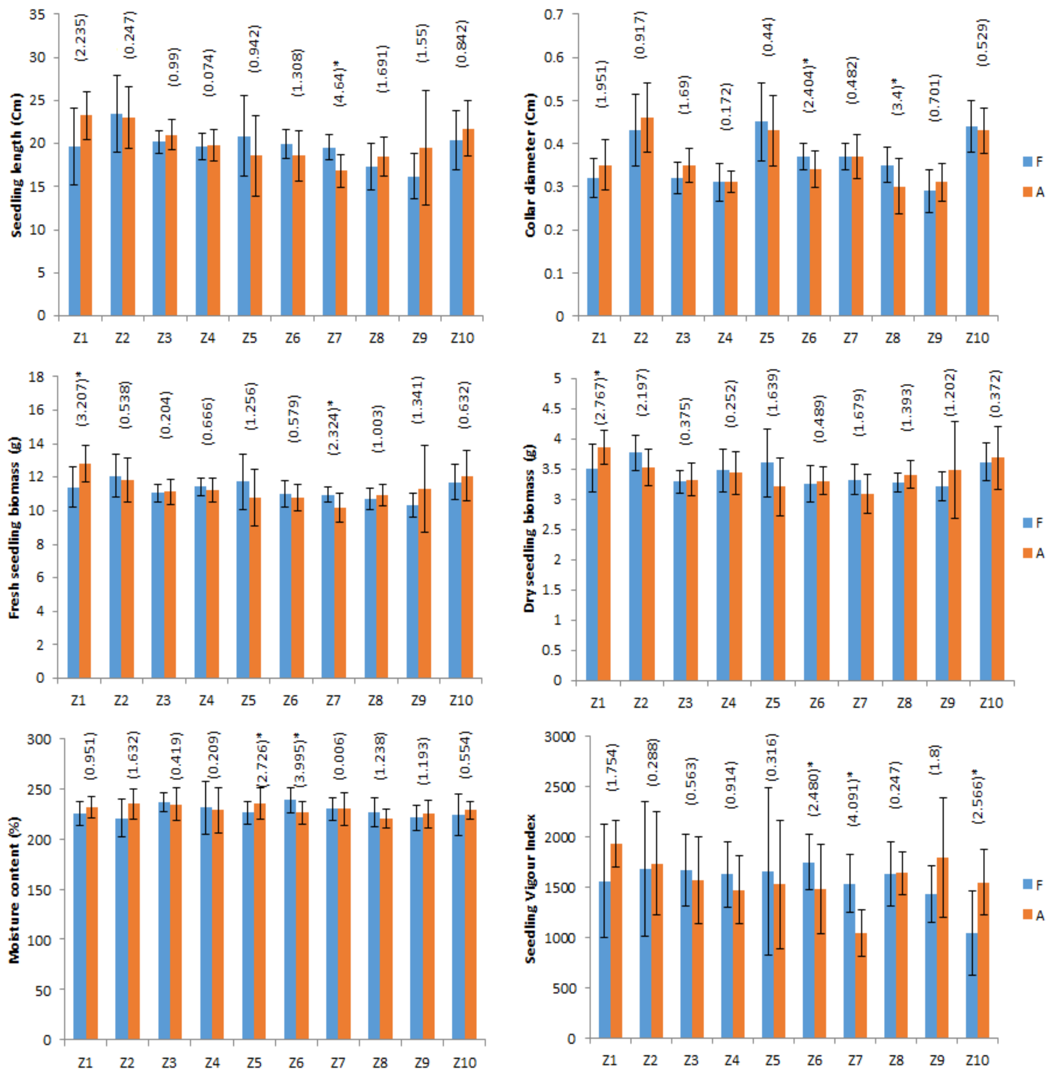
Among the agroclimatic zones for seedlings raised from seeds collected from forest lands , the values of all the germination characters are found maximum in agroclimatic zone -8 and seedling characters in agroclimatic zone -2 (Fig. 69-78) . Similarly for seedlings raised from seeds collected from agricultural lands, germination characters are found maximum in agroclimatic zone -9 and seedling characters in agroclimatic zone -1(Fig.69-78) . Seedling characters found maximum in agroclimatic zone-2 and zone-1 in forest and agricultural land respectively as mean fresh seed weight were also found higher in the same zone for forest (zone -2) and agricultural land (zone -1). Fresh seed weight may promoted early germination of seeds and establishment of seedlings respectively there by resulting better growth. Besides that seedling characters also depends upon the environmental conditions and interaction of seed characters like seed weight with environmental conditions for growth and development of seedlings . The finding was also inline as reported by Saveninattu and Westoby (1996) that the seedling from a larger seeds may have sufficient reserves to continue growth for a much longer period. Zimmernan and Weis (1983) also reported that seed size and weight also affects the seedling biomass. However, germination percentage and other germination characters are not significantly affected by seed weight , oil content rather it may be affected more on the biochemical changes within the seeds for breaking its dormancy and the environmental conditions favoring germination. Metabolic activities involved with in seed are mainly responsible for the germination (Rosental et al., 2014)and mobilization of seed reserves normally considered to be a post-germination process responsible for seedling development (Eastmond and Graham, 2001; Pritchard et al., 2002). Wang et al.(2011) reported that the starch content of seeds was not positively correlated with the final germination percentage in *Citrullus lanatus* and Kanmaz and Ova (2015) discussed that fat content also has no significant correlation with the germination percentage of *Linum usitatissimum* seeds rather according to Ataíde et al. (2013) the lipid concentration in seeds of *Dalbergia nigr*a remained constant or even increased slightly during germination.

From seedlings raised from all the sample trees seeds , maximum germination percentage (100%) and other germination characters were found in sample tree -STAGA 6 where as important seedling characters like Shoot vigour index (2962.00) and seedling oven dry biomass (15.34 g) were found to have maximum value in sample tree -STKMF 1 in agroclimatic zone -5. This maximum values for the above characters of seedlings expressed by the respective sample trees are attributed to its genetic make-up and environmental interaction as explained earlier.



Number within parenthesis represent t value
***represents significant at P < 0.05**

Figure 6.1: Variations in seed germination characteristics for the 10 agroclimatic zones (z) of *M. latifolia* grown in forest (F) and agriculture land (A).



Number within parenthesis represents t value
***represents significant at p < 0.05**

Figure 6.2: Variations in seedling growth characteristics for the 10 agroclimatic zones (z) of *M. latifolia* grown in forest (F) and agriculture land (A).

Table 6.1: Variation in the seedling characters of Plus trees of *M. latifolia* from Forest land across different agroclimatic zones

Agroclimatic Zone	germination percentage	Mean daily germination	Peak value	Germination Value	Seedling length (cm)	Collar diameter (cm)	Seedling (Shoot) vigour Index	Fresh seedling biomass(g)	Oven dry seedling Biomass(g)	moisture content (%)
ACZ-1	77.10	1.93	3.32	6.70	19.64	0.32	1562.67	11.40	3.51	225.42
ACZ-2	70.90	1.77	2.91	5.63	23.39	0.43	1682.61	12.09	3.77	220.62
ACZ-3	82.60	2.07	3.48	7.46	20.21	0.32	1670.50	11.06	3.29	236.23
ACZ-4	82.70	2.07	3.58	7.60	19.68	0.31	1628.01	11.44	3.48	230.79
ACZ-5	76.00	1.90	3.09	6.63	20.85	0.45	1658.79	11.73	3.61	225.93
ACZ-6	87.70	2.19	3.78	8.40	19.94	0.37	1750.12	11.00	3.26	238.44
ACZ-7	78.90	1.97	3.23	6.55	19.51	0.37	1538.67	10.95	3.33	229.84
ACZ-8	93.80	2.35	4.04	9.47	17.33	0.35	1632.98	10.72	3.28	226.63
ACZ-9	88.60	2.22	3.71	8.35	16.17	0.29	1434.09	10.34	3.22	221.20
ACZ-10	53.00	1.33	2.30	3.65	20.43	0.44	1045.84	11.70	3.62	224.10
Mean	**79.13**	**1.98**	**3.34**	**7.04**	**19.71**	**0.36**	**1560.43**	**11.24**	**3.44**	**227.92**

Table 6.2: Variation in the germination characters of Plus trees of *M. latifolia* from Agricultural land across different agroclimatic zones

Agroclimatic Zone	germination percentage	Mean daily germination	Peak value	Germination Value	Seedling length (cm)	Collar diameter (cm)	Seedling (Shoot) vigour Index	Fresh seedling biomass(g)	Oven dry seedling Biomass(g)	moisture content (%)
ACZ-1	83.60	2.09	3.33	7.04	23.26	0.35	1935.10	12.81	3.86	231.65
ACZ-2	75.40	1.89	2.76	5.42	22.95	0.46	1740.10	11.81	3.53	234.52
ACZ-3	75.00	1.88	3.13	6.26	21.03	0.35	1570.67	11.12	3.33	234.44
ACZ-4	75.20	1.88	3.07	6.10	19.74	0.31	1474.29	11.22	3.44	228.32
ACZ-5	78.60	1.97	3.20	6.71	18.59	0.43	1531.05	10.77	3.21	235.39
ACZ-6	79.10	1.98	3.07	6.42	18.56	0.34	1483.90	10.79	3.31	225.99
ACZ-7	63.00	1.58	2.62	4.38	16.80	0.37	1047.99	10.17	3.09	229.87
ACZ-8	89.30	2.23	3.71	8.37	18.53	0.30	1642.04	10.90	3.41	220.29
ACZ-9	92.70	2.32	4.00	9.27	19.47	0.31	1799.20	11.34	3.49	224.99
ACZ-10	72.50	1.81	3.43	6.55	21.76	0.43	1550.47	12.08	3.69	228.24
Mean	**78.44**	**1.96**	**3.23**	**6.65**	**20.07**	**0.36**	**1577.48**	**11.30**	**3.44**	**229.37**

Table 6.3 : Variation in Germination % of plus trees of *M. latifolia* within agroclimatic zones

Variation parameters	ACZ-1	ACZ-2	ACZ-3	ACZ-4	ACZ-5	ACZ-6	ACZ-7	ACZ-8	ACZ-9	ACZ-10
Forest land										
CV %	6.8	6.91	6.71	6.71	6.82	6.64	6.77	6.57	6.63	7.39
SED	2.10	2.03	1.98	2.11	2.23	2.15	2.27	1.95	2.08	2.41
CD (5%)	4.43	4.28	4.11	4.37	4.70	4.55	4.79	4.01	4.24	5.09
PCV	23.65	32.17	21.01	19.35	37.55	14.23	18.37	8.88	14.37	49.57
GCV	22.66	31.42	19.91	18.15	36.93	12.59	17.08	5.97	12.74	49.02
Agriculture										
CV %	6.7	6.83	6.83	6.83	6.77	6.76	7.09	6.62	6.58	6.88
SED	2.16	2.23	2.03	2.15	2.26	2.09	2.32	2.01	1.94	2.21
CD (5%)	4.51	4.69	4.35	4.58	4.64	4.29	4.74	4.25	4.01	4.58
PCV	12.18	23.18	28.40	24.54	28.15	26.25	25.49	14.48	10.43	20.56
GCV	10.18	22.15	27.57	23.57	27.32	25.37	24.48	12.88	8.10	24.77

Table 6.4: Variation in Mean daily germination of plus trees of *M. latifolia* within agroclimatic zones

Variation parameters	ACZ-1	ACZ-2	ACZ-3	ACZ-4	ACZ-5	ACZ-6	ACZ-7	ACZ-8	ACZ-9	ACZ-10
Forest land										
CV %	4.04	4.27	3.87	3.87	4.08	3.73	3.98	3.58	3.71	5.22
SED	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
CD (5%)	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
PCV	22.94	31.74	20.12	18.55	37.03	13.05	17.45	6.87	13.19	49.06
GCV	22.62	31.39	19.79	18.12	36.78	12.51	16.95	5.86	12.69	48.91
Agriculture										
CV %	3.84	4.1	4.11	4.11	3.99	3.98	4.62	3.69	3.61	4.2
SED	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
CD (5%)	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
PCV	10.85	22.45	27.79	23.90	27.49	25.51	24.78	13.29	8.73	25.12
GCV	10.11	22.11	27.52	23.56	27.23	25.23	24.35	12.77	7.97	24.69

Table 6.5 : Variation in peak value of plus trees of *M. latifolia* within agroclimatic zones

Variation parameters	ACZ-1	ACZ-2	ACZ-3	ACZ-4	ACZ-5	ACZ-6	ACZ-7	ACZ-8	ACZ-9	ACZ-10
Forest land										
CV %	4.01	4.22	3.94	3.9	4.12	3.82	4.04	3.74	3.85	4.68
SED	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
CD (5%)	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
PCV	27.65	33.23	24.02	19.82	40.05	15.87	18.89	13.62	18.91	46.54
GCV	27.38	32.93	23.70	19.45	39.87	15.41	18.43	13.09	18.52	46.37
Agriculture										
CV %	4	4.31	4.1	4.13	4.06	4.13	4.41	3.85	3.75	3.96
SED	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
CD (5%)	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
PCV	15.16	22.13	29.76	29.17	28.49	27.37	27.48	12.33	11.79	27.56
GCV	14.64	21.70	29.47	28.87	28.21	27.08	27.08	11.69	11.18	27.30

Table 6.6 : Variation in Germination value of plus trees of *M latifolia* within agroclimatic zones

Variation parameters	ACZ-1	ACZ-2	ACZ-3	ACZ-4	ACZ-5	ACZ-6	ACZ-7	ACZ-8	ACZ-9	ACZ-10
Forest land										
CV %	5.74	6.03	5.59	5.57	5.76	5.44	5.78	5.31	5.45	6.99
SED	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
CD (5%)	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
PCV	38.97	50.82	40.82	34.18	56.49	25.67	34.35	14.53	27.62	88.29
GCV	38.53	50.49	40.47	33.73	56.23	25.07	33.86	13.52	27.07	87.97
Agriculture										
CV %	5.67	6.1	5.85	5.89	5.74	5.81	6.54	5.44	5.33	5.78
SED	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
CD (5%)	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
PCV	24.76	41.09	49.30	45.31	48.01	46.18	47.90	22.53	13.79	51.51
GCV	24.10	40.68	48.90	44.96	47.62	45.83	47.50	21.85	12.72	51.19

Table 6.7 : Variation in Seedling length of plus trees of *M. latifolia* within agroclimatic zones

Variation parameters	ACZ-1	ACZ-2	ACZ-3	ACZ-4	ACZ-5	ACZ-6	ACZ-7	ACZ-8	ACZ-9	ACZ-10
Forest land										
CV %	12.8	12.39	12.72	12.79	12.65	12.76	12.81	13.13	13.34	12.7
SED	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
CD (5%)	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
PCV	25.86	22.68	14.18	14.98	25.61	15.23	14.75	20.44	21.04	21.00
GCV	22.47	19.00	6.25	7.81	22.27	8.31	7.31	15.66	16.26	16.72
Agriculture										
CV %	12.4	12.43	12.63	12.78	12.94	12.94	13.23	12.95	12.82	12.55
SED	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
CD (5%)	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
PCV	17.16	19.82	14.97	15.72	28.10	20.27	17.21	17.80	36.52	19.44
GCV	11.86	15.44	8.05	9.16	24.94	15.61	11.01	12.21	34.19	14.85

Table 6.8 : Variation in Collar diameter of plus trees of *M. latifolia* within agroclimatic zones

Variation parameters	ACZ-1	ACZ-2	ACZ-3	ACZ-4	ACZ-5	ACZ-6	ACZ-7	ACZ-8	ACZ-9	ACZ-10
Forest land										
CV %	4.40	3.63	4.42	4.51	3.53	3.97	3.97	4.17	4.75	3.56
SED	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CD (5%)	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
PCV	14.65	19.52	12.50	14.41	20.31	9.03	9.03	12.17	17.55	13.91
GCV	13.89	19.22	11.65	13.62	20.08	7.94	8.04	11.52	17.01	13.40
Agriculture										
CV %	4.14	3.46	4.15	4.48	3.63	4.29	4.03	4.64	4.57	3.61
SED	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CD (5%)	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
PCV	17.17	18.00	11.82	9.08	19.24	13.20	14.10	21.84	14.78	12.82
GCV	16.58	17.56	10.99	7.76	18.85	12.49	13.61	21.32	14.09	12.17

Table 6.9 : Variation in Fresh seedling biomass of plus trees of *M. latifolia* within agroclimatic zones

Variation parameters	ACZ-1	ACZ-2	ACZ-3	ACZ-4	ACZ-5	ACZ-6	ACZ-7	ACZ-8	ACZ-9	ACZ-10
Forest land										
CV %	9.89	9.77	9.96	9.89	9.83	9.97	9.98	10.03	10.12	9.84
SED	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
CD (5%)	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43
PCV	14.50	14.50	11.01	10.85	17.18	12.31	10.78	11.49	12.06	13.34
GCV	10.60	10.72	4.69	4.43	14.10	7.22	4.03	5.61	6.56	9.00
Agriculture										
CV %	9.65	9.82	9.95	9.93	10.02	10.02	10.16	9.99	9.9	9.77
SED	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
CD (5%)	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43
PCV	12.85	14.73	11.98	11.79	18.35	12.22	13.22	11.52	24.86	15.80
GCV	8.49	10.97	6.68	6.36	15.37	7.00	8.48	5.76	22.81	12.43

Table 6.10 : Variation in Oven dry seedling biomass of plus trees of *M. latifolia* within agroclimatic zones

Variation parameters	ACZ-1	ACZ-2	ACZ-3	ACZ-4	ACZ-5	ACZ-6	ACZ-7	ACZ-8	ACZ-9	ACZ-10
Forest land										
CV %	7.63	7.53	7.72	7.64	7.59	7.74	7.7	7.72	7.75	7.58
SED	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
CD (5%)	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
PCV	13.60	10.92	9.44	12.71	17.39	12.02	10.56	9.10	10.68	11.37
GCV	11.27	7.91	5.45	10.17	15.67	9.24	7.24	4.79	7.34	8.46
Agriculture										
CV %	7.49	7.62	7.7	7.66	7.76	7.71	7.82	7.67	7.63	7.56
SED	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
CD (5%)	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
PCV	10.51	11.62	11.19	12.88	16.92	10.51	13.20	10.22	24.02	16.05
GCV	7.38	8.80	8.13	10.37	15.05	7.16	10.61	6.76	22.78	14.18

Table 6.11 : Variation in moisture content (%) of plus trees of *M. latifolia* within agroclimatic zones

Variation parameters	ACZ-1	ACZ-2	ACZ-3	ACZ-4	ACZ-5	ACZ-6	ACZ-7	ACZ-8	ACZ-9	ACZ-10
Forest land										
CV %	4.22	4.20	4.16	4.15	4.19	4.15	4.21	4.27	4.36	4.20
SED	2.06	1.97	2.04	1.98	2.02	2.04	2.09	2.17	2.28	2.01
CD (5%)	4.34	4.15	4.28	4.17	4.24	4.28	4.39	4.55	4.78	4.22
PCV	6.63	9.32	5.60	11.96	6.56	6.62	6.50	7.54	7.06	10.13
GCV	5.11	8.32	3.76	11.21	5.05	5.16	4.96	6.21	5.55	9.22
Agriculture										
CV %	4.05	4.12	4.17	4.20	4.26	4.27	4.31	4.3	4.35	4.14
SED	1.80	1.95	2.04	2.05	2.22	2.16	2.26	2.16	2.29	1.93
CD (5%)	3.78	4.09	4.29	4.30	4.67	4.54	4.76	4.55	4.81	4.06
PCV	6.03	7.41	8.24	10.71	7.78	6.52	8.33	5.96	7.47	5.55
GCV	4.46	6.16	7.11	9.85	6.52	4.92	7.13	4.12	6.08	3.69

Table 6.12 : Variation in Seedling shoot vigour index of plus trees of *M. latifolia* within agroclimatic zones

Variation parameters	ACZ-1	ACZ-2	ACZ-3	ACZ-4	ACZ-5	ACZ-6	ACZ-7	ACZ-8	ACZ-9	ACZ-10
Forest land										
CV %	3.80	3.57	3.71	3.77	3.68	3.66	3.85	3.94	4.24	4.61
SED	48.45	49.10	50.64	50.19	49.89	52.28	48.43	52.58	49.62	39.39
CD (5%)	101.79	103.16	106.40	105.45	104.83	109.85	101.75	110.47	104.25	82.77
PCV	36.00	39.74	21.72	20.39	50.57	15.86	19.15	20.03	19.74	40.70
GCV	35.80	39.58	21.40	20.03	50.44	15.43	18.75	19.63	19.28	40.44
Agriculture										
CV %	3.37	3.52	3.78	3.93	3.89	3.98	4.65	3.86	3.68	3.77
SED	53.21	50.08	48.43	47.27	48.61	48.24	39.83	51.73	54.03	47.75
CD (5%)	111.79	105.22	101.75	99.31	102.13	101.36	83.68	108.68	113.53	100.33
PCV	12.06	29.81	27.31	23.14	41.82	30.18	22.16	13.45	33.17	21.37
GCV	11.58	29.60	27.05	22.81	41.64	29.91	21.67	12.88	32.96	21.03

Table 6.13: Variation in the seedling characters of Plus trees of *M. latifolia* from forest land across different agroclimatic zones

Variation parameters	germination percentage	Mean daily germination	Peak value	Germination Value	Seedling length (cm)	Collar diameter (cm)	Fresh seedling biomass(g)	Oven dry seedling Biomass(g)	moisture content (%)	Shoot vigour Index
CV %	6.76	3.98	4.00	5.67	12.79	4.04	9.72	7.65	4.23	4.00
SED	2.12	0.04	0.04	0.08	0.41	0.01	0.20	0.04	2.10	50.73
CD (5%)	4.44	0.09	0.09	0.17	0.86	0.02	0.43	0.09	4.40	106.58
PCV	15.89	14.83	15.44	23.85	16.07	16.46	10.73	9.35	4.89	12.71
GCV	14.38	14.31	14.89	23.15	9.74	15.75	4.50	5.40	2.46	12.06

Table 6.14: Variation in the seedling characters of Plus trees of *M. latifolia* from Agricultural land across different agroclimatic zones

Variation parameters	germination percentage	Mean daily germination	Peak value	Germination Value	Seedling length (cm)	Collar diameter (cm)	Fresh seedling biomass(g)	Oven dry seedling Biomass(g)	moisture content (%)	Shoot vigour Index
CV %	6.77	4.00	4.05	5.75	12.74	4.04	9.71	7.66	4.20	.77
SED	2.17	0.04	0.04	0.08	0.41	0.01	0.20	0.04	2.07	48.56
CD (5%)	4.53	0.09	0.09	0.17	0.86	0.02	0.43	0.09	4.34	102.03
PCV	12.78	11.37	13.32	21.33	16.51	15.81	11.74	10.08	4.65	12.78
GCV	10.84	10.70	12.72	20.74	10.44	15.43	6.58	6.49	2.00	14.93

Table 6.15 : Correlation among seed morphological traits and seedling traits of Agricultural lands

	Fruit length	Fruit width	Fruit thickness	Seed length	Seed width	Seed thickness	Hilum length	Kernel length	Kernel width	Kernel thickness	100 Fresh fruit weight	100 Fresh seed weight	100 kernel Fresh weight	100 kernel ovendry weight
Germination percentage	-0.081^{NS}	-0.438^{NS}	-0.271^{NS}	0.083^{NS}	0.009^{NS}	0.195^{NS}	0.064^{NS}	-0.224^{NS}	0.590^{NS}	-0.728*	-0.635*	0.174^{NS}	0.159^{NS}	0.482^{NS}
Mean daily germination	-0.035^{NS}	-0.457^{NS}	-0.286^{NS}	0.133^{NS}	0.029^{NS}	0.178^{NS}	0.108^{NS}	-0.255^{NS}	0.622^{NS}	-0.749*	-0.676*	0.185^{NS}	0.171^{NS}	0.475^{NS}
Peak value	0.222^{NS}	-0.338^{NS}	-0.182^{NS}	0.318^{NS}	0.028^{NS}	0.333^{NS}	0.282^{NS}	-0.193^{NS}	0.540^{NS}	-0.552^{NS}	-0.377^{NS}	0.416^{NS}	0.477^{NS}	0.492^{NS}
Germination Value	0.130^{NS}	-0.389^{NS}	-0.225^{NS}	0.263^{NS}	-0.004^{NS}	0.259^{NS}	0.230^{NS}	-0.239^{NS}	0.590^{NS}	-0.656*	-0.531^{NS}	0.336^{NS}	0.374^{NS}	0.504^{NS}
Seedling length (cm)	0.288^{NS}	-0.079^{NS}	0.133^{NS}	-0.007^{NS}	0.735*	0.495^{NS}	-0.066^{NS}	0.091^{NS}	0.452^{NS}	-0.180^{NS}	0.192^{NS}	0.040^{NS}	-0.044^{NS}	0.279^{NS}
Collar diameter (cm)	0.315^{NS}	-0.167^{NS}	-0.160^{NS}	0.010^{NS}	0.356^{NS}	-0.104^{NS}	-0.057^{NS}	-0.108^{NS}	-0.035^{NS}	0.106^{NS}	0.344^{NS}	-0.352^{NS}	-0.322^{NS}	-0.144^{NS}
Fresh seedling biomass(g)	0.218^{NS}	-0.263^{NS}	-0.079^{NS}	0.112^{NS}	0.728*	0.589^{NS}	0.089^{NS}	0.115^{NS}	0.353^{NS}	-0.163^{NS}	0.080^{NS}	0.162^{NS}	0.054^{NS}	0.252^{NS}
Oven dry seedling Biomass(g)	0.126^{NS}	-0.328^{NS}	-0.149^{NS}	0.067^{NS}	0.587^{NS}	0.519^{NS}	0.039^{NS}	0.136^{NS}	0.340^{NS}	-0.207^{NS}	0.049^{NS}	0.150^{NS}	0.048^{NS}	0.250^{NS}
Moisture content (%)	0.427^{NS}	0.319^{NS}	0.332^{NS}	0.208^{NS}	0.588^{NS}	0.289^{NS}	0.222^{NS}	-0.090^{NS}	0.049^{NS}	0.211^{NS}	0.179^{NS}	0.067^{NS}	0.061^{NS}	-0.006^{NS}

Plate 6.1 : Progeny testing of seeds collected from sample trees of different agroclimatic zones of Odisha

CHAPTER-7

EFFECT OF SEED STORAGE ON OIL QUALITY AND OTHER PHYSICOCHEMICAL PROPERTIES OF OIL IN *Madhuca latifolia*

7.1 Introduction

Madhuca latifolia (Mahua tree) is considered a boon by the tribes who are forest dwellers and keenly conserve this tree. The tribes consider the mahua tree and the mahua drink as part of their cultural heritage. The seeds and flower are very important source of income and livelihoods for the people. The seeds are reported to contain apogenins, triterpenoids, steroids, saponins, flavonoids and glycosides. Drying and decertification yield kernels (70% by wt) and recovery of kernel are a village level activity and lack of proper facilities for drying and preservation affects quality. It is reported that the Kernel contains 20-50 percent oil depending on expelled by *ghani* or expeller. The expelled cake is solvent extracted to recover residual oil. The quality of expelled oils may largely depend on storage conditions and duration, exposure to light and other environmental conditions. The chemical composition of the oil extract consequently gives a qualitative identification of oils and is a very important area in the selective application guide for the commercialization and utility of oil products. Fats and oils are also very important indigenous raw materials for many edibles and non-edible purposes. In view of the fact that there is a growing demand for petroleum products and impact of environment pollution, simultaneously there is consequent decline in crude oil reserves, and therefore, an urgent need to develop and study alternate source of energy.

In order to have optimum utilization of oil seeds many a time the harvested seeds need to be stored under best suited conditions. Storage conditions, duration and exposure may influence the quality of oil content and its other physic-chemical properties (Martini and Anon, 2005). Seed storage is essential to maintain not only the harvesting quality of its products but also to improve it (Sisman and Delibas, 2004). The oil composition of the stored seeds could be influenced greatly by the storage conditions. The fatty acid contents of the oil seeds are mostly susceptible to oxidation (Morello et al. 2004). During storage, the extent of chemical reaction that take place in the seed would be influenced by the type of fatty acid and particularly the number of double bonds, present in the oil. There is a very limited study on how the storage container and duration of storage affect the oil content and quality of this important seed trees and therefore this chapter is devoted to understand the best storage container, duration and environment for oil stability and quality.

7.2 Materials and Methods

The present investigation on the effect of different storage conditions and durations on seed oil content and its physico-chemical properties was conducted during the 2017-18 in laboratory located at the college of Forestry, OUAT, Bhubaneswar. The ripened fruits were collected from the sample tree STSGF 7 from Sundergarh district under AEZ-1 of Odisha in the month of June 2017. The fruits were de-pulped and the seeds were cleaned and dried in sun for 2 days. After that seeds were collected and oven dried for 48 hours at 55-60^{0}C. Then oven dried seeds (100g) were then stored in different storage containers like polythene bags , cotton bags and plastic containers under different storage conditions (Closed light, Open light, Closed dark, Open dark) for 30, 60, 90, 120 and 180 days. The stored seeds were taken out from storage containers under different agroclimatic zone after each storage duration and the kernels were separated out from the seeds. 50 gm of kernels from each treatment were taken and cut into small pieces with the help of knife and then grinded and reduced to suitable fine meal in priestle mortar. The ground sample were then placed in the thimble in the extraction chamber of Soxhlet apparatus. The experiment was laid out on a factorial completely randomized design involving a total of 84 treatments as 3 storage containers (polythene bags, cotton bags, plastic container), 4storage conditions (under dark and light and again under open and closed condition), 7 storage duration (0, 30, 60, 90, 120, 150, 180 days) with each three replicates totalling 252samples for the purpose. The details of the treatment used are as follows:

Treatment Combinations	Storage Material (A)	Storage Conditions (B)	Storage Durations (Days) (C)
1.	Polythene bag	Closed light	0
2.	Polythene bag	Closed light	30
3.	Polythene bag	Closed light	60
4.	Polythene bag	Closed light	90
5.	Polythene bag	Closed light	120
6.	Polythene bag	Closed light	150
7.	Polythene bag	Closed light	180
8.	Polythene bag	Closed dark	0
9.	Polythene bag	Closed dark	30
10.	Polythene bag	Closed dark	60
11.	Polythene bag	Closed dark	90
12.	Polythene bag	Closed dark	120
13.	Polythene bag	Closed dark	150
14.	Polythene bag	Closed dark	180
15.	Polythene bag	Open light	0
16.	Polythene bag	Open light	30
17.	Polythene bag	Open light	60
18.	Polythene bag	Open light	90
19.	Polythene bag	Open light	120
20.	Polythene bag	Open light	150
21.	Polythene bag	Open light	180
22.	Polythene bag	Open dark	0
23.	Polythene bag	Open dark	30
24.	Polythene bag	Open dark	60
25.	Polythene bag	Open dark	90
26.	Polythene bag	Open dark	120
27.	Polythene bag	Open dark	150
28.	Polythene bag	Open dark	180
29.	Cotton bag	Closed light	0
30.	Cotton bag	Closed light	30
31.	Cotton bag	Closed light	60
32.	Cotton bag	Closed light	90
33.	Cotton bag	Closed light	120
34.	Cotton bag	Closed light	150
35.	Cotton bag	Closed light	180
36.	Cotton bag	Closed dark	0

37.	Cotton bag	Closed dark	30
38.	Cotton bag	Closed dark	60
39.	Cotton bag	Closed dark	90
40.	Cotton bag	Closed dark	120
41.	Cotton bag	Closed dark	150
42.	Cotton bag	Closed dark	180
43.	Cotton bag	Open light	0
44.	Cotton bag	Open light	30
45.	Cotton bag	Open light	60
46.	Cotton bag	Open light	90
47.	Cotton bag	Open light	120
48.	Cotton bag	Open light	150
49.	Cotton bag	Open light	180
50.	Cotton bag	Open dark	0
51.	Cotton bag	Open dark	30
52.	Cotton bag	Open dark	60
53.	Cotton bag	Open dark	90
54.	Cotton bag	Open dark	120
55.	Cotton bag	Open dark	150
56.	Cotton bag	Open dark	180
57.	Plastic Container	Closed light	0
58.	Plastic Container	Closed light	30
59.	Plastic Container	Closed light	60
60.	Plastic Container	Closed light	90
61.	Plastic Container	Closed light	120
62.	Plastic Container	Closed light	150
63.	Plastic Container	Closed light	180
64.	Plastic Container	Closed dark	0
65.	Plastic Container	Closed dark	30
66.	Plastic Container	Closed dark	60
67.	Plastic Container	Closed dark	90
68.	Plastic Container	Closed dark	120
69.	Plastic Container	Closed dark	150
70.	Plastic Container	Closed dark	180
71.	Plastic Container	Open light	0
72.	Plastic Container	Open light	30
73.	Plastic Container	Open light	60
74.	Plastic Container	Open light	90
75.	Plastic Container	Open light	120
76.	Plastic Container	Open light	150
77.	Plastic Container	Open light	180
78.	Plastic Container	Open dark	0

79.	Plastic Container	Open dark	30
80.	Plastic Container	Open dark	60
81.	Plastic Container	Open dark	90
82.	Plastic Container	Open dark	120
83.	Plastic Container	Open dark	150
84.	Plastic Container	Open dark	180

The effect of different treatment on oil content (%), density, specific gravity and other physicochemical properties such as, Acid value, Saponification value, Ester value, Carbonyl value etc. were estimated.

Oil extraction and physicochemical properties of the stored seeds:

The seed kernels were ground, using a mechanical grinder, and defatted in a soxhlet apparatus, using hexane (boiling point of 40–60 ◦C). The extracted lipid was obtained by filtrating the solvent lipid contained to get rid of the solid from solvent before the hexane was removed using rotary evaporator apparatus at 40 ◦C. Extracted seed oil was stored in freezer at−2 ◦C for subsequent physicochemical analysis.

7.2.1.5.1 Oil Content (%)

Kernels from sample seeds collected from each sample tree of different agroclimatic zone and were dried at 55^{o}C in hot air oven for 48 hrs. 50 g of dried kernels were taken and grinded and reduced to suitable fine meal in pestle mortar. The ground sample were then placed in the thimble in the extraction chamber of Soxhlet apparatus .The extraction chamber was fixed over a round bottom flask containing Petroleum ether (60^{0}C-80^{0}C) as extraction solvent. Then a condenser was fitted over the extraction chamber of Soxhlet apparatus. The Soxhlet apparatus was kept over the heating element and allowed to heat at 70^{0}C. When the temperature reached boiling point of Petroleum ether it started boiling which was evaporated and then condensed and fall in to the thimble containing the ground kernel. The oil was extracted by hot Petroleum ether falling on the kernel in the thimble. When the extracted oil and Petroleum ether mixture reached the maximum in the extraction chamber it siphoned out and went back to the round bottom flask. The extraction was carried out for 15 times or till the solvent in the extraction chamber became clear containing no oil. The round bottom flask containing the mixture Petroleum ether and oil was removed and distilled till no petroleum ether left over in the flask containing the oil. The flask was kept till it cooled down and the weight of the flask containing the oil was recorded. The oil content (%) was calculated as:

$$\text{Percentage of Oil Content} = \frac{W_2 - W_1}{50} \times 100$$

Where, W_1- Weight of the empty flask in gram (g), W_2- Weight of flask with oil in gram (g), W_3- Weight of kernel in gram (g).

7.2.1.5.2 Oil yield (g)

Oil yield from kernels was calculated on basis of oven dry weight of kernels and oil content (%) .

Oil yield (g) = Oil content (%) x Oven dry kernel weight (g)

7.2.1.5.3 Density

Density is a physical property of matter and can be defined as the ratio of mass to a unit volume of matter. It is expressed by the formula:

$$\rho = M/V$$

Where,

ρ is the density,

M is the mass,

V is the volume

It is expressed by 1,000 kg/m^3 = 1,000 g/l = 1 g/cm^3

7.2.1.5.4 Specific gravity

Specific gravity is the ratio between weights of a volume of oil to the weight of equal volume of water. Specific gravity is the *ratio* of density of oil with that of water at 4 °C.For determining the specific gravity, weight of the empty container was taken separately first. Then weight of the bottle with oil has taken together and also weight of the bottle with water taken together. The specific gravity was calculated by using the formula:

$$\text{Specific gravity} = \frac{(\text{Weight of the bottle with oil} - \text{Weight of the empty bottle})}{(\text{Weight of the bottle with water} - \text{Weight of the empty bottle})}$$

5.2.1.5.5 Acid value

The acid value was determined by directly titrating the oil in an alcoholic medium with aqueous KOH solution. About 3gm of oil was taken in a flask to which 30ml of a mixture of equal volumes of alcohol and ether was added. Then 1mL of phenolphthalein indicator was added to the above flask and titrated with 0.1 N potassium hydroxide until the solution remained faintly pink after shaking for 30sec (AOAC Method). Acid value was calculated with the following formula:

Acid value = (M × V) × (N/W)

Where, M= Molecule weight of Potassium hydroxide (56.11)

V= Volume (ml),N = Normality of the Potassium hydroxide solution, W= Weight of the Oil sample taken (g)

7.2.1.5.6 Free Fatty Acid (FFA %)

Free Fatty Acids (FFA) are the result of the breakdown of oil or biodiesel. FFA% is usually used to describe the FFA content of oils. Free fatty acids is frequently expressed as the percentage of free acids present in the sample. The percentage of free fatty acids in most of the oils and fats is calculated on the basis of oleic acid (AOAC Method) . It was calculated as:

Free Fatty Acid (FFA %) = 0.5 x Acid value of Oil

7.2.1.5.7 Saponification value

The saponification value is the number of mg of Potassium hydroxide required to neutralize the free acids and saponify the esters contained in 1.0 g of the oil.1.5-2 g of the oil was placed in a tared 250 mL flask and weighed accurately. 25.0mL of 0.5N alcoholic Potassium hydroxide was added to it and the flask was refluxed for 90 min such that the contents were frequently rotated. Then 1mL of phenolphthalein indicator was added and titrated the excess Potassium hydroxide with 0.5 N Hydrochloric acid . A blank determination under the same condition was also performed (AOAC Method) . The titration also can be carried out and the saponification value was calculated by:

$$\textbf{Saponification value} = \frac{[M_r \times (V_b - V_T) \times N]}{W}$$

Where,

M_r = Molecule weight of potassium hydroxide, 56.11

V_b = Volume of 0.5 N hydrochloric acid consumed in the blank test (mL)

V_T = Volume of 0.5 N hydrochloric acid consumed in the actual test (mL)

N= Normality of the hydrochloric acid

W= Weight of the substance taken for the test (g)

7.2.1.5.8 Iodine Value

The iodine value is an identity characteristics nature of oil. The iodine value of an oil or fat is defined as the grams of iodine absorbed by 100g sample. The iodine value or iodine number e generally represents the degree of un-saturation or the number of carbon-carbon double bonds in fats or oils.About 1g of oil sample was weighed into a 500mL volumetric flask. 15mL of carbon tetrachloride was added to the sample and swirled to ensure that the sample is completely dissolved. 25mL of Wijs solution was then dispensed into the flask containing the sample using a pipette. The flask was stopper and swirled to ensure complete mixing. The sample was then placed in the dark for 30 minutes at room temperature. The flask was removed from storage to which 20ml of 10% Potassium iodide (KI) solution was added which was followed by 150mL of distilled water. Then the mixture was titrated with 0.1N thiosulphate ($Na_2 S_2 O_3$) solution by adding gradually and with constant shaking till the yellow colour had disappeared. After that, 1.5mL of starch indicator solution was added to it and the titration was continued until the blue colour disappeared (AOAC Method). A blank determination was conducted simultaneously.

The iodine value was calculated using the formula below:

Iodine value = 12.69 (V_2 - V_1) / W

Where, N = normality of thiosulphate solution,

V_1 = Volume of thiosulphate solution used in test,

V_2 = Volume of thiosulphate solution used in blank,

W = Weight of sample

7.2.1.6 Statistical Analysis

The data regarding the variation of oil content under different storage container, storage conditions and duration were subjected to statistical analysis under Factorial CRD as described by Snedecor and Cochran (1980) 2ndedition. The data were analysed in statistical package OPSTAT.

7.3 Results

7.3.1 Effect of different storage conditions and durations on the stored seed oil content and its physico-chemical properties

7.3.1.1 Oil Content (%)

The effects of storage conditions, storage durations and interactions on oil content percentage for stored seeds of *M. latifolia* were found significant (Table 7.1). In all the storage containers and storage conditions oil content of stored seed decreased with increase in storage period. The mean oil content (averaged over three storage containers and four storage conditions) decreased continuously from the time of seed storage (51.23%) to minimum (40.25%) after 180 days of storage (Table-7.1) .Among the storage containers the mean oil content (averaged over storage period for 180 days and four storage conditions) found maximum (47.34 %) in seeds stored in polythene bags (Table-7.1). Similarly, after 180 days of storage, seeds stored in polythene bags found to have mean oil content (averaged over four storage conditions) maximum (44.09%) than other containers (Table-7.1). Among the storage conditions, the mean oil content (averaged over storage period for 180 days and three storage containers) found maximum (47.81%) in seeds stored in closed light condition (Fig-7.1). Similarly, after 180 days of storage- , seeds stored in closed light condition found to have mean oil content (averaged over three storage containers) maximum (44.70%) than other storage conditions (Fig -7.1). In seeds stored in polythene bags, the mean value of oil content (averaged over storage period for 180 days for each storage condition) was found maximum in seed stored in closed polythene bag kept in light (49.60%), however, the minimum oil content (43.00 %) was recorded in seed stored in open polythene bag kept in dark. After 180 days of storage the maximum oil content was also observed in the closed polythene bags stored in light (48.01%) (Table-7.1). The mean value of oil content (averaged over four storage conditions) was found decreasing continuously from the time of storage of seeds (51.23%) till 180 days of storage (44.09%).

Similarly, in seeds stored in cotton bags, the mean value of oil content (averaged over storage period for 180 days for each storage condition) was found also maximum in seed stored in closed cotton bag kept in light (48.89%), however, the minimum oil content (46.17 %) was recorded in seed stored in open cotton bag kept in dark. After 180 days of storage the maximum oil content was observed in the closed cotton bags stored in light (46.93%). The mean value of oil content (averaged over four storage conditions) was found decreasing continuously from the time of storage of seeds (51.23%) till 180 days of storage (42.78%).However, in case of seeds stored in plastic containers, the mean value of oil content (averaged over storage period for 180 days for each storage condition) was found maximum in seed stored in closed plastic container kept in light (44.93%), however, the minimum oil content (39.42%) was recorded in seed stored in open plastic container kept in light. After 180 days of storage the maximum oil content was also observed in the closed plastic container stored in light (39.15%). The mean value of oil content (averaged over four storage conditions) was found decreasing continuously from the time of storage of seeds (51.23%) till 180 days of storage (33.89%). After 180 days of storage among all the treatments it was also found that the seeds stored in the closed polythene bags kept in light recorded the highest oil content (48.01%) with least degradation (6.28%) (Table-7.1).

7.3.1.2 Acid value

In all the storage containers and storage conditions acid value of oil extracted from stored seed increased with increase in storage period. The mean acid value (averaged over three storage containers and four storage conditions) increased continuously from the time of seed storage (6.45) to maximum (75.15) after 180 days of storage (Table-7.2).Among the storage containers the mean acid value (averaged over storage period for 180 days and four storage conditions) found minimum (24.30) in oil extracted from seeds stored in plastic container. Similarly, after 180 days of storage, seeds stored in plastic container found to have acid value (averaged over four storage conditions) minimum (56.93) than other containers.. Among the storage conditions, the mean acid value (averaged over storage period for 180 days and three storage containers) found minimum (25.96) in oil extracted from seeds stored in closed dark condition (Fig-7.2). Similarly, after 180 days of storage, seeds stored in closed dark condition found to have acid value (averaged over three storage containers) minimum (57.72) than other storage conditions. In seeds stored in polythene bags, the mean value of acid value (averaged over storage period for 180 days for each storage condition) was found minimum in oil extracted from seeds stored in closed polythene bag kept in light (28.81), however, the maximum acid value (51.94) was recorded in seed stored in open polythene bag kept in dark. After 180 days of storage the minimum acid value was also observed in the closed polythene bags stored in light (64.92). The mean value of acid value (averaged over four storage conditions) was found increasing continuously from the time of storage of seeds (6.45) till 180 days of storage (94.83) (Table-7.2). Similarly, in seeds stored in cotton bags, the mean value of acid value (averaged over storage period for 180 days for each storage condition) was found also minimum in oil extracted from seeds stored in open cotton bag kept in dark (25.37), however, the maximum acid value (37.52) was recorded in seed stored in closed cotton bag kept in light. After 180 days of storage the minimum acid value was observed in the open cotton bag kept in dark (57.66). The mean acid value (averaged over four storage conditions) was found increasing continuously from the time of storage of seeds (6.45) till 180 days of storage (73.70), However, in case of seeds stored in plastic containers , the mean value of acid value (averaged over storage period for 180 days for each storage condition) was found minimum in oil extracted from seeds stored in Closed plastic container kept in dark (19.38), however, the maximum acid value (33.10) was recorded in seed stored in Closed plastic container kept in light. After 180 days of storage the minimum acid value was also observed in the Closed plastic container kept in dark (40.17).. The mean value of acid value (averaged over four storage conditions) was found increasing continuously from the time of storage of seeds (6.45) till 180 days of storage (56.93).After 180 days of storage, among all the treatments it was also found that the seeds stored in the closed plastic container kept in dark recoded the lowest acid value (40.17).

7.3.1.3 Saponification Value

In all the storage containers and storage conditions saponification value of oil extracted from stored seeds decreased with increase in storage period. The mean saponification value (averaged over three storage containers and four storage conditions) decreased continuously from the time of seed storage (162.90) to minimum (68.17) after 180 days of storage (Table-7.3). Among the storage containers the mean saponification value (averaged over storage period for 180 days and four storage conditions) found maximum (117.81) in oil extracted from seeds stored in polythene bags (Table-94). Similarly, after 180 days of storage, seeds stored in polythene bags found to have saponification value (averaged over four storage conditions) maximum (79.39) than other containers (Table-7.3). Among the storage conditions the mean saponification value (averaged over storage period for 180 days and three storage containers) found maximum (118.33) in oil extracted from seeds stored in closed dark condition (Fig-7.3). Similarly, after 180 days of storage, seeds stored in closed dark condition found to have saponification value (averaged over three storage containers) maximum (76.28) than other storage conditions (Fig -82). In seeds stored in polythene bags, the mean value of saponification value (averaged over storage period for 180 days for each storage condition) was found maximum in oil extracted from seeds stored in closed polythene bag kept in dark (126.86), however, the minimum saponification value (110.92) was recorded in seed stored in closed polythene bag kept in light. After 180 days of storage the maximum saponification value was also observed in the closed polythene bags stored in dark (89.83). The mean value of saponification value (averaged over four storage conditions) was found decreasing continuously from the time of storage of seeds (162.90) till 180 days of storage (79.39). In case of seeds stored in cotton bags, the mean value of saponification value (averaged over storage period for 180 days for each storage condition) was found maximum in oil extracted from seeds stored in closed cotton bag kept in light (115.81), however, the minimum saponification value (98.48) was recorded in seed stored in open cotton bag kept in dark. After 180 days of storage the maximum saponification value was observed in the closed cotton bags stored in light (69.44).. The mean value of saponification value (averaged over four storage conditions) was found decreasing continuously from the time of storage of seeds (162.90) till 180 days of storage (58.04).

However, in case of seeds stored in plastic containers, the mean value of saponification value (averaged over storage period for 180 days for each storage condition) was found maximum in oil extracted from seeds stored in closed plastic container kept in dark (118.46), however, the minimum saponification value (107.22) was recorded in seed stored in open plastic container kept in dark. After 180 days of storage the maximum saponification value was also observed in the closed plastic container stored in dark (81.49) (Table-7.3). The mean value of saponification value (averaged over four storage conditions) was found decreasing continuously from the time of storage of seeds (162.90) till 180 days of storage (67.09) (Table-7.3).After 180 days of storage , among all the treatments it was also found that the seeds stored in the closed polythene bags kept in dark recorded the highest saponification value (89.83).

7.3.1.4 Free Fatty Acid (%)

In all the storage containers and storage conditions FFA of oil extracted from stored seed increased with increase in storage period. The mean FFA(averaged over three storage containers and four storage conditions) increased continuously from the time of seed storage (3.24) to maximum (37.77) after 180 days of storage (Table-7.4). Among the storage containers the mean FFA (averaged over storage period for 180 days and four storage conditions) found minimum (12.21) in oil extracted from seeds stored in plastic container. Similarly, after 180 days of storage, seeds stored in plastic container found to have FFA (averaged over four storage conditions) minimum (28.61) than other containers (Table-7.4). Among the storage conditions, the mean FFA (averaged over storage period for 180 days and three storage containers) found minimum (13.05) in oil extracted from seeds stored in closed dark condition (Fig-7.4). Similarly, after 180 days of storage, seeds stored in closed dark condition found to have FFA (averaged over three storage containers) minimum (29.01) than other storage conditions (Fig -7.4). In seeds stored in polythene bags, the mean value of FFA (averaged over storage period for 180 days for each storage condition) was found minimum in oil extracted from seeds stored in closed polythene bag kept in light (14.48), however, the maximum FFA(26.10) was recorded in seed stored in open polythene bag kept in dark. After 180 days of storage the minimum FFA was also observed in the closed polythene bags stored in light (32.62) (Table-7.4). The mean value of FFA(averaged over four storage conditions) was found increasing continuously from the time of storage of seeds (3.24) till 180 days of storage (47.65). Similarly, in seeds stored in cotton bags, the mean value of FFA (averaged over storage period for 180 days for each storage condition) was found also minimum in oil extracted from seeds stored in open cotton bag kept in dark (12.75), however, the maximum FFA (18.85) was recorded in seed stored in closed cotton bag kept in light. After 180 days of storage the minimum FFA was observed in the open cotton bag kept in dark (28.97). The mean FFA (averaged over four storage conditions) was found increasing continuously from the time of storage of seeds (3.24) till 180 days of storage (37.04).However, in case of seeds stored in plastic containers , the mean value of FFA (averaged over storage period for 180 days for each storage condition) was found minimum in oil extracted from seeds stored in Closed plastic container kept in dark (9.74), however, the maximum FFA (16.63) was recorded in seed stored in Closed plastic container kept in light. After 180 days of storage the minimum FFA was also observed in the Closed plastic container kept in dark (20.19). The mean value of FFA (averaged over four storage conditions) was found increasing continuously from the time of storage of seeds (3.24) till 180 days of storage (28.61). After 180 days of storage , among all the treatments it was also found that the seeds stored in the Closed plastic container kept in dark recoded the lowest FFA (20.19) .

7.3.1.5 Iodine value

In all the storage containers and storage conditions iodine value of oil extracted from stored seed decreased with increase in storage period. The mean iodine value (averaged over three storage containers and four storage conditions) decreased continuously from the time of seed storage (62.70) to minimum (39.83) after 180 days of storage (Table-7.5).Among the storage containers the mean iodine value (averaged over storage period for 180 days and four storage conditions) found maximum (52.10)in oil extracted from seeds stored in polythene bags. Similarly, after 180 days of storage, seeds stored in polythene bags found to have iodine value (averaged over four storage conditions) maximum (41.83) than other containers (Table-98). Among the storage conditions, the mean iodine value (averaged over storage period for 180 days and three storage containers) found maximum (52.34)) in oil extracted from seeds stored in closed dark condition (Fig-7.5). Similarly, after 180 days of storage, seeds stored in open light condition found to have iodine value (averaged over three storage containers) maximum (41.37) than other storage conditions. In seeds stored in polythene bags, the mean value of iodine value (averaged over storage period for 180 days for each storage condition) was found minimum in oil extracted from seeds stored in open polythene bag kept in dark (50.77), however, the maximum iodine value (53.88) was recorded in seed stored in closed polythene bag kept in dark. After 180 days of storage the maximum iodine value was also observed in the closed polythene bags stored in dark (43.60). The mean value of iodine value (averaged over four storage conditions) was found decreasing continuously from the time of storage of seeds (62.70) till 180 days of storage (41.83). Similarly, in seeds stored in cotton bags , the mean value of iodine value (averaged over storage period for 180 days for each storage condition) was found minimum in oil extracted from seeds stored in open cotton bag kept in dark (45.92), however, the maximum iodine value (52.09) was recorded in seed stored in closed cotton bag kept in light. After 180 days of storage the maximum iodine value was observed in the open cotton bag kept in light (41.20). The mean iodine value (averaged over four storage conditions) was found decreasing continuously from the time of storage of seeds (62.70) till 180 days of storage (36.95).However, in case of seeds stored in plastic containers, the mean value of iodine value (averaged over storage period for 180 days for each storage condition) was found minimum in oil extracted from seeds stored in open plastic container kept in dark (50.64), however, the maximum iodine value (53.52)was recorded in seed stored in closed plastic container kept in dark. After 180 days of storage the maximum iodine value was also observed in the Closed plastic container kept in dark (43.60).. The mean value of iodine value (averaged over four storage conditions) was found decreasing continuously from the time of storage of seeds (62.70) till 180 days of storage (40.70) (Table-7.5).After 180 days of storage, among all the treatments it was also found that the seeds stored in the closed polythene kept in dark as well as closed plastic container kept in dark recorded the highest iodine value (43.60).

7.3.1.6 Oil Density

In all the storage containers and storage conditions density of oil extracted from stored seed decreased with increase in storage period. The mean density (averaged over three storage containers and four storage conditions) increased from the time of seed storage (0.891) to maximum (0.894) after 180 days of storage (Table-7.6).Among the storage containers the mean density (averaged over storage period for 180 days and four storage conditions) found maximum (0.894)in oil extracted from seeds stored in polythene bags and plastic container. Similarly, after 180 days of storage, seeds stored in polythene bags found to have density (averaged over four storage conditions) maximum (0.898) than other containers (Table-99). Among the storage conditions, the mean density (averaged over storage period for 180 days and three storage containers) found maximum (0.894) in oil extracted from seeds stored in closed dark and open light condition (Fig-7.6). Similarly, after 180 days of storage, seeds stored in closed dark condition found to have density (averaged over three storage containers) maximum (0.899) than other storage conditions. After 180 days of storage, among all the treatments it was also found that the seeds stored in the closed polythene kept in dark as well as closed plastic container kept in dark recorded the highest density (0.901).

7.3.1.7 Specific Gravity

In all the storage containers and storage conditions specific gravity of oil extracted from stored seed decreased with increase in storage period. The mean specific gravity (averaged over three storage containers and four storage conditions) increased from the time of seed storage (0.898) to maximum (0.904) after 180 days of storage (Table-7.7).Among the storage containers the mean specific gravity (averaged over storage period for 180 days and four storage conditions) found maximum (0.901)in oil extracted from seeds stored in polythene bags and plastic container (Table-7.7) .Similarly, after 180 days of storage, seeds stored in polythene bags found to have specific gravity (averaged over four storage conditions) maximum (0.905) than other containers. Among the storage conditions the mean specific gravity (averaged over storage period for 180 days and three storage containers) found maximum (0.901) in oil extracted from seeds stored in closed dark and open light condition (Fig-7.7). Similarly, after 180 days of storage, seeds stored in closed dark condition found to have specific gravity (averaged over three storage containers) maximum (0.906) than other storage conditions (Fig -7.7). After 180 days of storage, among all the treatments it was also found that the seeds stored in the closed polythene kept in dark as well as closed plastic container kept in dark recorded the highest specific gravity (0.908).

7.4 Discussion

7.4.1 Oil Content (%)

The oil content of the stored seeds decreased continuously with increase in storage time irrespective of storage container and storage conditions. The mean oil content (averaged for all storage containers and storage conditions) was maximum (51.23%) at the time of storage of seeds and decreased to minimum (40.25%) after 180 days of storage with maximum degradation (21.43%). The decrease in oil content is due to degradation of oil which may be due to the interaction effect of physical environment of storage conditions like air, light, temperature and humidity with more exposure to storage time favouring degradation in oil content. The oil degradation takes place by oxidative breakdown and hydrolysis of triglycerides. During oxidative breakdown the unsaturated triglycerides in presence of oxygen in stored air are converted to short chain fatty acids ,esters and volatile compounds like aldehydes, ketones and alcohols. During hydrolysis the triglycerides were converted to free fatty acids, diacyl glycerides and monoacyl glycerides due to lipase activity. In presence of even minimum moisture content these free fatty acids formed undergo further changes to acdetyl CoA and involved in beta oxidation and citric acid cycle which finally converted to various compounds like carbohydrate, protein, hormones etc. Some of these by-products of oxidative break down and hydrolysis of triglycerides might have been stored as non-oil portion of seed while other by products might have been volatilised resulting in lowering of oil content. The result observed in this study is in conformity with Sisman (2005) and Sisman et al. (2004) showed that during a period of three months storage of sunflower seeds, the percentage of seed oil gradually decreased with increasing storage time. Similar result was also reported by Ghasemezhadet al. (2007) showed with increase in storage time there is a corresponding rapid decrease of oil percent.

Maximum oil was extracted from seeds stored under closed light condition irrespective of container. In all the storage containers i.e polythene bag, cotton bag and plastic container maximum oil was also extracted from seeds stored under closed light condition. *M. Latifolia* seeds are very much prone to fungal decay even at lower moisture content. In case of seeds stored in closed light condition there is very limited air present and the rise in air temperature inside the containers due to diffused light of stored condition (laboratory condition) may be sufficient to resist the faster growth of fungus. Besides that these storage conditions (storage temperature, air content of the container and humidity), may not be favouring higher rate of degradation and conversion of certain triglycerides (by induced conversion due to storage factors and auto conversion) into other non-oil phytochemicals. Production of lipase by fungal species might be reason for the reduction in fat content of oilseeds. Decrease in oil content was positively related with increase in lipase activity on account of fungi infection by

Saraswat and Mathur (1985), Saxenaet al. (1998), Taung and Mcdonald (1995). Similarly other metabolic process of fungal organisms on the oilseeds might be responsible for the decrease in fat content and reducing sugars as suggested by Reddy and Rao (1975) and Inmax (1965). Embabyet al. (2006) reported that most reduction and loss percent was found with fat, carbohydrate in legume seeds by *Fusrium oxysporum*. Kakde and Chavan (2011) also reported the change in crude fat by various fungi in oil seeds. Canakei (2007) explained that oxidation of unsaturated fatty acid component in *Jatropha* easily occurs which could leads to degradation of oil.

Irrespective of storage conditions and storage durations, seeds stored in container like polythene bags gave maximum oil than other containers. This may be due to transparency and less thickness of polythene bags than plastic container and cotton bag which helps in comparatively more heating of air there by resisting the growth of fungus .Decrease in oil content even in closed dark condition indicates the auto degradation of triglycerides and conversion of one compound to another.For similar reasons, after 180 days of storage the maximum oil content (48.01%) was found in the seeds stored in closed polythene bags kept in light.

7.4.2 Acid Value and Free Fatty Acid (%)

The acid value and FFA % of the oil extracted from stored seeds found to be increased from the time of storage (6.45; 3.24) till 180 days of storage period (75.15; 37.77)irrespective of storage container and conditions. The acid value and FFA% depends upon free fatty acids present in the oil. The free fatty acids increased in the oil after the degradation of triglycerides into fatty acids. Similarly with increase in exposure time of stored seeds to air, temperature, humidity may be conducive for hydrolysis of triglycerides into fatty acids. Neg and Anderson (2005) showed that storage time and storage temperature had significant effect on free fatty acid content in the Quinoa (*Chenopedium quinoa*) seed oil. Villiers et al., (1986) indicated that high storage temperature and humidity had significant effect on sunflower seed oil quality as well as quality. The degradation also accounts to certain extent due to fungal effect and auto degradation of compounds. Besides that conversion of one fatty acid to another fatty acid also takes place which affects the acid value and FFA% of the oil. The increase in fatty acids with increase in storage period also confirmative with Reszeau and Cavalie (1995), Trawathaet al. (1995) and Balasevic-Tubicet al. (2005) which showed in oil seed crops like soybean and sunflower that the auto-oxidation of lipids and increased in free fatty acid content with increased in seed storage period. Adetola et al. (2016) and Cobzaru (2016)also found increase in fatty acids with storage period in case of African palm tree oil and olive oil. According to Ahmadkhan and Shahidi (2000) fatty acid composition and the proportion of different fatty acid of oil seed during storage are dependent on the degradation rate of different fatty acid which convert to each other. However, Martini and Anon (2005) reported that during storage of sunflower seed in different temperature the oil content did not influence. It seems temperature; moisture and the storage duration are the most important factors which influence on stored product quality and quantity (Anderson and Lingnert, 1998; Chen and Ahn, 1998).

Irrespective of storage conditions and storage durations, seeds stored in container like plastic containers gave minimum acid value and FFA% of oil than other containers. This may be due to translucent nature and more thickness of plastic containers than polythene bag and cotton bag which keeps comparatively lower atmosphere there by reducing the rate of degradation of triyglycerides into free fatty acids.

Similarly, irrespective of storage containers and storage durations, seeds stored in closed dark condition recorded low acid value and fatty acid % which may be due to lesser conversion of fatty acids due to less air content in the container, low temperature of dark condition and also to some extent of auto conversion of one fatty acids to another. However, different storage conditions of seeds showed low acid value and fatty acid % in different containers like closed light in polythene bags, open dark in cotton bag and closed dark in plastic container indicates extent of auto conversion of one fatty acid to another mainly responsible for lower value of acid value and free fatty acid % than light and stored air. By analysing the acid value and fatty acid % in different containers it was found that in case of plastic containers acid vale and free fatty acid % was lowest in closed dark condition where as in case of polythene bags , the closed dark condition was followed to closed light, in case of cotton bags closed dark followed to open dark . Thus, closed dark condition may be taken up in all the three storage containers for storage of seeds without much affecting acid value of the oil. After 180 days of storage, the best storage condition with least acid value (40.17) and FFA% (20.19%) was the seeds stored in closed dark plastic container which was due to the reasons explained earlier in the above paragraphs.

7.4.3 Saponification value and Iodine value

Saponification value is a measure of the average molecular weight or chain length of all the fatty acids present in the oil or fat. The saponification value of oil extracted from stored seeds decreased irrespectively of storage containers and storage durations from the day of packing (162.90) till 180 days of storage (68.17). The highest saponification value during initial storage indicates a high content of triglycerides in the oil (Tesfaye and Abebaw,2016) which gradually reduces after 180 days of storage. Besides that it also indicates that the triglycerides had higher number of short chain fatty acids during the initial time of storage and with increased in storage duration the less no. of triglycerides with long chain fatty acids were present in the oil. This is because of exposure of seed to the air , humidity and sunlight in different storage containers and conditions for a longer period there by favouring the degradation of short chain triglycerides present in the oil without affecting much the long chain fatty acids and also may be favouring the synthesis of some long chain triglycerides from short chain triglycerides. Cobzaru (2016) reported in olive oil and Saba et al. (2018) in Shea butter decrease in saponification value with increased storage duration. Similar type of work has been carried out in corn and mustard oil by Zahir et al. (2014) and in *Pongamia pinnata* seed oil by Alam (2002).

Irrespective of storage conditions and storage durations, seeds stored in container like polythene bags gave maximum saponification value of oil than other containers.

Similarly, irrespective of storage containers and storage durations, seeds stored in closed dark condition recoded higher saponification value of oil. The higher values of saponification value may be due to presence of more triglycerides and free fatty acids of short chain category. For similar reasons, after 180 days of storage the maximum saponification value of extracted oil (89.83) was found in the seeds stored in closed polythene bags kept in dark. Iodine value determines the amount of un-saturation in fatty acids and triglycerides. The higher the iodine number, the more C=C bonds of the fat. The Iodine value of oil extracted from the seeds at the time storage (62.70) is low which indicates the oil is medium level unsaturated oil with moderate number of C=C bonds The Iodine value of oil from the stored seeds decreased irrespective of storage containers and storage durations from the day of packing till 180 days of storage (39.83) . It indicates the increase in saturation of oil. It might be due to with increase in storage duration the triglycerides and fatty acids are more exposed to storage conditions favouring its degradation and conversion into saturated fatty acids. Bukola et al. (2015) also reported in decreased in iodine value of groundnut, palm and other edible oils with increased storage durations. Alhibshi (2016) in corn oil and Cobzaru (2016) in olive oil reported iodine value decreased with increased storage duration.

Similarly, seeds stored in container like polythene bags gave maximum Iodine value of oil than other containers. Similarly, irrespective of storage containers and storage durations, seeds stored in closed dark condition (Fig.7.5) recoded higher iodine value of oil. The higher values of iodine value may be due to presence of more unsaturated tryglycerides. For similar reasons, after 180 days of storage the maximum iodine value of extracted oil (43.60) was found in the seeds stored in closed polythene bags and plastic containers kept in dark.

7.4.4 Density and Specific gravity

Density and specific gravity of oil extracted from stored seeds increased irrespectively of storage containers and storage durations from the day of packing (0.891; 0.898) till 180 days of storage (0.897; 0.904) . As the amount of oil degradation increased with increase in storage time , oxidative breakdown and hydrolysis of triglycerides released various by products like short chain fatty acids, diacyl glycerides , monoacyl glycerides , esters and volatile compounds (aldehydes, ketones and alcohols) . The presence of these compounds in oil might be the reason for increased density and specific gravity of oil with increase in storage duration. Adetola et al. (2016) also found increased in density of oil with storage period in case of African plam oil tree *Elaei sguineensis*. Seeds stored in container like polythene bags gave maximum density and specific gravity of oil than other containers irrespective of storage conditions and storage durations. Similarly, irrespective of storage containers and storage durations, seeds stored in closed dark condition (Fig. 7.6 and 7.7) recoded higher density and specific gravity of oil. The higher values of density and specific gravity of oil might be due to presence of more phytochemicals after degradation of triglycerides. After 180 days of storage the maximum density and specific gravity of extracted oil (0.901; 0.908) was found in the seeds stored in closed polythene bags and plastic containers kept in dark because of the reason cited earlier in this paragraph.

Conclusions

The oil quality gradually decreased with respect to its oil content, saponification value and iodine value with increase in storage time. The oil content in the stored containers was in the order of Polythene bag>Cotton bag>Plastic container. The closed containers exposed to light had always better oil quality than those kept under dark and similarly, the containers which were kept open had poor oil quality compared to those that were closed while storage. On the contrary, the acid value, free fatty acid and specific gravity gradually increased with increase in storage time, irrespective of the storage containers.

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Table-7.1: Effect of storage condition and duration on oil content (%) of stored seed of *M.latifolia*

Storage Material	Storage Condition	Storage Duration							
		0 Days	30 Days	60 Days	90 Days	120 Days	150 Days	180 Days	Mean
Polythene Bag	Closed polythene bag kept in light	51.23	51.01	49.86	49.50	49.03	48.57	48.01	**49.60**
	Closed polythene bag kept in dark	51.23	50.56	48.66	48.05	47.23	46.67	45.52	**48.27**
	Open polythene bag kept in light	51.23	50.62	49.18	48.21	47.34	46.88	45.94	**48.48**
	Open polythene bag kept in dark	51.23	49.03	43.37	41.95	40.07	38.44	36.88	**43.00**
	Mean (A)	**51.23**	**50.30**	**47.77**	**46.93**	**45.92**	**45.14**	**44.09**	**47.34**
Cotton Bag	Closed cotton bag kept in light	51.23	50.73	49.59	48.72	47.72	47.31	46.93	**48.89**
	Closed cotton bag kept in dark	51.23	49.80	48.10	46.47	44.47	42.62	41.33	**46.29**
	Open cotton bag kept in light	51.23	49.95	48.26	46.67	44.72	42.98	41.57	**46.48**
	Open cotton bag kept in dark	51.23	49.74	47.95	46.36	44.21	42.42	41.28	**46.17**
	Mean (B)	**51.23**	**50.05**	**48.48**	**47.05**	**45.28**	**43.83**	**42.78**	**46.96**
Plastic Container	Closed plastic container kept in light	51.23	49.54	46.96	45.02	42.12	40.49	39.15	**44.93**
	Closed plastic container kept in dark	51.23	48.87	43.27	41.64	39.96	37.98	36.26	**42.74**
	Open plastic container kept in light	51.23	48.00	41.83	38.87	34.96	31.49	29.58	**39.42**
	Open plastic container kept in dark	51.23	48.51	44.91	41.43	37.01	33.54	30.56	**41.03**
	Mean (C)	**51.23**	**48.73**	**44.24**	**41.74**	**38.51**	**35.88**	**33.89**	**42.03**
Mean (A B C)		**51.23**	**49.69**	**46.83**	**45.24**	**43.24**	**41.62**	**40.25**	**45.44**
Factors		**CD(5%)**	**SE(d)**	**SE(m)**					
Storage material		0.091	0.046	0.033					
Storage condition		0.106	0.053	0.038					
Storage material x Storage condition		0.183	0.093	0.065					
Storage Duration		0.140	0.071	0.050					
Storage material x Storage Duration		0.242	0.122	0.087					
Storage condition x Storage Duration		0.279	0.141	0.100					
Storage Material x Storage condition x storage duration		0.484	0.245	0.173					

Table-7.2: Effect of storage condition and duration on Acid value of oil from stored seed of *M.latifolia*

Storage Material	Storage Condition	Storage Duration							
		0 Days	30 Days	60 Days	90 Days	120 Days	150 Days	180 Days	Mean
Polythene Bag	Closed polythene bag kept in light	6.45	9.03	12.90	22.57	35.47	50.31	64.92	**28.81**
	Closed polythene bag kept in dark	6.45	9.67	14.83	24.51	38.05	56.11	74.52	**32.02**
	Open polythene bag kept in light	6.45	10.96	18.06	26.44	44.50	70.30	96.60	**39.04**
	Open polythene bag kept in dark	6.45	11.61	18.70	34.18	55.47	93.90	143.29	**51.94**
	Mean (A)	**6.45**	**10.32**	**16.12**	**26.93**	**43.37**	**67.65**	**94.83**	**37.95**
Cotton Bag	Closed cotton bag kept in light	6.45	10.32	16.77	25.80	43.21	68.36	91.74	**37.52**
	Closed cotton bag kept in dark	6.45	7.74	10.96	19.99	33.54	48.37	58.46	**26.50**
	Open cotton bag kept in light	6.45	9.03	14.83	23.86	39.34	62.56	86.96	**34.72**
	Open cotton bag kept in dark	6.45	7.09	9.67	18.70	32.25	45.79	57.66	**25.37**
	Mean (B)	**6.45**	**8.55**	**13.06**	**22.09**	**37.08**	**56.27**	**73.70**	**31.03**
Plastic Container	Closed plastic container kept in light	6.45	8.38	13.54	21.93	38.05	59.98	83.39	**33.10**
	Closed plastic container kept in dark	6.45	7.09	9.03	14.83	25.15	32.89	40.17	**19.38**
	Open plastic container kept in light	6.45	7.74	10.32	17.41	30.31	40.63	54.29	**23.88**
	Open plastic container kept in dark	6.45	4.51	6.45	14.19	27.09	37.41	49.88	**20.85**
	Mean (C)	**6.45**	**6.93**	**9.84**	**17.09**	**30.15**	**42.73**	**56.93**	**24.30**
Mean (A B C)		**6.45**	**8.60**	**13.01**	**22.04**	**36.87**	**55.55**	**75.15**	**31.09**
Factors		**CD at 5%**	**SE (d)**	**SE(m)**					
Storage material		0.177	0.089	0.063					
Storage condition		0.204	0.103	0.073					
Storage material x Storage condition		0.353	0.179	0.127					
Storage Duration		0.270	0.137	0.097					
Storage material x Storage Duration		0.468	0.237	0.167					
Storage condition x Storage Duration		0.540	0.273	0.193					
Storage Material x Storage condition x storage duration		0.935	0.474	0.335					

Table-7.3: Effect of storage condition and duration on Saponification value of oil from stored seed of *M.latifolia*

Storage Material	Storage Condition	Storage Duration							
		0 Days	30 Days	60 Days	90 Days	120 Days	150 Days	180 Days	Mean
Polythene Bag	Closed polythene bag kept in light	162.90	130.32	118.92	105.89	96.11	86.34	75.98	110.92
	Closed polythene bag kept in dark	162.90	148.24	135.21	125.43	115.66	110.77	89.83	126.86
	Open polythene bag kept in light	162.90	144.98	130.32	117.29	109.14	99.37	84.17	121.17
	Open polythene bag kept in dark	162.90	144.98	128.69	109.14	92.85	79.82	67.59	112.28
	Mean (A)	**162.90**	**142.13**	**128.28**	**114.44**	**103.44**	**94.07**	**79.39**	**117.81**
Cotton Bag	Closed cotton bag kept in light	162.90	149.87	136.84	114.03	96.11	81.45	69.44	115.81
	Closed cotton bag kept in dark	162.90	143.35	128.69	110.77	91.22	73.30	57.51	109.68
	Open cotton bag kept in light	162.90	146.61	131.95	109.14	92.85	79.82	69.10	113.20
	Open cotton bag kept in dark	162.90	135.21	115.66	101.00	78.19	60.27	36.11	98.48
	Mean (B)	**162.90**	**143.76**	**128.28**	**108.74**	**89.59**	**73.71**	**58.04**	**109.29**
Plastic Container	Closed plastic container kept in light	162.90	138.46	125.43	110.77	99.37	89.59	78.01	114.93
	Closed plastic container kept in dark	162.90	141.72	130.32	115.66	102.63	94.48	81.49	118.46
	Open plastic container kept in light	162.90	146.61	135.21	117.29	99.37	81.45	63.70	115.22
	Open plastic container kept in dark	162.90	144.98	130.32	112.40	84.71	70.05	45.16	107.22
	Mean (C)	**162.90**	**142.94**	**130.32**	**114.03**	**96.52**	**83.89**	**67.09**	**113.96**
Mean (A B C)		**162.90**	**142.94**	**128.96**	**112.40**	**96.52**	**83.89**	**68.17**	**113.69**

Factors	CD at 5%	SE (d)	SE(m)
Storage material	0.430	0.218	0.154
Storage condition	0.496	0.251	0.178
Storage material x Storage condition	0.859	0.435	0.308
Storage Duration	0.656	0.332	0.235
Storage material x Storage Duration	1.136	0.576	0.407
Storage condition x Storage Duration	1.312	0.665	0.470
Storage Material x Storage condition x storage duration	2.273	1.151	0.814

Table-7.4: Effect of storage condition and duration on Free Fatty Acid (FFA) % of oil from stored seed of *M.latifolia*

Storage Material	Storage Condition	Storage Duration							
		0 Days	30 Days	60 Days	90 Days	120 Days	150 Days	180 Days	Mean
Polythene Bag	Closed polythene bag kept in light	3.24	4.54	6.48	11.34	17.82	25.28	32.62	14.48
	Closed polythene bag kept in dark	3.24	4.86	7.45	12.32	19.12	28.20	37.45	16.09
	Open polythene bag kept in light	3.24	5.51	9.08	13.29	22.36	35.33	48.54	19.62
	Open polythene bag kept in dark	3.24	5.83	9.40	17.18	27.87	47.19	72.01	26.10
	Mean (A)	**3.24**	**5.19**	**8.10**	**13.53**	**21.79**	**33.99**	**47.65**	**19.07**
Cotton Bag	Closed cotton bag kept in light	3.24	5.19	8.43	12.96	21.71	34.35	46.10	18.85
	Closed cotton bag kept in dark	3.24	3.89	5.51	10.05	16.85	24.31	29.38	13.32
	Open cotton bag kept in light	3.24	4.54	7.45	11.99	19.77	31.44	43.70	17.45
	Open cotton bag kept in dark	3.24	3.56	4.86	9.40	16.21	23.01	28.97	12.75
	Mean (B)	**3.24**	**4.30**	**6.56**	**11.10**	**18.63**	**28.28**	**37.04**	**15.59**
Plastic Container	Closed plastic container kept in light	3.24	4.21	6.80	11.02	19.12	30.14	41.90	16.63
	Closed plastic container kept in dark	3.24	3.56	4.54	7.45	12.64	16.53	20.19	9.74
	Open plastic container kept in light	3.24	3.89	5.19	8.75	15.23	20.42	27.28	12.00
	Open plastic container kept in dark	3.24	2.27	3.24	7.13	13.61	18.80	25.07	10.48
	Mean (C)	**3.24**	**3.48**	**4.94**	**8.59**	**15.15**	**21.47**	**28.61**	**12.21**
Mean (A B C)		**3.24**	**4.32**	**6.53**	**11.07**	**18.52**	**27.91**	**37.77**	**15.62**

Factors	**CD at 5%**	**SE (d)**	**SE(m)**		
Storage material	0.089	0.045	0.032		
Storage condition	0.103	0.052	0.037		
Storage material x Storage condition	0.178	0.090	0.064		
Storage Duration	0.136	0.069	0.049		
Storage material x Storage Duration	0.235	0.119	0.084		
Storage condition x Storage Duration	0.271	0.137	0.097		
Storage Material x Storage condition x storage duration	0.470	0.238	0.168		

Table-7.5: Effect of storage condition and duration on Iodine value of oil from stored seed of *M.latifolia*

Storage Material	Storage Condition	Storage Duration							
		0 Days	**30 Days**	**60 Days**	**90 Days**	**120 Days**	**150 Days**	**180 Days**	**Mean**
Polythene Bag	**Closed polythene bag kept in light**	62.70	59.57	55.18	51.41	48.28	45.14	41.50	51.97
	Closed polythene bag kept in dark	62.70	60.19	57.68	55.18	50.16	47.65	43.60	53.88
	Open polythene bag kept in light	62.70	58.31	53.30	51.41	48.28	45.77	42.80	51.80
	Open polythene bag kept in dark	62.70	57.68	55.18	50.79	46.40	43.26	39.40	50.77
	Mean (A)	**62.70**	**58.94**	**55.33**	**52.20**	**48.28**	**45.46**	**41.83**	**52.10**
Cotton Bag	**Closed cotton bag kept in light**	62.70	60.19	57.05	52.04	47.65	44.52	40.50	52.09
	Closed cotton bag kept in dark	62.70	58.31	53.92	50.16	45.77	40.76	35.60	49.60
	Open cotton bag kept in light	62.70	58.94	53.92	50.16	47.03	44.52	41.20	51.21
	Open cotton bag kept in dark	62.70	57.68	50.79	45.14	39.50	35.11	30.50	45.92
	Mean (B)	**62.70**	**58.78**	**53.92**	**49.38**	**44.99**	**41.23**	**36.95**	**49.71**
Plastic Container	**Closed plastic container kept in light**	62.70	58.31	55.80	50.16	46.40	43.89	41.90	51.31
	Closed plastic container kept in dark	62.70	59.57	57.06	53.92	50.79	47.03	43.60	53.52
	Open plastic container kept in light	62.70	58.94	56.43	52.04	47.65	42.64	40.10	51.50
	Open plastic container kept in dark	62.70	58.94	55.18	51.41	47.03	42.01	37.20	50.64
	Mean (C)	**62.70**	**58.94**	**56.12**	**51.88**	**47.97**	**43.89**	**40.70**	**51.74**
Mean (A B C)		**62.70**	**58.89**	**55.12**	**51.15**	**47.08**	**43.53**	**39.83**	**51.18**
Factors		**CD at 5%**	**SE (d)**	**SE(m)**					
Storage material		0.079	0.040	0.028					
Storage condition		0.091	0.046	0.033					
Storage material x Storage condition		0.158	0.080	0.057					
Storage Duration		0.121	0.061	0.043					
Storage material x Storage Duration		0.209	0.106	0.075					
Storage condition x Storage Duration		0.242	0.122	0.087					
Storage Material x Storage condition x storage duration		0.419	0.212	0.150					

Table-7.6: Effect of storage condition and duration on Density (gm/ml) of oil from stored seed of *M.latifolia*

Storage Material	Storage Condition	Storage Duration							
		0 Days	**30 Days**	**60 Days**	**90 Days**	**120 Days**	**150 Days**	**180 Days**	**Mean**
Polythene Bag	**Closed polythene bag kept in light**	0.891	0.892	0.892	0.893	0.894	0.895	0.896	0.893
	Closed polythene bag kept in dark	0.891	0.892	0.894	0.894	0.897	0.896	0.901	0.895
	Open polythene bag kept in light	0.891	0.893	0.894	0.894	0.896	0.898	0.900	0.895
	Open polythene bag kept in dark	0.891	0.891	0.892	0.892	0.894	0.893	0.895	0.893
	Mean (A)	**0.891**	**0.892**	**0.893**	**0.893**	**0.895**	**0.896**	**0.898**	**0.894**
Cotton Bag	**Closed cotton bag kept in light**	0.891	0.892	0.893	0.893	0.894	0.895	0.894	0.893
	Closed cotton bag kept in dark	0.891	0.893	0.893	0.892	0.894	0.894	0.894	0.893
	Open cotton bag kept in light	0.891	0.891	0.892	0.894	0.895	0.895	0.896	0.893
	Open cotton bag kept in dark	0.891	0.891	0.893	0.893	0.893	0.894	0.894	0.893
	Mean (B)	**0.891**	**0.892**	**0.893**	**0.893**	**0.894**	**0.895**	**0.895**	**0.893**
Plastic Container	**Closed plastic container kept in light**	0.891	0.892	0.892	0.894	0.894	0.895	0.896	0.893
	Closed plastic container kept in dark	0.891	0.892	0.892	0.893	0.896	0.899	0.901	0.895
	Open plastic container kept in light	0.891	0.891	0.892	0.893	0.893	0.894	0.895	0.893
	Open plastic container kept in dark	0.891	0.893	0.893	0.893	0.894	0.895	0.895	0.893
	Mean (C)	**0.891**	**0.892**	**0.892**	**0.893**	**0.894**	**0.896**	**0.897**	**0.894**
Mean (A B C)		**0.891**	**0.892**	**0.893**	**0.893**	**0.894**	**0.896**	**0.897**	**0.894**
Factors		**CD at 5%**	**SE (d)**	**SE(m)**					
Storage material		0.000	0.000	0.000					
Storage condition		0.000	0.000	0.000					
Storage material x Storage condition		0.001	0.000	0.000					
Storage Duration		0.000	0.000	0.000					
Storage material x Storage Duration		N/A	0.000	0.000					
Storage condition x Storage Duration		N/A	0.000	0.000					
Storage Material x Storage condition x storage duration		0.002	0.001	0.001					

Table-7.7: Effect of storage condition and duration on Specific gravity of oil from stored seed of *M.latifolia*

Storage Material	Storage Condition	Storage Duration							
		0 Days	**30 Days**	**60 Days**	**90 Days**	**120 Days**	**150 Days**	**180 Days**	**Mean**
Polythene Bag	**Closed polythene bag kept in light**	0.898	0.899	0.899	0.900	0.901	0.902	0.903	0.900
	Closed polythene bag kept in dark	0.898	0.899	0.901	0.901	0.904	0.903	0.908	0.902
	Open polythene bag kept in light	0.898	0.900	0.901	0.901	0.903	0.905	0.907	0.902
	Open polythene bag kept in dark	0.898	0.898	0.899	0.899	0.901	0.900	0.902	0.900
	Mean (A)	**0.898**	**0.899**	**0.900**	**0.900**	**0.902**	**0.903**	**0.905**	**0.901**
Cotton Bag	**Closed cotton bag kept in light**	0.898	0.899	0.900	0.900	0.901	0.902	0.901	0.900
	Closed cotton bag kept in dark	0.898	0.900	0.900	0.899	0.901	0.901	0.901	0.900
	Open cotton bag kept in light	0.898	0.898	0.899	0.901	0.902	0.902	0.903	0.900
	Open cotton bag kept in dark	0.898	0.898	0.900	0.900	0.900	0.901	0.901	0.900
	Mean (B)	**0.898**	**0.899**	**0.900**	**0.900**	**0.901**	**0.902**	**0.902**	**0.900**
Plastic Container	**Closed plastic container kept in light**	0.898	0.899	0.899	0.901	0.901	0.902	0.903	0.900
	Closed plastic container kept in dark	0.898	0.899	0.899	0.900	0.903	0.906	0.908	0.902
	Open plastic container kept in light	0.898	0.898	0.899	0.900	0.900	0.901	0.902	0.900
	Open plastic container kept in dark	0.898	0.900	0.900	0.900	0.901	0.902	0.902	0.900
	Mean (C)	**0.898**	**0.899**	**0.899**	**0.900**	**0.901**	**0.903**	**0.904**	**0.901**
Mean (A B C)		**0.898**	**0.899**	**0.900**	**0.900**	**0.901**	**0.903**	**0.904**	**0.901**
Factors		**CD at 5 %**	**SE (d)**	**SE(m)**					
Storage material		0.000	0.000	0.000					
Storage condition		0.000	0.000	0.000					
Storage material x Storage condition		N/A	0.000	0.000					
Storage Duration		0.000	0.000	0.000					
Storage material x Storage Duration		N/A	0.000	0.000					
Storage condition x Storage Duration		N/A	0.000	0.000					
Storage Material x Storage condition x storage duration		0.002	0.001	0.001					

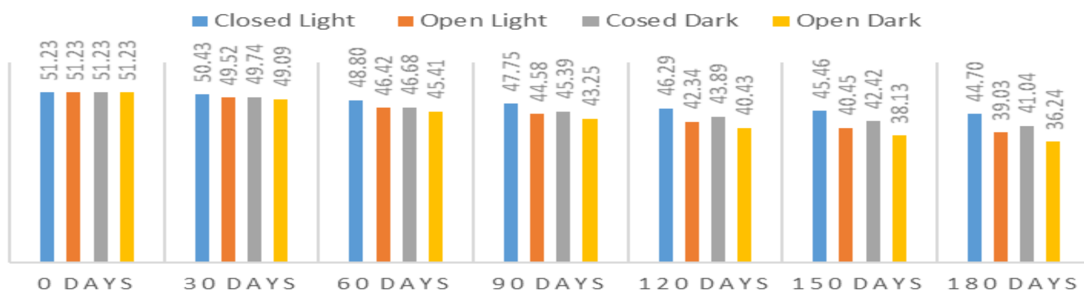

Fig.7.1: Change in oil content (%) of stored seed with storage condition and duration irrespective of storage container

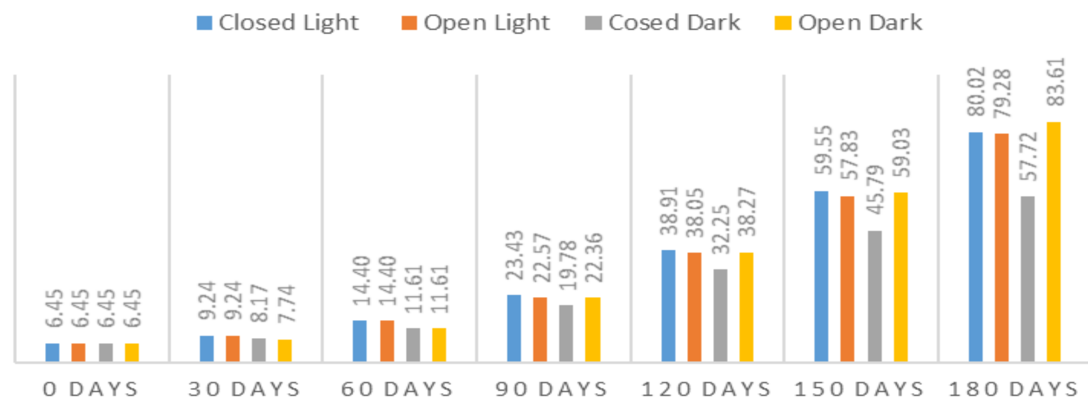

Fig.7.2: Change in Acid Value of oil with storage condition and duration irrespective of storage container

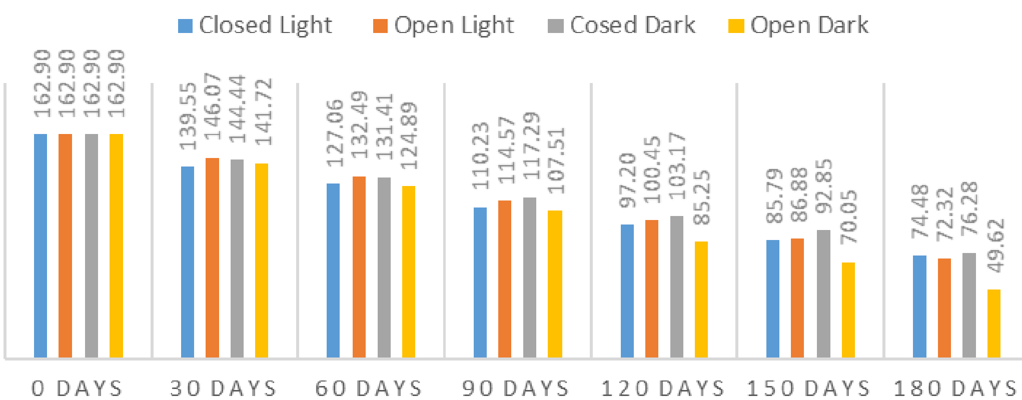

Fig.7.3: Change in Saponification Value of oil with storage condition and duration irrespective of storage container

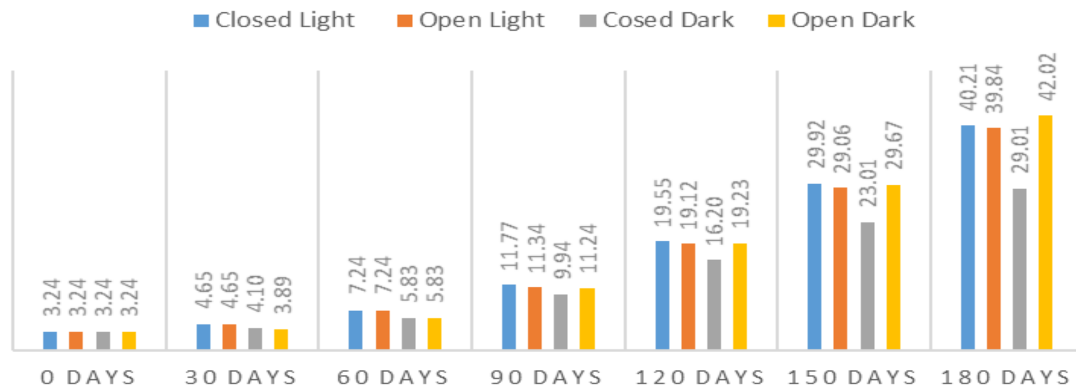

Fig.7.4: Change in FFA (%) of oil with storage condition and duration irrespective of storage container

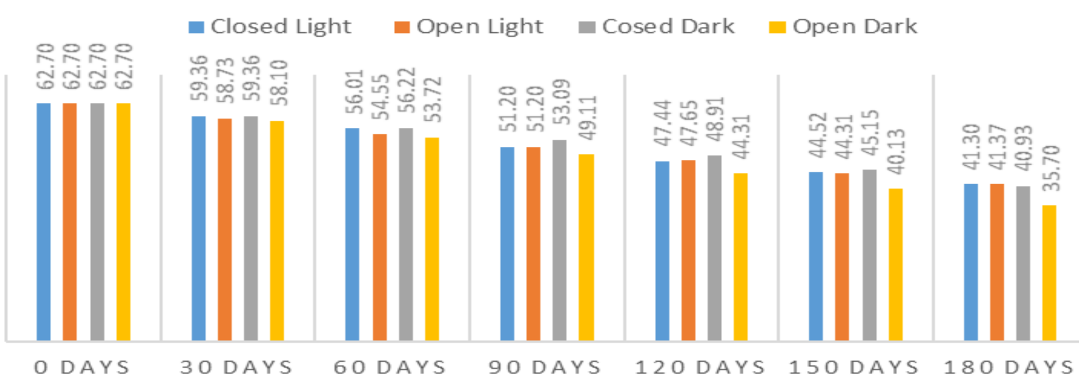

Fig.7.5: Change in Iodine Value of oil with storage condition and duration irrespective of storage container

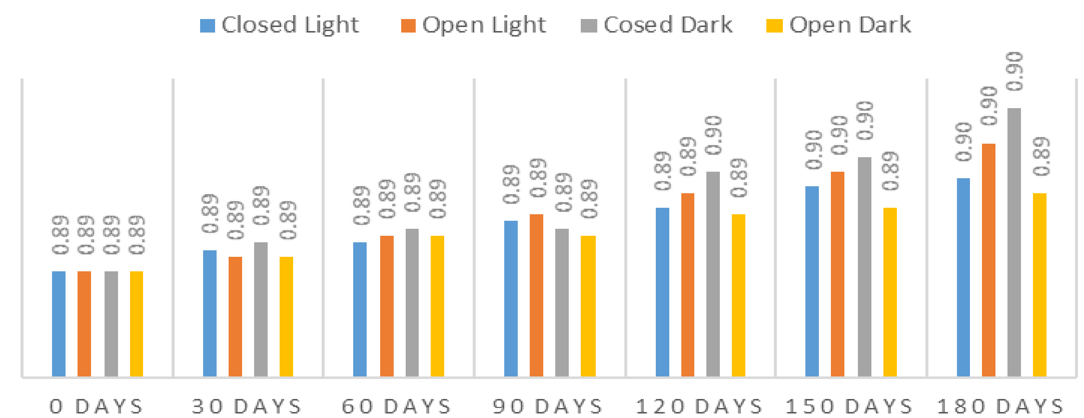

Fig.7.6: Change in density (g/ml) of oil with storage condition and duration irrespective of storage container

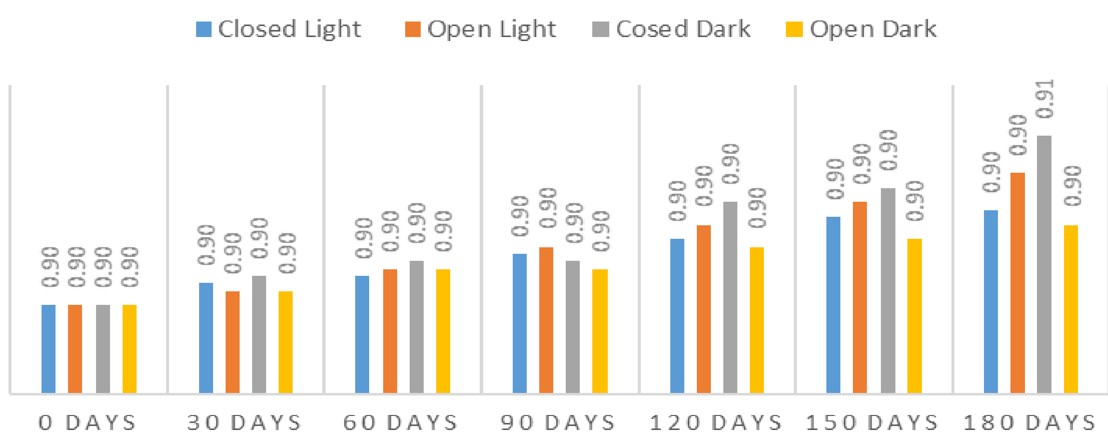

Fig.7.7: Change in Specific gravity of oil with storage condition and duration irrespective of storage container

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CHAPTER-8

ECONOMICCONTRIBUTION OF MAHUA FLOWERS AND FRUITS TO HOUSEHOLD FOOD SECURITY AND LIVELIHOOD DEPENDENCY

8.1 Introduction

Since ages the forests and their associated products have been sustaining livelihoods (Momo et al. 2006, Bwalya 2013, Mukul et al. 2016) particularly for the forest-depended communities which live in creeping poverty (Shackleton, 2004; Shackleton et al. 2007, Timko et al. 2010; Shackleton et al. 2011; Kabubo-Mariara 2013). It is estimated that globally about 200 million native communities are fully dependent on forest for their livelihoods (Langat 2015) and there are about 1.095 to 1.745 billion people who depend on forest to a varying degree. There is growing evidence that non-timber forest products (NTFPs) contribute significantly to rural livelihoods in developing countries (Heubach et al. 2011; Uberhuang et al. 2012; Akani and State 2013; Prabhakaran et al. 2013; Dolni and Chatterjee 2014; Dagm et al. 2016; Suleiman et al. 2017) and in India there are about 15000 plant species out of which nearly 3000 species (20%) yields NTFPs. Another report mention that collection of NTFPs is a major activity for about 500 million people living in or near the forest for meeting their daily needs (Alexander et al. 2002). The role of NTFPs in village economy (Malhotra et al. 1991; Mukhopadhy 2009; Malhotra and Bhattacharya 2010) and socioeconomic factors contributing to forest dependency (Kamang et al. 2008; Garekae et al. 2017; Htun et al. 2017) have been studied. These reports suggest that the forests contribute substantially to the food supply of the tribal population as well as their livelihood system (Babulo et al. 2008; Bhattacharya and Hayat 2009; Reddy and Chakravorty, 1999; Ghosal, 2011; Shit and Pati 2012; Pandey et al. 2016) and thus constitute an integral part of the social life of the tribes and other communities living in and around the forests (Falcon and Arnold 1991; Malhotra et al. 1991). The preference of extraction of some NTFPs especially the fuel wood species are based on forest dwellers' perception (Sahoo et al. 2014).

Maduca latifolia (Mahua) is one of the few trees that have a special status among NTFPs in Central and Eastern India as it is linked to the tribal livelihood systems in different ways. It is one of the multipurpose forest tree species that provide an answer for the three major Fs, i.e. food, fodder and fuel. Apart from meeting food and other requirements, it is also an important source of seasonal income. Almost all parts of this poor man's fruit tree (as it is popularly called) are of immense use. Since birth to death many ceremonies of the tribes find the use of Mahua. Mahua oil is being applied on the new born child after cutting the umbilical cord, during wedding the bride and groom are made to hold the stick of mahua tree and besides, mahua drinks are served in tribal marriages. The tender light green shoots of the tree are cooked as a vegetable. The narrow young branches are used as datuns or teeth cleaning twigs by the Adivasi (tribal) population. Since it is considered as an auspicious tree, the central pillar of the Mandap at Adivasi weddings is made with branches of the tree. The raw fruit is cooked as a vegetable which contains nearly 68% sugar hence it is a rich source of energy. It has got 6.3% of protein. Apart from that it has also got significant amount of vitamin B & C (Ramadan et al. 2016). The fruit contains large seeds from which tora oil is extracted and used for cooking, as hair oil and for therapeutic massages. The sap from the mahua tree is used to make a gum which is applied on nets and hung on trees and used to catch small game birds. The broad mahua leaves are stitched into bowls which are used as cups to drink mahua liquor as well as rice wine. They are also used as bowls to both steam food and eat. The most lucrative part of the tree, the flowers, are dried, and used to make the liquor. Apart from this, when there is a scarcity of rice and grains or a famine-like situation, the dried flowers are mixed with jaggery and eaten as laddoos or cooked as they are an important source of vitamins, minerals and iron. Fruit pulp may be used for alcoholic fermentation. Seeds containing 20 to 50% fatty oil can be used for the manufacture of soap. Mahua oil seed cake can be used as manure. The smoke generated from Mahua cake is believed to drive away snakes and insects. Tribals use Mahua cake for killing fish as well as in treatment of snakebites (Bhatia 1970; Lakshman 1983; Vinothkumar et al. 2018). .Mahua oil is used in medicine as emmoilment, cure of skin diseases, rheumatism, headache, as laxative, in piles and haemorrhoids. Seeds yield about 22% water-soluble gum. Husk can be used in the preparation of active carbon (Mishra et al. 2009; Ganvir and Dwivedi 2012).

This tree is a way of life for the tribal and is a cultural identity under which villager meetings are often held. While other trees are cut, this tree is left untouched due to its economic importance and religious taboos threatening wrath of the spirits upon cutting the trees (Ahirwar 2015). In Odisha, there are several tribes who live inside the forest areas and depend on the forests for their daily livelihoods and for income generation activities. Mahua seeds and flowers that are of particular importance are collected by the tribes for self-consumption and for sale to generate income to purchase daily household needs. However, it is imperative to clearly understand how Mahua has been contributing to the socio-economic domains and rural livelihoods of these communities and besides, to understand the linkages between various socio-economic factors (location, wealth status, gender, education, and seasonality) affecting the level of dependency on Mahua with particular reference to flower and seeds in different districts/agroecological zones of Odisha.

The objectives of this paper was to analyze (i) How important is Mahua's access and other forest resources (NTFPs) for the livelihoods of communities? (ii) Are the poorest communities more or less dependent on forest resources than other groups? (iii) To what extent Mahua flowers and seeds have been contributing to the economies of the households, (iv) How do access to forest resources and the resulting livelihood implications vary across the survey sample, e.g., a district or across agroclimatic zone? And how do land ownership, tenure and user rights affect the livelihoods of communities?

8.2 Materials and Methods

8.2.1 Study area

Odisha is located between 170 49′ N to 220 34′ North latitudes and from 810 27′ E to 870 29′ East longitude on the eastern coasts of India. It is bounded by the states of West Bengal on the North-East, Jharkhand on the North, Chhattisgarh on the West, Andhra Pradesh on the South and Bay of Bengal on the east. It spreads over an area of 1,55,707 sq. Km (4.74% of India's total area) and has a coastline of about 529 Km. The study was carried out in Sundargarh, Mayurbhanj, Baleswar, Nayagarh, Kandhamal, Nabarangpur, Koraput, Malkangiri, Nuapada,Bolangir and Angul district under all ten agroclimatic zones of Odisha. The detail demographic profile of district and of studied villages study is presented in are given in Tables 1 and 2.

8.2.2 Method of investigation, site selection and sampling procedure

8.2.2.1 Method of Investigation

The steps followed in the present study are selection of the area, collection of specific records of the relevant factor, designing the sampling technique, finalizing the period of investigation, preparation of the interview schedule, rapport building with respondents, collection of data, processing and analysis of data. In this method of study 40 respondents were selected randomly from villages under each agroclimatic zone. The selected villages were situated from the outskirt to 8 kms of the natural forest areas with sufficient mahua trees on field bunds which are dependent on mahua trees.

8.2.2.2 Selection of the Study area

In accordance with the objectives of the study and considering the limitations of the research with respect to time, man power and other facilities, the research work was carried out in twenty seven villages of eleven districts under ten agroclimatic zones. The details of villages selected in different districts are given in Table 2. As the distribution of *Madhuca latifolia* in Odisha is extensive covering all agroclimatic zones in both natural forest and raised under traditional agroforestry systems contributing to the rural population, there was a strong need to study the impact of mahua tree produces on their livelihood. The dependency on mahua tree for socio-economic condition of these people was studied through scientific surveys, considering their views, constraints, supply chain and expert suggestion. The selection of the study area, however, was based on the following main consideration:

i. The study site had plenty availability of *Madhuca latifolia* as a major livelihood option.

ii. The sites were the representatives of different agroclimatic zones of Odisha

iii. Co-operation from the collector's to be high and therefore, reliable data should be collected.

8.2.2.3 Preparation of survey schedule

In conformity with the set objectives of the study, a set of preliminary survey schedules was designed for collection of data for the study. The survey schedule carefully designed in such a way that all the factors associated with the economics of various components could be ascertained. Simple questions regarding their basic factors were included in the schedule. The draft schedule was pre tested by interviewing some sample collectors and traders of selected area by the researcher himself and with discussion with facilitators' forest officials, members of the respective villages. Some parts of the draft schedule were modified on basis of the actual experiences gained during the pre-testing. The final schedule was prepared in a simple manner maintaining logical sequences and necessary adjustments.

8.2.2.4 Period of data collection

The researcher made all possible efforts to explain the purpose of the study to the respondents to get valid and pertinent information. Appointments with the interviewer were made in advance with the help of village committee chairman, field level facilitators and also Forest Department officials. The researcher administrated the interview schedule personally to the respondents. Rapport was established with the respondents through informal discussion regarding objectives of the interview. Co-operation was obtained from respondents during data collection from April 2017 to June 2017 in a phased manner.

8.2.2.5 Characteristics of study and development of the research instrument

The characteristics included in the study were (a) family size of respondents, (b) land holding of respondents, (c) employment in various sectors, (d) presence of *Madhuca latifolia* in fields and homesteads, (d) collection of NTFPs including mahua flowers and seeds and their availability, (e) processing, home consumption and selling of mahua flowers and seeds, (f) storage methodology adopted for mahua flowers and seeds, (g) total annual income from different sources, (h) comparative economics and (i) constraints in mahua flowers and seed collection and its trade. Family size of a respondent was determined in terms of the total number of members in the family of each respondent. The family member included respondent himself, spouse, sons, daughters and other dependents. The scoring was made by the actual member of family, expressed by respondents. If a respondent had four members in his family, his score was given as 4.Farm size was measured in terms of acres by collecting the information from the farmers. Some farmers expressed the land holding in terms of acre or guntha then these data were converted to acres and recorded. The nature of employment in different sectors such as NTFP collection, agriculture, farm labour and other sectors were recorded and represented in table for analysis. The availability of different NTFPs including mahua flowers and seeds in the localities, amount of bearing in tree, collection quantity and their season of collection were asked and recorded. The indigenous methods followed in processing of mahua flowers and seeds, the quantity consumed in home and the quantity sold with their rates were recorded, calculated and represented in table. The selling of NTFPs in different supply chain was identified. Different storage methodology practised was recorded at primary collector as well as at licensed trader's level. The total earnings of all family members of respondents from agriculture, business, service, NTFP collection including mahua flowers and seeds and other sources as contained in items of interview schedule. The amount is recorded separately and the total is calculated and expressed. The researcher analysed the total income and the relative contribution of income from mahua flowers and mahua seeds, other NTFPs to total income. Problems faced in mahua flowers and seeds collection were recorded by asking the respondents as prepared in the interview schedule. The respondents were also asked to give their opinion towards the problems along with their extent of confrontation in collection and marketing of mahua flowers.

8.2.2.6 Data collection, processing and analysis

The study was conducted for field-level primary data and researcher himself collected data required for the study. There are three main methods by which the survey data were gathered. These are (i) direct observation, (ii) interviewing respondents (iii) record kept by respondents. Data were collected through field visits in the study area and personal interview with the sample mahua flowers collectors and traders. Interviews were normally conducted in respondent's house in their leisure time. They provided information from their memory and experiences. In order to minimize the response error, cross-question were asked in simple Odia. In some areas where the respondents don't understand Odia the help of local tribal interpreter were taken. After completion of each interview, each interview schedule was checked and noted properly. After completion of field survey data from all the interview schedules were compiled, tabulated and analysed in accordance with the objectives of study. In the process, all the responses in the interview schedule are given numerical coded value and local units were converted into standard units whenever necessary. The responses to the question in the interview schedules were transferred to a master sheet to facilitate tabulation. For describing the different characteristics and their constraint they are facing, the respondents were classified into several categories. Descriptive analyses such as range, average, percentage, increasing or decreasing order were used whenever possible.

8.3 Results

8.3.1 Socioeconomic status of Mahua dependant Forest dwellers

Analysing the family members of the respondents of villages dependant on mahuaunder different agroclimatic zones, it was found that average number of members per household ranges between 4.7-6.6 in all agroclimatic zones. The maximum average number of members per household (6.6) was found in agroclimatic zone -7 and 9 and minimum average number of members per household

(4.7) in agroclimatic zone -4 and 6 (Table 3). Agroclimatic zone wise trend showed that average numbers of males per household ranges from 1.8-2.3 with maximum (2.3) in agroclimatic zone -9 and minimum (1.8) in agroclimatic zones – 3,4,6 and 8. The average number of females per household ranges from 1.5-2.3 with maximum (2.3) in agroclimatic zone -10 and minimum (1.5) in agroclimatic zones - 6. Similarly, among the respondents, Small family size was found maximum (70%) in agroclimatic zone-1 and minimum (7.5%) in agroclimatic zone -7. Medium family size was found maximum (87.5%) in agroclimatic zone-7 and minimum (20%) in agroclimatic zone -1, whereas, large family size was found maximum (17.5%) in agroclimatic zone-10 and minimum (2.5%) in agroclimatic zone -8 (Table 3).

8.3.2 Agricultural Land Holdings

The average agricultural land /household among the respondents of villages' dependant on mahuaunder different agroclimatic zones range between 1.8-7.9 acre in all agroclimatic zones. The maximum agricultural land per household (7.9) was found in agroclimatic zone -10 and minimum average number of members per household (1.8) in agroclimatic zone -6 (Table 4, Figure 4). Among the respondents, agroclimatic zone wise trend showed that marginal land holding was found maximum (40%) in agroclimatic zone-7 and minimum (5%) in agroclimatic zone -9, whereas, no marginal land holding was found in agroclimatic zones-4 and 10. Small land holding was found maximum (62.5%) in agroclimatic zone-3 and minimum (10%) in agroclimatic zone -10. Small medium land holding was found maximum (50%) in agroclimatic zone-1 and minimum (7.5%) in agroclimatic zone -7. Medium land holding was found maximum (55%) in agroclimatic zone-4 and minimum (5%) in agroclimatic zone -5, whereas, no medium land holding was found in agroclimatic zones-3 and 6. Large land holding was found maximum (15%) in agroclimatic zone-9 and minimum (5%) in agroclimatic zone -5 and 7, whereas, no large land holding was found in agroclimatic zones-2,3 and 6 (Table 4, Figure 5).

8.3.3 Collection and contribution of *Madhuca latifolia* to the annual Income

The average number of mahua trees per Household among the respondents of villages under different agroclimatic zones ranges between 4.5-9.0 across all agroclimatic zones. The maximum No. of trees per household (9.0) was found in agroclimatic zone -10 and minimum average number of members per household (4.5) in agroclimatic zone -6 (Table 5). Analysing the respondents of villages dependant on mahua the average annual Income from agricultural produce varies from Rs 10622 – Rs 76636 among all agroclimatic zones with maximum in agroclimatic zone -9 and minimum in agroclimatic zone-2. Annual income from wages found highest (Rs 35452) in agroclimatic zone -7 and lowest (Rs 6500) in agroclimatic zone -4.Annual Income from ‘NTFPs other than Mahua’ was found highest (Rs 5412) in agroclimatic zone -7 and lowest (Rs 1072) in agroclimatic zone -9. Annual Income from flowers and seed oil of Mahua was found highest (Rs 22306) in agroclimatic zone -9 and lowest (Rs 7631) in agroclimatic zone -3 (Table 6).

Analysing the contribution of Mahua products to the total income generated from NTFPs it was found that maximum contribution was found incase of agroclimatic zone -9 (95.49%) and minimum contribution in case ofagroclimatic zone -8 (60.23%). Similarly, Contribution of Mahua products to the total income generated from all sources was found maximum (21.94%) in agroclimatic zone-1 and minimum (14.12%) in agroclimatic zone -3 (Table 6).

8.3.4 Collection of *Madhuca latifolia* flowers and Seeds

Analysing the respondents views from all agroclimatic zones on basis of flowering two different categories of trees are present one is early flowering type and other late flowering type although gap in flowering is not wide. It was found that in agroclimatic zone 5, 6 and 7 such type of late flowering *Madhuca latifolia* trees exists. The showering season of *Madhuca latifloia* flowers was from March -April in all parts of Odisha. The corollas after getting matured after 30 days of initiation of flowers changed its colour to creamy white started falling on the ground after getting moulted on the tree. Normally showering took place in the early part of the day between 4 O’clock -11 O’clock. The primary collectors clean the ground to avoid unwanted materials mixed with the flowers during collection. The collection starts early morning and continues even upto noon. During collection whole family are involved to get maximum collection which lasts for three to four weeks. The whole collection period can be marked into three phases starting, middle and end of which the middle phase had most collection when most of the matured flowers showered. It was revealed by the respondents that better sun shine favours more showering of flowers. It was also found that older trees produce smaller flowers than trees with younger age. Flowers of *Madhuca latifolia* were collected during the period from March 3rd week- April 3rd week in all agroclimatic zones except agroclimatic zone-5 , 6 and 7 where the collection was done during the period March 3rd week- April 4th week (Table 5). The average collection of mahua flowers per household among the respondents of villages under different agroclimatic zones ranges between 2.30 Qtls-7.07 Qtls across all agroclimatic zones. The maximum collection of mahua flowers per household (7.07 Qtls) was found in agroclimatic zone -9 and minimum collection of mahua flowers per household (2.30 Qtls) in agroclimatic zone -5 (Table 5, Figure 6). Seeds of *Madhuca latifolia* were collected for extraction of oil during the period from June 1st week-June 4th week in all agroclimatic zones -1, 2 and 3, whereas, the collection was done during the period June 1st week-July1st week in rest of the agroclimatic zones. The average collection of mahua seeds per household among the respondents of villages under different agroclimatic zones ranges between 31.26 kg -327.4 kg across all agroclimatic zones. The maximum collection of mahua seeds per household (327.4 kg) was found in agroclimatic zone -9 and minimum collection of mahua flowers per household (31.26 kg) in agroclimatic zone -3 (Table 5).

8.3.5 Processing of *Madhuca latifolia* flowers and Seeds

The flowers collected were taken to home and spread on opened grounds for sun drying and made upside down 2 times a day to ensure uniform drying. Sun-drying is done continuously for 3-4 days till the flowers turn reddish in colour with reduction in weight up to 65-75%. As per respondents view cloudy weather affects the quality of flowers making it dark in colour which ultimately reduces its market price. The selling rate of dried mahua flowers at primary collector level varies from place to place and ranges between Rs 22.60 - Rs 29.00/ kg over all agroclimatic zones of Odisha. The maximum selling rate (Rs 29.00) at the primary collector level found in agroclimatic zone- 1 whereas the minimum selling rate (Rs 22.60) in agroclimatic zone- 9 (Table 5, Figure 7). The fruits collected during June-July which was then de-pulped to get the seeds from it. The seeds were dried for 1 day and then the thin seed cover was removed to expose the kernel. The kernels were made into two haves and then sun dried on cleaned open home yards for 4-5 days till it turns into reddish colour. During this drying period the reduction in weight of seed is about 15-20%. The seeds are prone to quick decaying and turn black in colour due to fungus attack for which it is dried before marketing. The seeds were then taken by the respondents to local mechanical oil extractors (Ghanis) for extraction of oil from dried kernels. Most of the oils were utilised for home consumption for cooking purposes where as some sold in the local markets. he average utilisation of mahua seed oil per household among the respondents of villages under different agroclimatic zones ranges between 13.50 litre-129.12 litre across all agroclimatic zones. The maximum utilisation of mahua seed oil per household (129.12 litre) was found in agroclimatic zone -9 and minimum utilisation of mahua seed oil per household (13.50 litre) in agroclimatic zone -3 (Table 5).

8.3.6 Marketing of *Madhuca latifolia* flowers

The dried mahua flowers collected by the primary collectors during harvesting season passed through intermediate traders and stored which were then sold in the lean season when the prices were higher. During March 2000, the Government of Odisha adopted a new NTFP resolution in which 67 NTFPs including mahua flowers which were earlier under control of state forest department were included under the control of gram panchayats. After analysing the respondents it was found that the traders who procure the mahua flower from villages of a panchayat must register themselves for licence with that panchayat by paying a nominal fee. The schematic pathway of marketing of mahua flowers in Odisha has been elicited (Figure 1).from the information provided by respondents including, primary collectors, grass root level middle man and licensed traders. The primary collectors collect mahua flowers from tree from their own land or from nearby forest lands which was dried for 3-4 days till its colour changes to red. As per the traders view the dried flowers are categorised into 3 classes depending upon the colour of flowers i.e red, yellow, and black. The red flower are well dried and contains less moisture content, yellow flowers are having more moisture content and less dried than red coloured flowers whereas the black coloured flowers are somewhat degraded due to higher moisture contents. The procurement price of red coloured flower is highest followed by yellow coloured flower and minimum for black coloured flower. The license holders collect dried mahua flowers from primary collectors directly, from grass root level middlemen (collects dried flower from primary collectors) and from local weekly markets (Haats) where primary collectors sell. The average procurement price from primary collector was @ Rs 24.49 /kg during 2016-17 , however, in some remote villages the procurers exchange mahua flowers with un-iodised salts in the volume ratio of flower : salt :: 1 : 2.5. The license holder traders sundried the procured mahua flowers for another 2-3 days after spreading it over drying yards after which it was kept in the stored house. After the rainy season and onset of winter on October onwards the stored dried mahua flowers were then sold. The dried flowers selling rate found to be fluctuated and were sold @ Rs 60/kg in 2016-17 and Rs 35/kg in 2017-18. These products were taken further by other traders, wholesalers who sell it to retailers, distilleries and other users. Some of the flowers were utilised within the state where as a considerable portion are illegally transported to bordering states like West Bengal, Andhra Pradesh and Chattisgarh.

After analysing the data collected from the traders it was found that average number of licensed traders per district was about 18 numbers with average storage capacity of dried mahua flowers of each trader about 2000 Qtl. With nearly 22 districts involved in the trade of Mahua flowers of 7,92, 000 Quintals occurs in the state contributing about Rs 1,93.96,080 to the primary collectors of the state.

8.3.7 Constraints, Views and Suggestions for better management Mahua tree and mahua products

The rural population residing near the natural forest of Odisha are dependent on various NTFPs of which mahua flowers and seeds contribute a substantial portion of their household income. The present investigation found that there are some constraints around the sustainable use of mahua flowers and seeds for better and secure livelihood. Among the respondents, 57 % (Figure 2) perceived that the fluctuating rates of mahua flowers are discouraging the rural population for collection of flowers. About 15 % of them did thought that the collection of mahua flowers and seeds are mostly restricted to agricultural field and forests outskirts because of fear of attack by wild animals, infection from wild plants in natural forests etc. About 12 % expressed that lack of other users of mahua flowers besides liquor industries affect the procuring price of mahua flowers. Nearly 7 % told that better drying could have increased the rate of collection and reduced degradation of flowers. About 5 % of respondents reported that better accessibility to forest patches will enhance the collection from natural forests. 4% correspondents reported fewer yields of some trees declines the production in the flowers particularly in less flowering years. The present use of mahua flower for various purposes is shown in Figure 3.

8.4 Discussion

8.4.1 Access of Mahua and other NTFPs to the forest fringe communities/dwellers

In the studied area, it was found that every mahua tree has an owner, usually an Adivasi family. The ownership of each tree is recorded with the forest department and is passed from one generation to the next. The community conserved this species and secured tenure rights of each tree mostly outside the forest area (near the village boundary) and in agricultural fields. The production of flower and fruits increases with age and girth of the trees. Our findings suggest that a single tree can produce up to 200 kg of flowers a year and the older trees are more fecund or fertile producing abundant quantities of flowers. Mahua trees bloom between latter half of March and April and shed its flower in the morning every day, over a period of 15-20 days. Some reports suggest that customary puja is performed under the Mahua tree in some villages sometime after holi and prior to the collection of mahua flower. The purchase price of flowers varies during the year. Besides, mahua other NTFPs are also being collected from the forest area. Most of these NTFPs are non-nationalized and therefore they are fully access to the forest fringe communities/Advasis in the state. A wide variety of other NTFPs that are available (Table 7) in the study area round the year further evince their role in the livelihood of tribes of Odisha

8.4.2 Dependence on Mahua across the people of different socio-economic strata

Mahua tree nevertheless is the most sacred tree among the tribes of Odisha. The various parts of the plants are used as NTFPs. The dried flowers are roasted, made into balls or laddus and are often used as snack, besides, the dried flowers are roasted with sesame and other wild seeds and used for household consumption. The households, irrespective of their land holding size and/economic status, have been depending on this species for various use from cultural to meeting economic or family household needs. All the households in the study sites consume the flower as vegetables and Mahua has been particularly important in providing critical subsistence during the lean seasons for mostly the disadvantageous and low landholding families. Besides, Mahua provides livelihood to all households who collect it for self-consumption and for sale and the income of which is used to buy household needs.Studies conducted in other parts of India such as Bihar, Madhya Pradesh and Andhra Pradesh show that the contribution of NTFPs to total household income range from 10– 55% and about 80% of forest dwellers depend on forests for 25 to 50% of their food requirements (Pandey et al. 2016). Most of the NTFPs are collected and used/sold by women, so it has a strong linkage to women's financial empowerment in the forest-fringe areas. Several other studies have shown high dependence of forest dwellers on a wide variety of NTFPs. For example, Saha and Sundriyal (2011) and Lalremruata et al. (2006) reported NTFPs in the humid tropics of northeast India contributed to 19.32% of the total household income for different communities, Sahoo et al. (2010a, b, c) assessed the degree of NTFPs dependency by the tribes of Mizoram which reveal that NTFPs collection is a source of income for the forest dwellers in the state. There have been some studies which clearly distinguish NTFP dependency among the landless and land owners. Poverty and fuel wood usage were the factors for land owners while rice insufficiency, off-farm income and fuel wood usage mostly affect the NTFPs dependency for landless people (Soe and Yeo-Cheng 2019).

8.4.3 Extent of Mahua and other NTFPs contribution to the economies of the households

Occupation pattern of the studied sites showed that paddy is the major crop. Maize, millet, groundnut and vegetables too are also grown in a varying degree by the tribes/forest fringe dwellers. However, the hilly terrain does not favour better paddy growth and it was observed the households having limited acres of land using for paddy cultivation with very low productivity. The engagement of tribal in agricultural practices reveals that the months of June to Oct is the busiest month as all the farming operations are done in this period. During the agricultural stress period and non-farming months, the dependence on NTFPs increases and during this period, more collection of forest produce takes place. Studies conducted in elsewhere and in India suggest that the rate of extraction of NTFPs is linked to the degree of agricultural stress (Thomas et al, 2011, Delacote, 2007). Several studies have also revealed that NTFPs/forest dependence decreases with increase off-farm or non-forest income (Hedge and Enters 2000; Bahuguna 2000). Higher agricultural productivity and agriculture income results in less extraction of forest resources (Guntilake, 1988; Momo et al. 2006; Rayamajhi et al. 2012). Since NTFPs have a ready and accessible local market, income from NTFPs helps compensate for lean harvests. Moreover, the typical flowering season of many of the major NTFPs coincides with the agricultural post-harvest period in March. Thus the quantum of agricultural harvest determines the level of NTFPs extraction from the forest. The income contribution of mahua to the total NTFPs income per household is substantial (60% in ACZ-8 to >90% in ACZ-9) which confer the substantial role of mahua in the livelihood of the forest dwellers compared to other NTFPs. The income from mahua varies from Rs 7631 to 22306 per household, this requires 15-20 days of hard work during the flowering season. In a season each household collects about 2.30-7.07 quintal of mahua flower per household, which contributes to 14.12 % of the total family income (in ACZ-3) and 21.94% of the total family income in ACZ-1 (Table 6).

8.4.5 Variations in forest resource availability and livelihood implication across the ACZs in climate change scenario

The constraint analysis revealed that the availability of various NTFPs and particularly mahua scenario in Odisha is no rosier. The current climate change coupled with other developmental activities in the state in the past few years is adding to the curtailment of forest resource availability for livelihoods of tribes. Decreasing availability of forest produce such as food, fuel, medicinal and herbs seem to deprive the rural poor from a supplementary source of income, food and healthcare (Basu, 2009), thus concentrated efforts to understand and assess how NTFPs can contribute to mitigation and adaption of climate change, but also by looking at if and how NTFPs are impacted by changing climates (Kirilenko and Sedjo 2007). Upon interaction with the tribes, they revealed that there is a significant change in the phenology of mahua with respect to flowering and fruiting. A gradual shift in fruiting and flowering from mid-March to mid-February affects the change in local forest ecology. This also affect the pollination pattern and reduced honey collection by up to 90% in Wayanad district of Kerala due to climate change (Manoj 2011; WWF 2011). Similar changes in mahua flowering and fruiting are reported in Mandla district of Madhya Pradesh (Sushant 2013). The study argue that during mid-February, the agricultural season is about to end and farmers are preoccupied with harvesting their produce. Early onset of mahua flowering during the harvest period leaves less time for the community to collect mahua. Studies in Madhya Pradesh (Malhotra and Bhattacharya 2010) have revealed that low agricultural productivity in a drought year forced tribals to extract and sell more NTFPs to meet the food security needs of their households. Therefore, in current and future climate change scenario where decline of production of the major crop paddy is already happening in the tribal belt of Odisha, NTFPs can be looked as potential future strategy to deal with challenges like food, nutritional and income security of the population.

8.4.6 Land ownership, tenure and user rights affecting the livelihoods

Many NTFPs in the state of Odisha operate in open or in semi-open access systems of resource tenure, resulting in exploitation of NTFPs. This happens mostly during the lean seasons when the poor households with little income on agriculture have no choice other than going to the forests and extracting the NTFPs to the extent possible to meet the basic needs. Women are more depended on subsistence forest income and their involvement in NTFP collection is more notable than the men in the study area. Mahua is a non-nationalized non-timber forest product, however, in Odisha it is kept under the control of Gram Panchyats as per the NTFP policy of 2000. It is still not a freely tradable item because of its classification as an intoxicant by the Orissa Excise Act, 1915 and Odisha government imposes 4% VAT on the flowers and 14% VAT on the finished products which affect the livelihood of the primary producers to a great extent. The neighboring states like Bihar and Chhattisgarh have lower taxes and duties on mahua and therefore these states have advantages over Odisha for boarder trading.

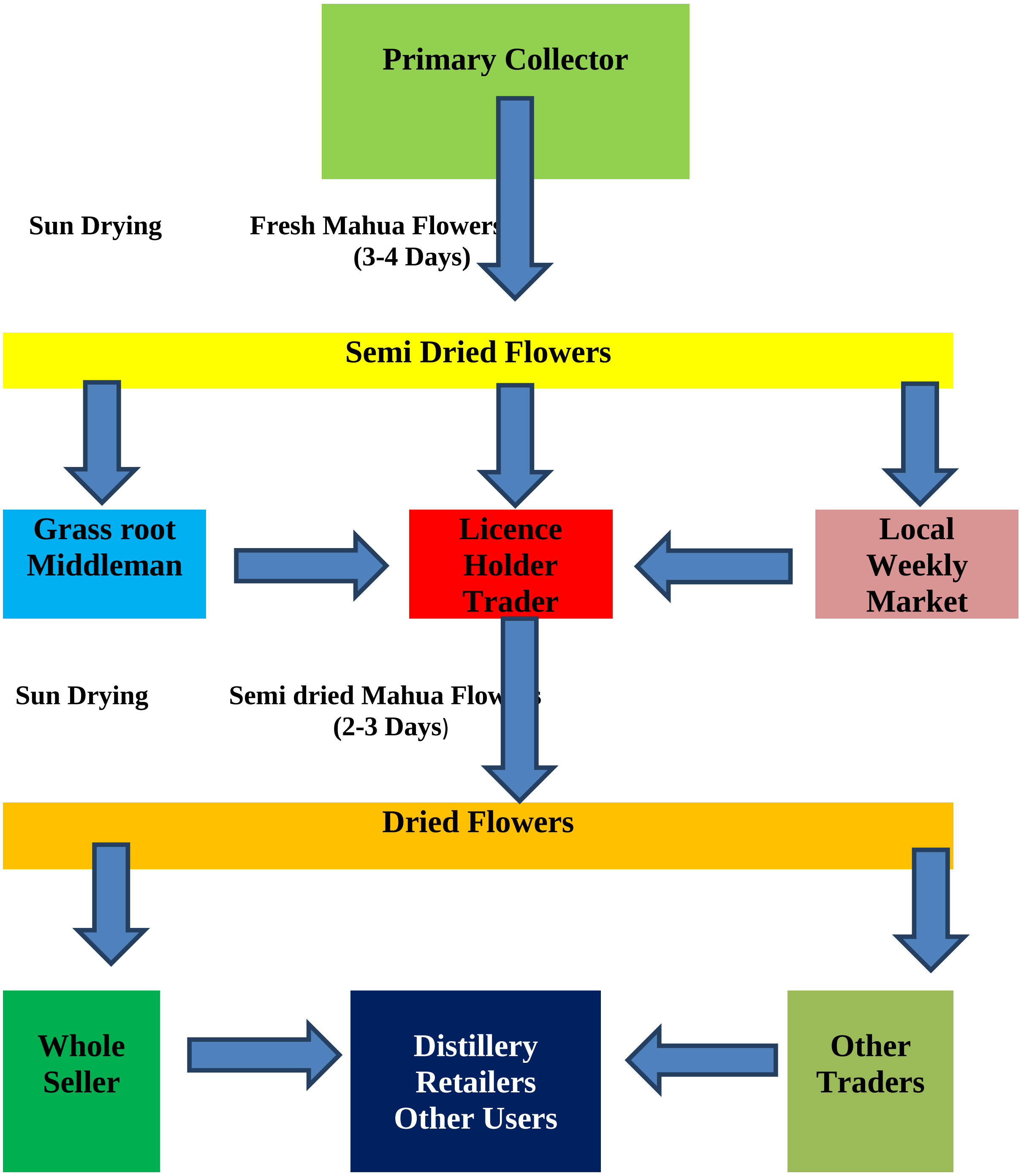

Figure 8.1: Collection, Processing and Marketing of *Madhucalatifolia* flowers

According to the licensed traders they were allowed to collect and sell mahua flowers within 30 km radius and beyond that it requires transit permit which prevents better marketing potentials for the produces within the state.

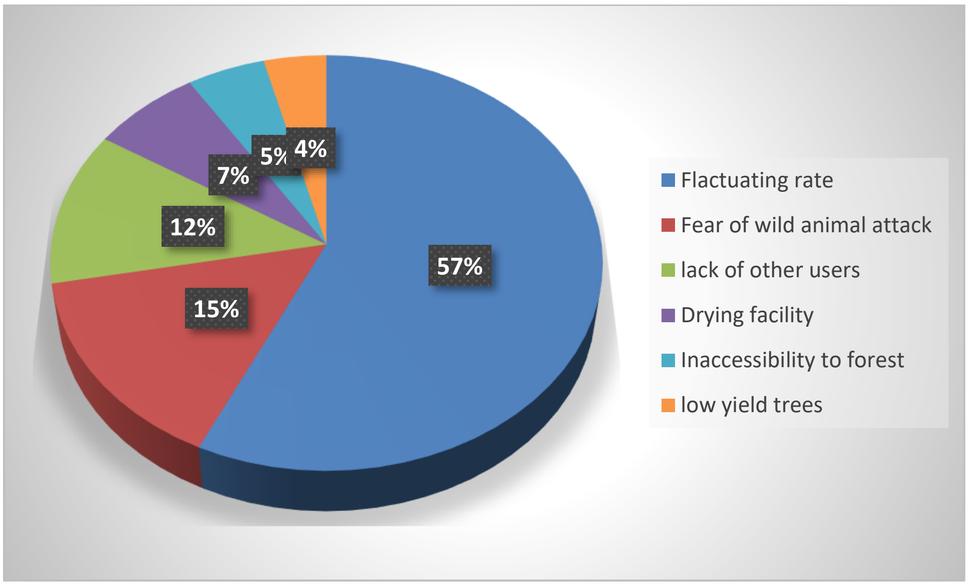

Figure 8.2: Constraints of Primary collectors of Mahua flower and seed

Table 8.1: Demographic Profile of the Districts of study area

District	No. of Blocks	No. of Gram Panchayat	No. of Village	No. of Household	Population	Area (ha)	SC (%)	ST (%)	Rural Population	Sex Ratio	Density (Persons km^{-2})
Sundargarh	17	262	1762	476142	2093437	9712	9.16	50.75	1355340	973	216
Mayurbhanj	26	382	3950	583670	2519738	10418	7.33	58.72	2326842	1006	242
Baleswar	12	289	2932	532281	2320529	3806	20.62	11.88	2067236	957	610
Nayagarh	08	180	1692	227927	962789	3390	14.17	6.1	883051	915	248
Kandhamal	12	153	2587	171120	733110	8021	15.76	53.58	660831	1037	91
Nabarangpur	10	169	891	272537	1220946	5291	14.53	55.79	1133321	1019	231
Koraput	14	226	2042	336200	1379647	8807	14.25	50.56	1153478	1032	157
Malkangiri	7	108	1055	136882	613192	5791	22.55	57.83	536664	1020	106
Nuapada	05	109	668	151761	610382	3852	13.46	33.8	576328	1021	158
Bolangir	14	285	1783	413833	1648997	6575	17.88	21.05	1451616	987	251
Angul	08	209	1871	296168	1273821	6375	18.81	14.1	1067275	943	200

Table 8.2: Demographic Profile of villages under different agroclimatic zones (ACZs) of Odisha

Agroclimatic zone	District	Block	Village	Households No	Population	Scheduled Caste (%)	Scheduled Tribe (%)	Total Land (Ha)
ACZ-1	Sundargarh	Hemgiri	Khodbahal	141	616	14.77	27.92	656
		Hemgiri	Kuchedega	204	979	6.74	37.39	666
		Hemgiri	Ramalata	68	327	72.17	0.00	125
ACZ-2	Mayurbhanj	Bangiriopshi	Chandbil	77	383	0.00	84.33	187
		Bisoi	Sanabalichua	81	374	0.27	87.17	346
ACZ-3	Baleswar	Nilagiri	Tulasidhia	509	2289	21.32	18.79	451
		Nilagiri	Gengutasahi	21	134	0.00	88.81	33
ACZ-4	Nayagarh	Daspalla	Banigochha	248	1149	7.05	14.27	288
		Daspalla	Neliguda	199	862	33.41	0.46	197
		Daspalla	Padapanda	50	232	0.00	26.72	34
ACZ-5	Kandhamala	Kotagarh	Srirampur	298	1588	33.19	9.38	369
		K Nuagaon	Kanjamendi	95	401	1.25	27.68	104
ACZ-6	Nabarangpur	Jharigan	Dhamnaguda	328	1705	10.67	37.65	355
		Dabugaon	Checheriguda	224	1075	21.67	34.42	308
		Dabugaon	Badaliguda	194	940	8.30	63.30	238
ACZ-7	Malkangiri	Mathili	Katapalli	113	622	3.22	79.26	490
	Koraput	Baipariguda	Haladikund	196	979	2.86	41.06	336
ACZ-8	Nuapada	Khariar	Bhaludungri	203	896	18.75	0.00	167
		Nuapada	Tanawat	442	2147	8.90	41.97	832
		Khariar	Kotipadar	318	1410	8.01	0.00	189
ACZ-9	Bolangir	Patnagarh	Hudapalli	36	151	6.62	49.67	308
		Patnagarh	Uluba	573	2361	5.68	27.19	351
		Khaprakhol	Nandupala	233	519	17.34	4.24	570
ACZ-10	Angul	Kishorenagar	Kasturibahal	187	800	17.75	5.75	233
		Kishorenagar	Baniadohali	83	563	0.00	46.71	238
		Kishorenagar	Raibahal	56	298	8.39	56.71	203
		Kishorenagar	Jhampuli	144	729	29.90	4.39	251

Table 8.3: Family size of sample rural population (%) dependant on *M. latifolia*

Agroclimatic Zone	Average no. of Members / Family	Average no. of Males / Family	Average no. of Females / Family	Average no. of Children / Family	Family size Small (Upto 4)	Family size Medium (Upto 5-8)	Family size Large (> 8)
ACZ-1	6.2	2.2	2.2	1.8	70.00	20.00	10.00
ACZ-2	5.6	2.0	1.8	1.8	27.50	60.00	12.50
ACZ-3	5.7	1.8	2.0	1.9	17.50	75.00	7.50
ACZ-4	4.7	1.8	1.7	1.2	50.00	40.00	10.00
ACZ-5	5.6	1.9	1.7	2.0	25.00	65.00	10.00
ACZ-6	4.7	1.8	1.5	1.4	60.00	35.00	5.00
ACZ-7	6.6	2.2	2.0	2.4	7.50	87.50	5.00
ACZ-8	5.5	1.8	1.9	1.8	22.50	75.00	2.50
ACZ-9	6.6	2.3	2.0	2.3	12.50	75.00	12.50
ACZ-10	6.5	2.2	2.3	2.0	30.00	52.50	17.50
Mean	**5.77**	**2.00**	**1.91**	**1.86**	**32.25**	**58.50**	**9.25**

Table 8.4: Agricultural land holdings (Acre) of sample Rural population (%) dependant on *M. latifolia*

Agroclimatic Zone	Average Agricultural land / Household	Major crops cultivated	Marginal (Upto 0.5 ha)	Small (> 0.5–1.0 ha)	Small medium (> 1.0-2.0 ha)	Medium (> 2.0-4.0 ha)	Large (> 4.0 ha)
ACZ-1	3.9	Paddy, vegetables	10.0	20.0	50.0	10.0	10.0
ACZ-2	2.6	Paddy , Groundnut	32.5	40.0	15.0	12.5	0.0
ACZ-3	1.9	Paddy, vegetables	10.0	62.5	27.5	0.0	0.0
ACZ-4	6.0	Paddy, Maize, Brinjal, Green gram, Black gram	0.0	17.5	17.5	55.0	10.0
ACZ-5	2.3	Paddy, Vegetables	30.0	40.0	20.0	5.0	5.0
ACZ-6	1.8	Paddy. Maize	35.0	45.0	20.0	0.0	0.0
ACZ-7	2.7	Paddy, Millet	40.0	40.0	7.5	7.5	5.0
ACZ-8	3.4	Paddy, Green gram, Black gram	7.5	42.5	32.5	15	2.5
ACZ-9	6.3	Paddy, Maize (Sweet corn) , Black gram , Groundnut	5.0	17.5	35.0	27.5	15.0
ACZ-10	7.9	Paddy, vegetables	0.0	10.0	35.0	42.5	12.5
Mean	3.88	Paddy	17.0	33.5	26	17.5	6.0

Table 8.5: Status, collection and utilisation of *M. latifolia* and its produces in sample villages of different agroclimatic zones (ACZs)

Agroclimatic Zone	No.of trees / HH	Period of collection of mahua Flower	Collection of Mahua flower/HH(Qtls)	Mahua flowers selling price (@Rs/ Kg)	Period of collection of mahua Fruits / Seeds	Collection of MahuaSeeds/HH (Kg)	Oil extracted from Seed /HH (Litre)
ACZ-1	8.9	March 3rd week- April 3rd week	4.36	29.00	June 1st week- June 4th week	71.00	28.80
ACZ-2	7.9	March 3rd week- April 3rd week	3.64	23.66	June 1st week- June 4th week	59.92	24.17
ACZ-3	7.3	March 3rd week- April 3rd week	2.58	25.20	June 1st week- June 4th week	31.26	13.50
ACZ-4	6.0	March 3rd week- April 3rd week	3.33	24.17	June 1st week- June 4th week	93.33	32.92
ACZ-5	5.9	March 3rd week- April 4th week	2.30	24.05	June 1st week- July1st week	56.16	24.42
ACZ-6	4.5	March 3rd week- April 4th week	2.74	23.74	June 1st week- July1st week	39.04	15.35
ACZ-7	7.3	March 3rd week- April 4th week	3.76	23.17	June 1st week- July1st week	38.23	14.70
ACZ-8	5.4	March 3rd week- April 3rd week	2.76	24.28	June 1st week- July1st week	41.96	18.43
ACZ-9	6.6	March 3rd week- April 3rd week	7.07	22.60	June 1st week- July1st week	327.4	129.12
ACZ-10	9.0	March 3rd week- April 3rd week	4.11	25.00	June 1st week- July1st week	71.47	26.59
Mean	**6.88**	March 3rd week- April 3rd week	**3.67**	**24.49**	June 1st week- June 4th week	**82.98**	**32.80**

Table 8.6: Contribution of *M. latifolia* to the total income / household / annum

Agroclimatic Zone	Income from Agricultural produce (Rs)	Income from Wages (Rs)	Income from NTFPs other than Mahua (Rs)	Income from Mahua flower (Rs)	Market value Mahua Seed Oil (Rs)	Income from Mahua Tree Products (Rs)	Income from NTFP's (Rs)	Total Income (Rs)	Contribution of Mahua products to income from NTFPs (%)	Contribution of Mahua products to Total income (%)
	A	B	C	D	E	F (D+E)	G(C+F)	H(A+B+G)		
ACZ-1	16070	28980	4540	12497	1440	13937	18477	63527	75.43	21.94
ACZ-2	10622	28400	1130	9090	1188	10278	11408	50430	90.09	20.38
ACZ-3	14378	27333	4716	6956	675	7631	12347	54059	61.80	14.12
ACZ-4	49320	6500	1850	8166	2062	10229	12079	67899	84.68	15.07
ACZ-5	18500	18356	4230	7650	845	8525	12725	49581	66.99	17.19
ACZ-6	18548	22133	4737	7025	767	7793	12530	53212	62.19	14.65
ACZ-7	13608	35452	5412	8688	735	9423	14517	63579	64.91	14.82
ACZ-8	21810	13384	5151	6882	921	7803	12955	47194	60.23	16.53
ACZ-9	76636	15968	1072	16818	5488	22306	23378	115982	95.41	19.23
ACZ-10	51857	16329	1247	10294	1329	11623	12870	81057	90.31	14.34

Table 8.7: List of non-timber forests (other than Mahua flower and seeds), their season of availability/collection/harvesting, parts used and household consumption/sell in the study area

Name of the NTFPs	Species	Family	Months of availability	Consumption/ sale	Parts used
Khaira	*Acacia catechu* (L.f.) Willd	Leguminosae	Jan-Feb, Dec	Sale	heartwood
Chirata/Kalmegh	*Andrographis paniculata* (Burm.f.) Wall. Nees.	Acanthaceae	Aug-Oct	Sale	The aerial portion of the plant
Bael fruit	*Agele mormelos* (L.) Correa	Rutaceae	Feb-Mar	Sale	Fruit
Sitafal	*Annona squamosa* Linn.	Annonaceae	Sep-Nov	Both	Seed, flower
Neem seed	*Azadirachta indica* A. Juss	Meliaceae	May	Sale	
Axle wood	*Anogeissus latifolia* (Roxb. ex DC.) Wall. ex Bedome.	Combretaceae	Jun-Sept	Sale	Leaves for tanning and gums/resin
Jackfruit	*Artocarpus heterophyllus* Lam.	Moraceae	Mar-Jun	Sale	Wild edible fruit
Satavar	*Asparagus racemosa* Willd	Asparagaceae	Mar, Dec	Sale	Root for medicine
Patal plate	*Bahunia roxburghiana* Voigt	Fabaceae	Mar-Apr	Sale	
Chironji	*Buchnania lanzan* Spreng	Anacardiaceae	Apr-May	Sale	Seeds
Palash fruit	*Butea monosperma* (Lam.) Taub.	Fabaceae	Feb	Sale	Fruits/seeds
Kumbhi	*Careya arborea* Roxb	Lecythidaceae	Nov-Dec, Jan-Feb	Sale	Bark and leaves
Garari	Cleistanthus collinus (Roxb.)Benth.ex.Hook.f.	Euphorbiaceae	May	Sale	Fertilizer
Bidi patta	*Dispyros melanoxylon*	Ebenaceae	May	Sale	Edible fruits
Karanja seeds	*Pongamia pinnata*	Fabaceae	Feb-Jun	Sale	Seeds
Kendu fruits	*Dispyros melanoxylon*	Ebenaceae	Apr-Jun	Self-consumption	Fruits

Amla	*Emblica officinalis*	Euphorbiaceae	May, Sep-Nov	Both	Fruits
Bamboo	*Dendrocalamus strictus* (Roxb.) Nees	Poaceae	Mar-Jun	Both	Agricultural tools Thatching
Indian coral tree	*Erythrina suberosa* Roxb.	Fabaceae	Throughout the year	Self consumption	-
Indian boxwwod	*Gardenia latifolia* Ait.	Rubiaceae	Feb-April	Both	Fruits and seeds
Dhaman	*Grewia tilifolia* Vahl.	Boraginaceae	Septembr	Both	Fruits and flower
Anjan	*Hardwica binnata* roxb.	Detarioideae	Oct-Feb	Self	Leaves for fodder
Kurchi	*Holiarhena antidysenterica* (Linn.) Wall. Synonym H. pubescens (Buch.Ham.) Wall. Ex G. Don.	Apocynaceae	Feb-Jun	Self	Fruits and flower
Crape Murtle	*Lagerstoemia parviflora* Roxb.	Lythraceae			
Indian Ash tree	*Lannea coromandelica* (Houtt.) Merr	Anacardiaceae		Self	Leaves for food
Menda	*Litsea glutinosa*		Jan, Mar, Dec		
Honey	*Madhuca Latifolia* (Roxb.) J. F. Macbr,	Sapotaceae	Apr-may, Oct	Both	Flower, fruits, seeds
Mango	*Mangifera indica*	Anacardiaceae	May-Jul	Both	Fruits
Night Jasmine	*Nyctanthes arbortristis* L.	Oleaceae		Both	Flower
Khajur leaves	Phoenix sylvestris	Arecaceae	Jan-Feb, Nov-Dec	Both	Leaves
Indian kino tree	*Pterocarpus marsupium* Roxb.	Fabaceae	March	Self	Fodder plant
Kusum	*Schleichera oleosa* (Lour.) Oken	Sapindaceae	Mar-April	Both	Flower
Bhelwa	*Semecarpus anacardium* L.	Anacardiaceae	Jan-Feb	Sell	Wild edible fruit, fertilizer
Sal Seed	*Shorea robusta*	Dipterocarpaceae	Apr-Jun	Sell	Seeds and leaves
Jamun	*Syzigium cumuni*	Myrtaceae	May-Jul	Both	Fruits

Imli	*Tamarindus indica*		May	Both	Fruits, firewood
Indian redwood	*Soymida febrifuga* (Roxb.) Juss	Meliaceae	Feb-Jun	Both	Bark, fruits, flowers
Bahera	*Terminalia bellerica* (Gaertn.) Roxb.	Combretaceae	Feb-Mar	Sale	Fruits
Harar	*Terminalia chebula* Retz.	Combretaceae	Jan-Mar, Dec	Sale	Fruits
Marda	*Terminalia tomentosa* (Roxb.) Wight & Arn.	Combretaceae	Apr-May	Sale	Fruits
Dhawi /Dhobo Flower	*Woodfolia fructosa*	Lythraceae	Feb	Sale	Flower for churnas and ghritas for various diseases
Ber	*Zizyphus mauritiana*	Rhamnaceae	Jan-Feb, May, Nov-Dec	Both	Wild edible fruits

Figure 8.3: Utilization of *M. latifolia* flowers

Fresh Mahua Flower												
Present Utilisation Status	**Future Scope for Utilisation**											
↓	↓				↓							
Sun Drying	**Puree/pulp/ whole flower**							**Juice**				
↓	↓		↓		↓					↓		↓
Uses	**Ladoo**	**Citric acid**	**Concentrated**	→	**Bakeries**	→	**Buscuit**	←	**Bakeries**	←	**Concentrated**	**Jelly**
Food	**Sauce**	**Medicinal uses**				→	**Cake**	←				
Cattle food	**Jam**			→	**Beverages**	→	**Sharbat**	←	**Beverages**	←		
Liquor	**Pickle**					→	**Wine**	←				
				→	**Confectionary**	→	**Candy**	←	**Confectionary**	←		

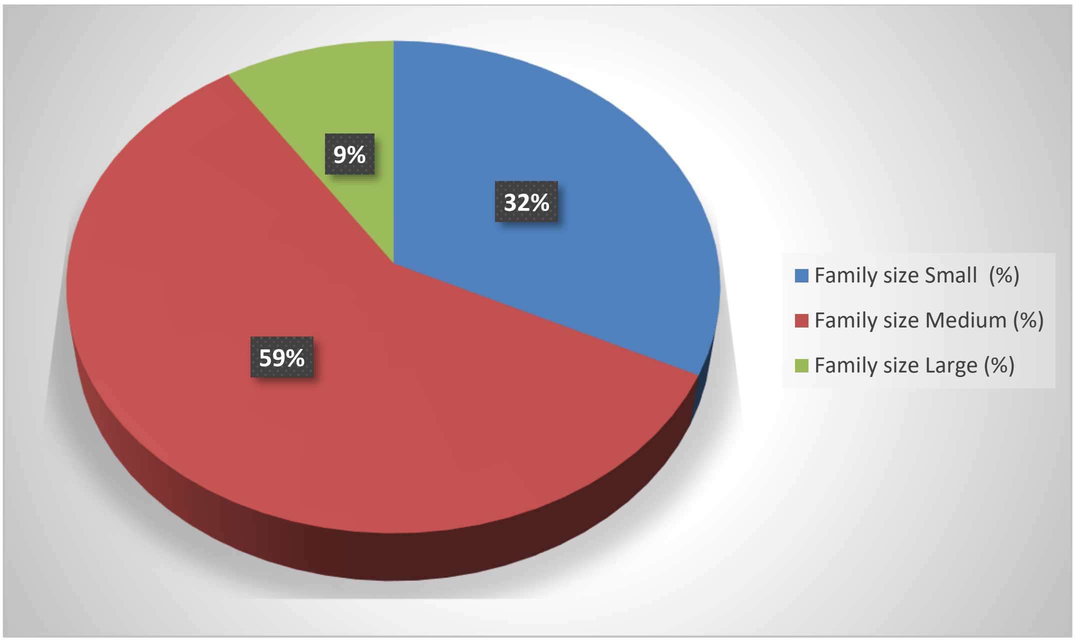

Figure 8.4: Percentage of Family size of respondents

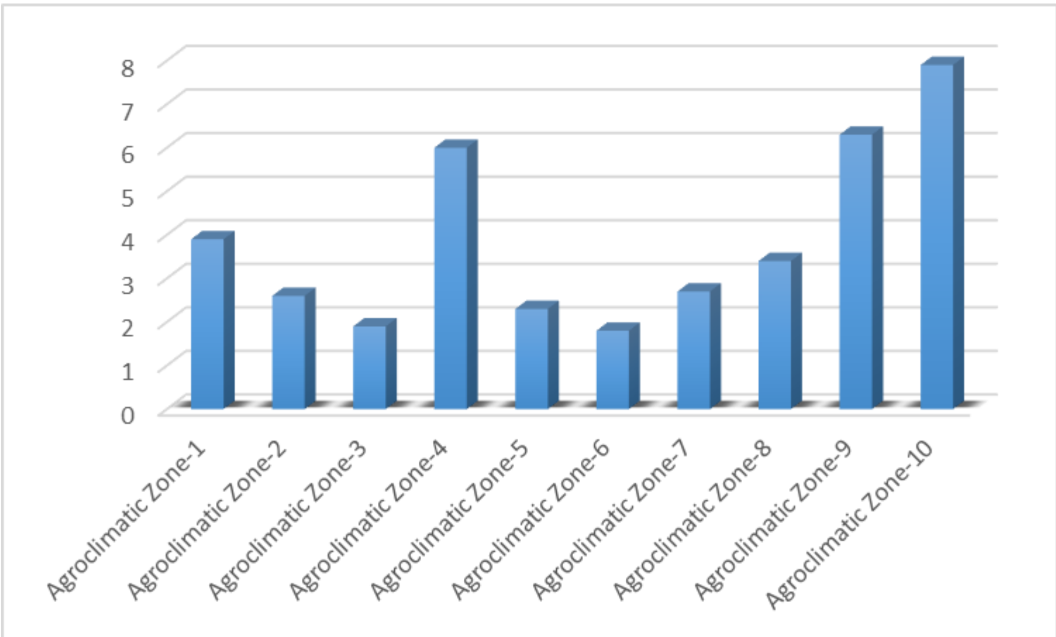

Figure 8.5: Average land holding (Acre / House hold) of respondents under different agroclimatic Zones

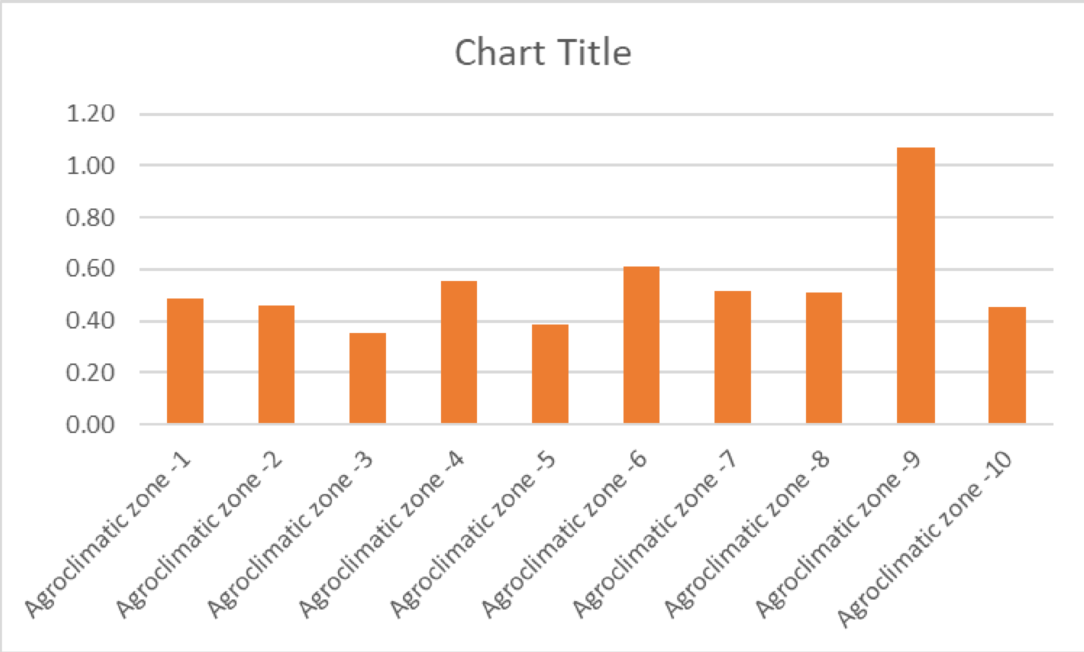

Figure 8.6: Yield of Flowers (Quintals)/ Tree under different agroclimatic zones

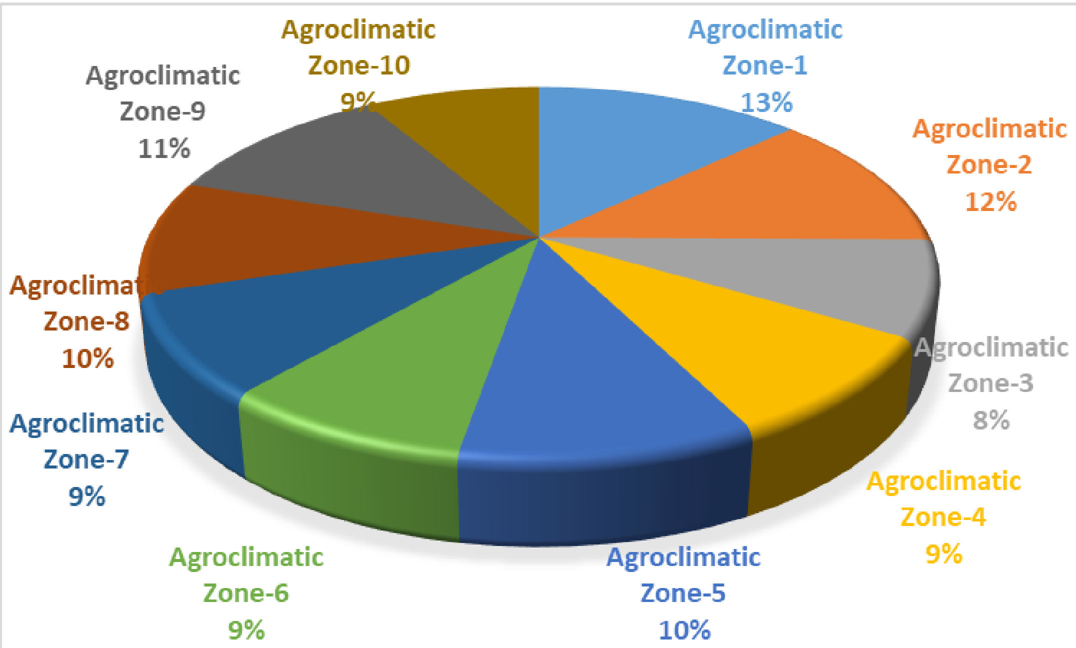

Figure 8.7: Contribution (%) of Mahua flowers and seeds to total income of respondents under different agroclimatic zones

Conclusions

Forest products are integral component of the livelihoods of the tribes and they are most critical and principal suppliers for livelihood. There are various ways in which forest can contribute to the tribal livelihoods such as providing household needs on timber, fuel wood, wild foods, medicinal plants, forest-based agriculture, food security (as safety net during agricultural stress), providing dietary supplements, income generation, income from forest based labour etc. However, there is limited marketing and use of the Mahua products. Widening the scope of mahua flowers marketing, diversifying the use of mahua flowers and seeds, creating important infrastructures for processing of mahua flowers, capacity building ofmahua flower and seed collectors and planting of high yielding mahua trees are some of the suggestive measures which may be undertaken to boost the rural economy especially for the forest dwellers in the state of Odisha.

Plate 8.1 : Processing of *Madhuca latifolia* seeds by villagers

Plate 8.2 : Drying of processed seed kernels of *Madhuca latifolia*

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CHAPTER-9

GENERAL DISCUSSION

Mahua (*Madhuca latifolia* Macbride) is not only one of the most important non-timber forest product tree species but also an ecologically important forest tree species in the state of Odisha. The tribal communities conserve this species owing to its immense socio-cultural importance. The sacredness of the tree may be ascertained due to a varying degree of ceremonies associated with this tree right from the birth of a child till marriage and community meetings frequently held under the tree. The dominance of this species in forests in wild and in domesticated form near agricultural bunds further evinces the conservation and ecological importance of this species (**Chapter-4**). The most noteworthy part is that the tree provides economic up-liftment to the forest dweller households from its flower and fruits which are used in a variety of ways for food, nutrient/ dietary supplements and for many other purposes., The income contribution of mahua to the total NTFPs income per household is substantial (60% in ACZ-8 to >90% in ACZ-9) which confer the substantial role of mahua in the livelihood of the forest dwellers compared to other NTFPs. The income from mahua varies from Rs 7631 to 22306 per household; this requires 15-20 days of hard work during the flowering season. In a season each household collects about 2.30-7.07 quintal of mahua flower per household, which contributes to 14.12 % of the total family income (in ACZ-3) and 21.94% of the total family income in ACZ-1 (**Chapter-8**).

In view of the fact that climate change is a reality, Mahua has been experiencing a gradual shift in fruiting and flowering from mid-March to mid-February which affects the change in local forest ecology. This may also affect the pollination pattern and reduced honey collection and other related forest depended related issues of the dwellers in the state.In the month of mid-February, in Odisha the agricultural season is about to end and farmers are preoccupied with harvesting their produce and therefore an early onset of Mahua flowering owing to climate change during the harvest period leaves less time for the community to collect Mahua which nevertheless affect the household economy. Ecology of Mahua and its phytosociology are other important consideration for understanding ecosystem services. The detailed information pertaining to tree diversity associated with Mahua trees and other diversity-related issues are important to comprehending ecological and organizational processes of plant communities and addressing the livelihood related issues (**Chapter-4).**There is thus a need to carry out provenance trials on this important tree species and to relate the effects of tree origin on climate-growth relationships. It is desirable to identify the provenances which appear more resilient to anticipated climate change. The scanning of provenance provides the best suited and adapted species that are naturally available with ample genetic variations to provide maximum productivity (**Chapter-5**). The importance of seedling studies where good numbers of seed provenances from different geographic origin (and often from different climatic origin) are planted under controlled conditions in a nursery of climate chambers are desirable in developing adaptive forest management strategies. Seedling studies often reveal high correlations of phenotypic and phenological traits with environmental variables and these correlations can be used as predictors for adaptation to current and future environmental conditions. However, since seedling studies are based only on one or very few test environments, the validity of such results for predicting the long-term stability of provenances under a wide range of conditions is limited. On the other hand, seedling studies allow direct tests for extreme conditions, e.g. simulated drought or frost and may therefore mimic effects that under natural conditions only take place on rare occasions. To observe the effect of such single extreme events in provenance tests is difficult, because they are usually controlled and measured in periods of one to five years. Therefore, they can only provide a surrogate for the general fitness of the tested genetic material under the given conditions.

Provenance/seed source studies in forest trees are very important as it helps in identifying the best and highly adaptable provenance. These studies help screen the naturally available genetic variation to utilize the best material for maximum productivity and for further breeding program. In the present study, we observed significant correlations between most of the examined traits. Morphological characters like fruit width, showed significant positive correlation with maximum temperature, minimum temperature and average temperature, fruit thickness with minimum temperature and average temperature, seed width with average temperature, 100 fresh fruit weight with minimum temperature, kernel length significantly positively correlated with average humidity and significantly negatively correlated with difference of maximum and minimum temperature. However, the Oil traits showed no significant positive correlation with the climatic parameters (**Chaper-5**). The correlations with in the germination-seedling characters of seeds showed that Germination percentage had significant positive correlation with mean daily germination, peak value, germination value , collar diameter, fresh seedling biomass and oven dry seedling biomass, Peak value showed significant positive correlation with mean daily germination and germination value whereas collar diameter showed significant positive correlation with seedling length , fresh seedling biomass and oven dry seedling biomass. The correlations among the morphological characters of seeds and germination-seedling characters found only seed length to be significantly positively correlated with fresh seedling biomass where as other traits to be non-significant. The correlations among the oil characters of seeds and germination-seedling characters found only moisture content of seeds to be significantly positively correlated with acid value and free fatty acid content of oil where as other traits to be non-significant (**Chapter-6**). Among all the sample trees under different agroclimatic zones, the best genotype showing maximum values for important morphological characters like maximum fruit length (8.14cm) ,maximum seed length (5.24cm), maximum 100 seed weight (583g), maximum 100 fresh kernel weight (397g) and maximum 100 oven dry kernel weight (273.30g) was sample tree-STMBA 8. The highest values expressed for the traits are due to its genotypic characters and environmental interaction as explained above.

Seed traits are nevertheless crucial fitness-related traits that are expected to underpin survival and reproductive success of plants in different environments. Seed oils serve as the primary energy source to the developing embryo during the heterotrophic stage (Pujar et al. 2006), prior to the initiation of photosynthesis. The quantity and quality of stored oils in seeds is crucial in determining plant fitness, germination success (Linder 2000), emergence and establishment of a plant (Bewley and Black 1994). Earliness of germination was positively correlated with seed lipid content and the seed area to mass ratio (Gardin et al. 2011). Thus, seed traits like seed size, weight and endosperm content determines to a great extent the reproductive success of plants. Studying seed oil content (total content and quality), a trait which is predicted to be under natural selection as it influences initial rapid growth will help us understand the evolutionary significance of seed oil content and will also be of great interest from an economical point of view as it will help in the breeding and cultivation of oilseed crops. Studies of the biogeographic distribution of seed oil content in plants are fundamental to understanding the mechanisms of adaptive evolution in plants as seed oil is the primary energy source needed for germination and establishment of plants (**Chapter-6**). However, seed oil content as an adaptive trait in plants could not be fully understood in the present study. In the present study we observed sufficient variation in seed oil content within and between the agroclimatic zones of this species and however, we could not confirm the predictable pattern of oil seeds in the species along either in an environment gradient or across their latitudinal or altitudinal range and this would require further study. Studying the relationship between seed oil content and latitude will nevertheless help us understand better the role of seed oil content in plant adaptation. However, there are several studies which provide evidences of differences in oil content in different biogeographical regions i.e significant variations in seed oil content of temperate and tropical plants. These studies indicate that multiple seed traits like seed oil content and the fatty acid composition of the seed oils determine the fitness of the plants and validate the adaptive hypothesis that seed oil quantity and quality are crucial to plant adaptation.

Interactions between soil habitat and geographic range/location may also affect plant fitness. Soil characteristics are key aspects of the habitat which are spatially variable. Because soils vary in nutrient levels, water diffusion, metal concentrations (Matthaus, 2012), and because they support different biotic communities (ONeill et al. 2003, Barker and McKenzie 1972) they can have strong effects on plant growth and fitness (Comstock et al. 1969). Further, the environment a plant experiences is partially dependent on interactions between soil substrate and climate. However, in the present study, we could not find any significant relationship between soil characteristics with seed traits, oil yield and oil characteristics (**Chapters-3,4 and 5**). Seed oils primarily accumulate neutral oils (Lersten et al. 2006) which are composed of triacyglycerols (TAGs). Storage of energy rich TAG likely determines the fitness of most plants as it is an immediate energy source for seed germination and plant establishment for 80 % of the plants which rely on TAGs in their seeds (Harwood 1980) while fewer plant species rely on starches and proteins. However, despite the variation, seed oil content is under strict genetic control. The heritability of oil content typically exceeds 50 % (Barker and McKenzie 1972), and plant density, climate and mineral levels in the soil have little effect on the seed oil content (Kittockand Williams 1970). The genetic variation and genetic control of seed oil content shows that seed oil content is under selection and subject to evolutionary change (Levin 1974).Previous studies have investigated the variation in the patterns of seed oil composition (FA composition in seed oils) with latitude within and between species (Sanyal and Linder 2013). These studies have shown that the proportions of saturated and unsaturated FAs and subsequently their melting points vary with latitude (Sanyal and Linder 2013). On a per carbon basis, unsaturated FAs cost more to produce and yield less energy when oxidized than saturated FAs (Lehninger 1993). Thus, at lower latitudes, seeds with higher proportions of saturated oils would be favoured because they would have more energy for growth without delaying or slowing germination. At higher latitude and cooler germination temperatures, seeds that have a higher proportion of unsaturated oils may germinate earlier and/or more rapidly than seeds that are higher in saturated FAs. The extra potential energy in seeds with higher proportions of saturated oils would be wasted as evidence suggests that lipases that catalyze the removal of FAs from glycerol prior to *ß*-oxidation operate more rapidly on liquid substrates (Huang 1992, Miquel and Browse 1994, Thompson and Li 1997).

The quality of seedlings produced in a simulated environment/nursery condition by drawing seeds from various seed source would determine the genotype of the seed from which it is originates. Characteristics of the seeds, especially the stored energy in seed oils and the nature of seed oil is crucial for successful germination and reproduction. The extent of variability observed in the species is also accessed by genotypic and phenotypic variances and genotypic and phenotypic coefficient of variation. The species showed higher values of Phenotypic coefficient of variation than Genotypic coefficient of variation in germination and seedling characters (**Chapter-6**) which indicates environmental factors has also a role in expression of the characters (Mohamed et al. , 2015). Higher PCV, GCV and CV values in an agroclimatic zone indicates higher variation of the trait in that zone (Wani and Wani , 2017). Again, higher the difference between the PCV and GCV value and higher the CV value indicates more influence of environmental factors for expression of the character in the particular agroclimatic zone (Reddy et al., 2011). In the above study also the differences observed for most of the germination and seedling parameters are genetic in nature because the environmental deviations were found less for the experimental site, while the randomization and replication might have further reduced the chances of side effects. This also explains the variation in observed phenotypic values (Vakshasya et al., 1992). However, characters like seedling length and fresh seedling biomass showed higher environmental variation than other characters. Seedlings from seeds obtained from the East and Southern regions consistently had higher shoot dry weight and total biomass than seeds obtained from the North and western regions. This could be attributed to the higher average growth rates recorded by seedlings of seeds from the east and south probably due to their large seed sizes. These are areas that favour the growth of forest trees. These results agree with Lauridsen and Kjaer (2002) who stated that seed source had an influence of growth and development of *Gmelina arborea*. Results of the correlation analysis showed strong positive correlation (r = 0.91) between seedling height and total biomass. Similarly, a positive correlation was observed between shoot dry weight and total biomass (r = 0.72) while the correlation of root dry weight and total biomass was very weak (r = 0.45). Seedling height had a strong positive correlation with shoot dry weight (r = 0.82).

However, there are certain advantages and disadvantages of provenance trials of seeds kept in a common garde. The basic test design for provenance trials is a common garden test, where seedlings from different provenances are grown parallel under site conditions as similar as possible. However, the actual soil or environmental conditions for each plant are varying even within a mostly homogeneous test areaand on how to remove such effects(Sackville 2001). Therefore, trees are planted in multiple repetitions to compensate for any site heterogeneities. The most common layout plan is a randomized block design, which can be either complete, i.e. all provenances are planted throughout all blocks (repetitions) or incomplete, where the blocks do not contain the complete set of provenances. Moreover, in field trials over several sites, it can be distinguished between balanced and unbalanced designs, wherein the latter, the same provenances are not tested at all sites. For such unbalanced trials it has been recommended to use certain provenances as standard populations to which the others can be compared (Middleton et al. 2010). To use data of provenance experiments for the development of adaptation schemes, the field data have to fulfill few requirements: First, seed collections and the seed origins have to be well documented. Coordinates of provenances and test sites should be available as accurate as possible. Also, seed origins should be mostly autochthonous in order to find adaptations to the local climate. Second, provenances should be planted on a wide spectrum of test sites covering at least the natural range of climate conditions where the species occurs. If possible, few test sites should be beyond the natural range of the respective species. Third, for climate transfer and universal transfer functions it is also necessary to collect provenances from a wide climatic range in order to enable statistically valuable calibrations. Many provenance experiments do not meet all of these requirements sufficiently, which might result in low statistical power.

Seed storage and the container in which the seeds are stored and the exposure and duration may affect the quality and content of oil. *M. latifolia* has a very high yield of seeds containing large percentages of long and short chain fatty acids (mainly palmitic fatty acid, along with some oleic, linoleic and linolenic fatty acids). The oil content of the stored seeds decreased continuously with increase in storage time irrespective of storage container and storage conditions (**Chapter-7).** The mean oil content decreased to minimum (40.25%) after 180 days of storage with maximum degradation (21.43%). The decrease in oil content is due to degradation of oil which may be due to the interaction effect of physical environment of storage conditions like air, light, temperature and humidity with more exposure to storage time favouring degradation in oil content. These experiments provided evidence that, after 180 days of storage, a controlled atmosphere did not produce any remarkable advantage over low cost air storage.The results validate the belief that no elaborate storage conditions are required to store this economically promising high oil content species.

Both seed provenance and site characteristics affected the performance of this species in term of oil content and oil quality to a great extent. However, our study was not designed to distinguish which aspects of the environment contributed to these differences. Besides, our study had a lot of limitations so far as the qualitative and quantitative characterization of the seed reserves derived from different seed sources are concerned. In many cases, larger seeds have been related to larger seedlings and to a higher probability of seedling survival (Poorter and Rose 2005). However, a relationship between reserves and seedling growth has rarely been reported (Ichie et al.

2001, Finkelstein and Grubb 2002). A higher concentration of lipids may be a complementary strategy to enhance total energy availability to seedlings (Levin, 1974; Finkelstein and Grubb, 2002). Future research should assess whether changes occur in seed reserves (due to the influence of the variations in climatic conditions (such as temperature, precipitation, other macroclimatic conditions in the provinces/seed source), nature of seed reserve (chemical constituents) affected by size variation in seeds, the mobilization of reserves during germination process.

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SUMMARY AND CONCLUSIONS

The present investigation entitled, "Effects of seed source, storage conditions and duration on germination, seedling traits and oil content in *Madhuca latifolia* Macbride in Odisha" was carried out in the experimental sites ,laboratory of College of Forestry and laboratory of Department of Soil Science, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha during the period 2016-2018. The main objectives of the study were:

(i) To assess the extent of variability in seed characters and oil content of *Madhuca latifolia* Macbride from different provenances of Odisha

(ii) To determine the effect of different storage conditions and duration on oil content of *M. latifolia*

(iii) To study the economic importance of fruits and flowers of *M. latifolia* on the livelihood of the local people

Seven experiments were conducted to meet these objectives detailed as follows:

1. Studies on variation in morphometric characters of fruits of *M. latifolia* Macb.
2. Studies on variation in physico-chemical properties of oil from seeds of *M. latifolia*
3. Studies on soil chemical properties of provenances of *M. latifolia*
4. Studies on ecological characters of *M. latifolia* in different agrocimatic zones
5. Studies on variation in morphometric characters of seedlings of *M. latifolia*
6. Effect of different storage conditions and durations on seed oil content and its physico-chemical properties of stored seeds of *M. latifolia*
7. To assess the economic *importanc*e of fruits and flowers of *M. latifolia* on the livelihood of the loc*al people.*

In the **first experiment** , fruits were collected from both from forest area and agricultural land area separately from all ten agroclimatic zones (ACZ) of Odisha .The fruit length (cm), fruit width (cm), fruit thickness (cm) , seed length (cm), seed width (cm), seed thickness (cm), seed helium length (cm), kernel length (cm), kernel width (cm), kernel thickness (cm) , 100 fruit weight (gm) , 100 seed weight (gm) , 100 kernel weight (gm) and 100 oven dry kernel weight (gm) of the sample trees were found to have significant variation .

The highest Fruit length (8.14cm) , Seed length (5.24 cm) , seed hilum length (4.69 cm) , 100 seed weight (583 g) , 100 kernel weight (397 g) and 100 oven dry kernel weight (273.3 g) in case of sample tree STMBA8 under ACZ – 2 , fruit width (4.10 cm) and fruit thickness (3.90 cm) in case of sample tree STBSA8 under ACZ– 3, seed width (1.99 cm) in case of sample tree STAGA 2 under ACZ– 10 , seed thickness (1.84 cm)) in case of sample tree STNPF1 under ACZ– 6 , kernel length (4.02 cm)) in case of sample tree STNPF2 under ACZ– 6 , kernel width (1.64 cm)) in case of sample tree STNWF1 under ACZ– 8 , kernel thickness (1.63 cm)) in case of sample tree STNPA1 under ACZ– 6 and 100 fruit weight (2310 g)) in case of sample tree STMGA8 under ACZ– 7 . The seeds from the above trees can be collected as per the required seed trait to raise seedlings of better quality for future plantation and for research purposes. It was also found that the sample tree showing higher values for important morphometric characters was STMBA8 .

Analyzing the variation of fruit characters under individual ACZ, the morphological characters showed higher value of coefficient of variations are seed thickness (10.64) in ACZ-10, seed helium length (10.22) in ACZ-3 and 100 fruit weight (11.25)in ACZ-9in case of forest lands . It helps for selection of a character with higher coefficient of variation in a particular ACZ. The above mentioned zones can be considered for selection purposes of that particular character for further improvement studies of the species. Similarly, from agricultural lands also morphological characters that showed higher value of coefficient of variations are seed length (11.21) in agroclimatic zone-6, kernel length (11.55) in ACZ-6and 100 fresh kernel weight (13.96) in ACZ-1which can be considered for selection purposes for further improvement studies of the species.

In some of the ACZ various morphological characters showed significant differences betweenthe mean values of fruits collected from forest lands and agricultural land. It was also found that the coefficient of variation of a particular character within a ACZ is higher than the coefficient of variation of the same seed character among the ACZ

Comparing among different agroclimatic zones, higher value of coefficient of variation were recorded for morphological characters of the fruits collected from forest lands like 100 fruit weight (5.28), fruit length (4.77) , kernel width (4.46) and kernel thickness (4.31). Similarly, Higher value of coefficient of variation were found for morphological characters of the fruits collected from agricultural lands like kernel width (4.75), kernel thickness (4.50), 100 kernel weight (3.63) and kernel length. It signifies that these characters can be useful for selection purposes when selection is carried out from the *M. latifolia* population present throughout the state (i.e. from all agroclimatic zones) not in a particular ACZ.

The mean values of morphometric characters of fruits collected from forest lands and agricultural lands under different ACZwill be helpful for collection of seeds of desirous trait in large scale (for industrial or other utilization aspects) from zone recording higher mean value . For the seeds collected from forest lands, the highest mean kernel length (3.12 cm) , kernel width (1.51 cm) and hilum length (3.18 cm) were found in ACZ-3 , seed thickness (1.75 cm) and kernel thickness (1.52 cm) was found in ACZ-6 , seed length (3.50 cm) and 100 fresh kernel weight (283.59 g) was found in ACZ-5 , fruit length (5.32 cm) was found in ACZ-1 and 100 fruit weight (1711.39 g) was found in ACZ-10. Similarly for the seeds collected from agricultural lands highest value were found in fruit width (3.55 cm) , fruit thickness (3.48 cm) and 100 seed weight (410.75 g) was found in ACZ-3, seed weight (1.82 cm)) was found in ACZ-1, kernel length (3.12 cm) in) was found in ACZ-6 and 100 oven dry kernel weight (195.44 g) was found in ACZ-5 .

In the **second experiment**, seeds of *M. latifolia* Macb. collected from 10 ACZ of Odisha and observations were recorded for Physico-chemical properties like Oil content (%), acid value , saponification value , ester value, FFA (%), iodine value , specific gravity and specific gravity . All characters except density and specific gravity of oil found to have significant variation among the sample trees under each zone.

The highest Oil content (51.84 %) was observed in case of sample tree STSGF 7 under ACZ– 1from the seeds collected from forests lands. However, in case of seeds collected from agricultural lands the highest Oil yield (125.08 g) was observed in sample tree STMBA 8 under ACZ– 2, saponification value (271.20) and ester value (268.12) in case of sample tree STKMA9 under ACZ– 5 , iodine value (68.07) in case of sample tree STBSA 8 under ACZ– 3 and lowest acid value (0.67) and free fatty acid content (0.34) in case of sample tree STAGA4 and STAGA7under ACZ– 10. The seeds from the above trees can be collected as per the required oil trait to raise seedlings of better quality for future plantation to meet the food and industrial requirement and for research purposes. It was also found that the sample tree showing higher values for some important oil characters was STMBA8.

Analyzing the oil content and physico-chemical properties of oil derived from fruits collected from forests and agricultural lands from different ACZ higher value of coefficient of variations are found in the agricultural lands than forest lands . Higher variation were found for FFA in ACZ-6 (28.82%), acid value in agroclimatic zone-3 (15.43) , Saponification value in ACZ-10 (10.55) and oil content in ACZ-6 (9.36) . The above mentioned zones can be considered for selection purposes of that particular character for further improvement studies on the species.

In some of the ACZ various oil characters showed significant differences between the mean values of fruits collected from forest lands and agricultural land. It was also found that the coefficient of variation of a particular oil character within a ACZ is higher than the coefficient of variation of the same oil character among the ACZ.

Comparing among different ACZ,, higher value of coefficient of variation were recorded for oil characters of the seeds collected from forest lands like acid value (13.72) and Iodine value (5.27), whereas, higher value of coefficient of variation were recorded for oil characters of the seeds collected from agricultural lands are free fatty acid content (12.71) , oil content (7.92) , saponification value (5.71) and oil yield (4.11) .

The mean values of oil characters of seeds collected from forest lands and agricultural lands under different agroclimatic zones will be helpful for collection of seeds of desirous trait in large scale (for industrial or other utilization aspects) from zone recording higher mean value .Basing on the oil characters , seeds collected from forest land under agroclimatic zone -8 may be collected for both food and industrial value as it has higher oil content (43.21%) , oil yield (80.91g), saponification value (212.17) and lesser free fatty acid content (1.92) and iodine value (55.42).

In the **third experiment,** soil profiles were exposed in both natural forest and agricultural lands having *M. latifolia* distribution under different ACZ. The soil were then collected for each profile from four zones i.e. 0-25cm , 25-50cm, 50-75cm and 75-100cm and tested for soil pH, soil electrical conductivity, soil organic carbon , available soil nitrogen, available phosphorus and available potassium.

It was found that pH value of soil in case of both forest as well as agricultural land in most of the ACZ to be acidic and pH was found to be increasing from top to the bottom layer of profile in most of the ACZ. The mean pH of agricultural land was found to be more than mean pH of forest land in all ACZ. The mean pH of soil profile of forest lands from different ACZfound to be acidic -neutral ranged between 5.51 – 6.97 , whereas, of agricultural land found to be acidic -alkali ranged between 6.03 – 7.59 .

It was found that EC value of soil in case of both forest as well as agricultural land in most of the agroclimatic zone found to be in normal range and decreasing from top to the bottom layer of profile . In case of forest land the mean EC ranged between 0.024 - 0.118 where as for agricultural land it ranged between 0.044 -0.169 .The mean EC of agricultural land was found to be more than mean EC of forest land in most of the ACZ.

Organic Carbon (SOC) Concentration of soil found to be decreasing from top to the bottom layer of profile in case of both forest as well as agricultural land in most of the ACZ. In case of forest land the mean SOC concentration ranged between 0.24 -1.04 where as for agricultural land it ranged between 0.29-0.66 .The mean SOC concentration of forest land was found to be more than that of agricultural land in most of the ACZ.

Available nitrogen of soil found to be decreasing from top to the bottom layer of profile in case of both forest and agricultural lands in most of the ACZ. In case of forest land the mean available nitrogen ranged between 71.88 kg/ha – 140.63kg/hawhere as for agricultural land it ranged between 65.63 kg/ha - 156.25 kg/ha .The mean available nitrogen of agricultural land was found to be more than that of forest land in most of the ACZ except ACZ3, 9 and 10 .

Available phosphorus of soil found to be decreasing from top to the bottom layer of profile in case of both forest and agricultural lands in most of the ACZ. In case of forest land the mean available phosphorus ranged between 2.49kg/ha – 8.25 kg/ha whereas for agricultural land it ranged between 6.14kg/ha – 21.70 kg/ha . The mean available phosphorus in soil agricultural land was found to be more than that of forest land in most of the ACZ. In both forest and agricultural lands, the available potassium of soil found to be increasing from top to the bottom layer of profile in some ACZ and decreasing in other zones . The mean available potassium ranged between 135.40 kg/ha – 901.78 kg/ha in forest land where as for agricultural land it ranged between 73.46 kg/ha – 545.15 kg/ha. Besides that the mean available Potassium was found higher in some ACZ in the soil of agricultural land and other ACZ in the soil of forest land.

The available Sulphur is found with higher values in the top layer of soil profile in some agroclimatic zones and higher in other layers of profile in rest of the ACZ. The mean available potassium ranged between 12.40 kg/ha – 48.00 kg/ha in forest land where as for agricultural land it ranged between 8.97 kg/ha – 14.99 kg/ha .The mean available Sulphur was found higher in all ACZ in the soil of forest lands .

In the **fourth experiment** ,tree associate study of *M. latifolia* in under taken in different natural forest 10 agroclimatic zones of Odisha . The study was carried out in the outer fringe of the natural forest which are mostly protected by villagers through Joint forest Management and from where the dependants collect the Non Timber Forest Products including Mahua flowers and seeds .

The Shannon-Wiener index (H′) for all the natural forests studied under different ACZ ranges from 1.592 – 2.560 (Table: 37-46) with maximum in agroclimatic zone - 9 and minimum in ACZ- 5.*M. latifolia* showed higher density inACZ2 (137.5 stems/ha), ACZ3 (127.25 stems/ha) and agroclimatic zone 5 (123.25 stems/ha) and contributes alone 17.41 %, 17.91% and 26.63% respectively of their total tree density. The relative frequency of *M. latifolia* was recorded maximum in forest under ACZ5 (20.83) and minimum in forest under ACZ10 (11.53) and it showed random dispersal pattern in most of the agroclimatic zones and contiguous dispersal pattern in few ACZ. In most of the ACZ, *Shorea robusta*, *M. latifolia* and *Buchnania lanza*nare found to be associated with each other in natural distribution. The IVI for *M. latifolia* was found between 84.27 - 28.25 with maximum in ACZ5 and minimum in ACZ10 .

In the **fifth experiment**, the seeds collected from different sample trees under various agroclimatic zones were evaluated by nursery testing, seedlings were raised from seeds of *M. latifolia* collected from all agroclimatic zones of Odisha and observations were recorded for germination percentage, seedling length, collar diameter, fresh seedling biomass , oven dry seedling biomass , mean daily germination, peak value, germination value, moisture content and shoot vigour index .

The germination percentage of all ACZ varies from 27 % -100 % in case of seeds collected from forest lands where as the germination of all provenances varies from 37 % -100 % in case of seeds collected from agricultural lands. The shoot vigour index of all agroclimatic zone varies from 394.2-2962.0 in case of seeds collected from forest lands where as the shoot vigour index of all ACZ varies from 2.57g-4.83g in case of seeds collected from agricultural lands. The seedling oven dry biomass of all ACZ varies from 394.2-2962.0 in case of seeds collected from forest lands where as the seedling oven dry biomass of all ACZ varies from 1.88g-4.81g in case of seeds collected from agricultural lands.

For the seedlings raised from the seeds collected from forest lands, higher variations with in each zone were found for all the germination traits with highest in germination value. ACZ-10 showed maximum variations with in the ACZ for the germination traits like germination value (PCV-88.29 , GCV-87.97 and CV-6.99) , germination percentage (PCV-49.57, GCV-49.02 and CV-7.39) , mean daily germination (PCV-49.06 , GCV-48.91 and CV-5.22) and peak value (PCV-46.54 , GCV-46.37 and CV-4.68) . Seedling traits like shoot vigour index, seedling length, fresh seedling biomass and oven dry seedling biomass showed higher variations with highest in shoot vigour index. ACZ-5 showed maximum variations within the ACZ for the seedling traits like shoot vigour index (PCV-50.57 , GCV-50.44 and CV-3.68), oven dry seedling biomass (PCV-17.39 , GCV-15.67 and CV-7.59) and fresh seedling biomass (PCV-17.18 , GCV-14.10 and CV-9.83).

Similarly, in case of seedlings raised from the seeds collected from trees on agricultural lands, ACZ-3 showed maximum variations (PCV, GCV and CV values) with in the ACZ for most of the germination traits except germination value which has second highest variation after ACZ-10 . Seedling traits showed maximum variation in for most of the traits in agroclimatic zone -8 except shoot vigour index which found second highest after ACZ-5.

These germinating and seedling traits has a scope for further assessment of variability in their respective ACZ mentioned above that will helpful for the improvement of the species.

From seedlings raised from all the sample trees seeds , maximum germination percentage (100%) and other germination characters were found in sample tree - STAGA 6 where as important seedling characters like Shoot vigour index (2962.00) and seedling oven dry biomass (15.34 g) were found to have maximum value in sample tree -STKMF 1 in ACZ-5.

In the **sixth experiment**, the oven dried seed sample of *M. latifolia* were stored in different containers (Polybags, Cotton bags and Plastic containers) under various storage conditions (open light, closed light, closed dark and dark) for 180 days. The oil was extracted and its physico-chemical properties were studied at different intervals (at the time of storage, 30 days , 60 days, 90 days, 120 days, 150 days and 180 days after storage) for each sample . The observations recorded were for the oil content (percentage), Acid value, Saponification value, Iodine value, Density and Specific gravity.

The mean oil content (averaged for all storage containers and storage conditions) was maximum (51.23%) at the time of storage of seeds and decreased to minimum (40.25%) after 180 days of storage with maximum degradation (21.43%) .Maximum oil was extracted from seeds stored under closed light condition irrespective of container. Irrespective of storage conditions and storage durations, seeds stored in container like polythene bags gave maximum oil than other containers. After 180 days of storage the maximum oil content (48.01%) was found in the seeds stored in closed polythene bags kept in light.

The acid value and FFA % of the oil extracted from stored seeds found to be increased from the time of storage (6.45 ; 3.24) till 180 days of storage period (75.15 ; 37.77) irrespective of storage container and conditions. Irrespective of storage conditions and storage durations, seeds stored in container like plastic containers gave minimum acid value and FFA% of oil than other containers. Similarly, irrespective of storage containers and storage durations, seeds stored in Closed dark condition recoded low acid value and fatty acid % . After 180 days of storage, the best storage condition with least acid value (40.17) and FFA% (20.19%) was the seeds stored in closed dark plastic container.

The saponification value of oil extracted from stored seeds decreased irrespectively of storage containers and storage durations from the day of packing (162.90) till 180 days of storage (68.17). Irrespective of storage conditions and storage durations, seeds stored in container like polythene bags gave maximum saponification value of oil than other containers. Similarly, irrespective of storage containers and storage durations, seeds stored in closed dark condition recoded higher saponification value of oil . After 180 days of storage the maximum saponification value of extracted oil (89.83) was found in the seeds stored in closed polythene bags kept in dark .

The Iodine value of oil extracted from the seeds at the time storage (62.70) was low The Iodine value of oil from the stored seeds decreased irrespective of storage containers and storage durations from the day of packing till 180 days of storage (39.83) .Irrespective of storage conditions and storage durations, seeds stored in container like polythene bags gave maximum Iodine value of oil than other containers. Similarly, irrespective of storage containers and storage durations , seeds stored in closed dark condition recoded higher iodine value of oil . After 180 days of storage the maximum iodine value of extracted oil (43.60) was found in the seeds stored in closed polythene bags and plastic containers kept in dark.

Density and specific gravity of oil extracted from stored seeds increased irrespectively of storage containers and storage durations from the day of packing (0.891; 0.898) till 180 days of storage (0.897; 0.904). Seeds stored in container like polythene bags gave maximum density and specific gravity of oil than other containers irrespective of storage conditions and storage durations. Similarly, irrespective of storage containers and storage durations, seeds stored in closed dark condition recoded higher density and specific gravity of oil .After 180 days of storage the maximum density and specific gravity of extracted oil (0.901; 0.908) was found in the seeds stored in closed polythene bags and plastic containers kept in dark.

In the **seventh experiment**, this investigation was carried out in the villages near to forests and also having *M. latifolia* trees under traditional agroforestry systems like field bunds and homesteads on which local people depend to certain extent for their livelihood . The study was carried out in 2-3 villages with total of forty respondents under each ACZ.

It was found that more than 80% of the respondents size belongs to medium and small sized family in all agro climatic zones . It was found that 58.50 % of respondents had medium sized family, 32.25 % had small families and 9.25 % of respondents had large families . The average land holding of respondents in the study area over all ACZ ranged 1.8 – 7.9 acre (0.72 – 3.16 ha) with an average of 3.88 acre (1.55 ha) .Contribution of Mahua products to the total income generated from NTFPs it was found that maximum contribution was found in case of agroclimatic zone -9 (95.49%) and minimum contribution in case ofACZ-8 (60.23%) . Similarly, Contribution of Mahua products to the total income generated from all sources was found maximum (21.94%) in ACZ-1 and minimum (14.12%) in ACZ-3 . The selling rate of dried mahua flowers at primary collector level varies from place to place and ranges between Rs 22.60 - Rs 29.00 / kg over all ACZ of Odisha with maximum in ACZ- 1 and minimum in ACZ- 9 . The mean collection of mahua flowers and mahua seeds per household across all agroclimatic zones of Odisha was about 3.67 Qtls and 82.98 kg respectively. The trade of Mahua flowers of approximately 7,92, 000 Quintals occurs in the state contributing about Rs 1.93 crore to the primary collectors of the state.

On the basis of the result obtained from the present investigation " Effects of seed source, storage conditions and duration on germination, seedling traits and oil content in *Madhuca latifolia* Macbride in Odisha" following conclusion were drawn:

1. Higher variations in seed characteristics like seed thickness , seed helium length , 100 fruit weight , seed length, kernel length and 100 fresh kernel weight of *M. latifolia* occurs in the germplasm collected from various agroclimatic zones and these can be taken up for improvement of the species.
2. More variation occurs within sample trees of agroclimatic zone than among the agroclimatic zones in both morphometric characters of *M. latifolia* seed and its seed oil characters.
3. Sample tree of *M. latifolia* showing higher values for important morphometric characters and oil characters was STMBA8 .
4. Higher variation were found for oil characters of *M. latifolia* like Free fatty acid , acid value, Saponification value and oil content in the germplasm collected from various ACZ which can be taken up for improvement of the species .
5. *M. latifolia* has higher IVI values along with *Shorea robusta* in most of the forests under different ACZ.
6. Higher variation occurs in germination traits like germination value, germination percentage, mean daily germination and seedling traits like shoot vigour index, oven dry seedling biomass and fresh seedling biomass.
7. In order to extract maximum oil, seeds should be stored in closed polythene bag in light.
8. In order to maintain the quality of oil with higher oil content, seeds should be stored in closed dark condition.
9. Flowers and fruits of *M. latifolia* contributes about 21.94% - 14.12% of the total income of tribal people dependent on it.

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Annexure-1: Geocoordinates and morphometric attributes of CPT (Candidate Plus Tree) of *M. latifolia* in Agroclimatic Zone (ACZ)-1

Land Type	Sample Tree No.	Sample Tree Code	Place of collection	District	Longitude	Latitude	Altitude (Ft.)	Tree Height (m)	GBH (Ft.)	Crown area (m^2)	No. of fruits /Bunch	Bunches/ Tree
Forest Land												
	1	STSGF 1	Surulata	Sundargarh	83°36'29.3"	21°58'34.6"	910.1	8.0	3.33	33.18	3 to 10	85
	2	STSGF 2	Surulata	Sundargarh	83°36'30.6"	21°58'34.0"	918.9	13.0	6.32	70.89	5 to 12	150
	3	STSGF 3	Surulata	Sundargarh	83°36'33.8"	21°58'31.5"	947.3	12.0	6.12	165.15	4 to 14	250
	4	STSGF 4	Surulata	Sundargarh	83°36'38.9"	21°58'16.9"	938.9	14.0	7.32	143.15	3 to10	280
	5	STSGF 5	Surulata	Sundargarh	83°36'33.4"	21°58'15.7"	937.4	11.0	5.46	63.62	3 to 10	400
	6	STSGF 6	Surulata	Sundargarh	83°36'27.1"	21°58'21.8"	912.4	12.5	6.13	121.10	2 to10	215
	7	STSGF 7	Surulata	Sundargarh	83°36'41.6"	21°58'22.9"	918.4	13.5	6.46	137.45	3 to10	230
	8	STSGF 8	Surulata	Sundargarh	83°36'43.5"	21°58'24.5"	927.5	11.5	5.21	70.34	5 to12	118
	9	STSGF 9	Surulata	Sundargarh	83°36'39.7"	21°58'29.6"	931.2	11.5	5.13	72.61	5 to13	105
	10	STSGF 10	Surulata	Sundargarh	83°36'46.8"	21°58'19.6"	920.7	11.0	5.27	67.58	4 to 15	178
Agricultural Land												
	1	STSGA 1	Jareikela	Sundargarh	83°39'23.5"	21°58'2.1"	956.3	8.0	3.99	42.63	3 to 10	90
	2	STSGA 2	Jareikela	Sundargarh	83°39'23"	21°58'0.5"	940.2	8.0	5.99	63.62	3 to 12	200
	3	STSGA 3	Jareikela	Sundargarh	83°39'31.3"	21°57'52.4"	983.0	7.0	4.66	50.27	4 to 19	100
	4	STSGA 4	Jareikela	Sundargarh	83°39'15.5"	21°58'0.8"	955.2	13.0	8.32	95.04	3 to 11	340
	5	STSGA 5	Jareikela	Sundargarh	83°39'13.1"	21°58'59.9"	939.4	12.0	8.32	50.27	5 to12	500
	6	STSGA 6	Jareikela	Sundargarh	83°39'25.6"	21°58'48.6"	978.4	11.0	8.12	85.42	2 to10	320
	7	STSGA 7	Jareikela	Sundargarh	83°39'28.1"	21°58'7.8"	945.5	10.5	8.10	91.40	3 to 12	300
	8	STSGA 8	Jareikela	Sundargarh	83°39'37.4"	21°58'43.7"	949.7	12.0	8.45	115.63	3 to10	260
	9	STSGA 9	Jareikela	Sundargarh	83°39'42.5"	21°58'19.6"	947.5	10.5	9.46	100.87	3 to11	285
	10	STSGA 10	Jareikela	Sundargarh	83°39'19.5"	21°58'27.4"	953.4	11.5	9.65	117.86	2 to 11	320

Annexure-2: Geocoordinates and morphometric attributes of CPT (Candidate Plus Tree) of *M. latifolia* in Agroclimatic Zone (ACZ)-2

Land Type	Sample Tree No.	Sample Tree Code	Place of collection	District	Longitude	Latitude	Altitude (Ft.)	Tree Height (m)	GBH (Ft.)	Crown area (m^2)	No. of fruits /bunch	Bunches/ Tree
Forest Land												
	1	STMBF 1	Sanabalichua	Mayurbhanj	86°27'30.8"	22°9'28.6"	352.2	11.0	6.1	82.52	5 to 21	640
	2	STMBF 2	Kadhambeda	Mayurbhanj	86°27'5"	22°10'27.3"	361.4	20.0	5.8	33.18	6 to14	180
	3	STMBF 3	Basketoda	Mayurbhanj	86°27'24.6"	22°8'17.3"	137.7	12.5	6.4	58.28	4 to 11	120
	4	STMBF 4	Kitabeda	Mayurbhanj	86°27'2.8"	22°9'12.9"	324.9	15.5	4.6	44.18	5 to 20	95
	5	STMBF 5	Baghania	Mayurbhanj	86°26'42.4"	22°8'50"	342.1	18.0	9.4	113.11	5 to 16	250
	6	STMBF 6	Chandbil	Mayurbhanj	86°27'1.1"	22°6'3.9"	131.7	17.0	7.5	113.11	8 to 25	230
	7	STMBF 7	Chandbil	Mayurbhanj	86°26'58.8"	22°6'7.6"	146.3	10.0	6.5	120.56	15 to 18	150
	8	STMBF 8	Kadhambeda	Mayurbhanj	86°26'1.8"	22°10'42.5"	359.1	17.0	6.2	70.89	12 to 17	200
	9	STMBF 9	Chandbil	Mayurbhanj	86°26'36.5"	22°6'4.1"	146.9	14.0	6.7	81.56	6 to 15	180
	10	STMBF 10	Chandbil	Mayurbhanj	86°26'41.7"	22°6'4.6"	145.7	13.0	8.1	96.45	4 to 13	210
Agricultural Land												
	1	STMBA 1	Bangriposi	Mayurbhanj	86°31'26.4"	22°9'25.8"	124.4	9.0	5.0	63.62	9 to 17	320
	2	STMBA 2	Bangriposi	Mayurbhanj	86°31'28"	22°9'21.4"	128.5	12.0	11.0	103.88	5 to 13	120
	3	STMBA 3	Deopata	Mayurbhanj	86°27'52.6"	22°10'36.8"	341.8	20.0	11.2	283.56	8 to 16	260
	4	STMBA 4	Sanabalichua	Mayurbhanj	86°27'46.1"	22°10'3.0"	365.9	12.0	5.0	44.18	6 to 15	110
	5	STMBA 5	Kadapani	Mayurbhanj	86°25'35.8"	22°10'34.9"	352.8	17.5	7.7	113.11	3 to 14	220
	6	STMBA 6	Kadapani	Mayurbhanj	86°25'31.5"	22°10'36.4"	347.5	20.0	7.6	95.04	5 to 14	120
	7	STMBA 7	Chandbil	Mayurbhanj	86°26'55.3"	22°6'4.9"	138.9	13.0	4.1	70.89	7 to 14	110
	8	STMBA 8	Chandbil	Mayurbhanj	86°26'54.0"	22°6'3.6"	150.2	23.0	7.7	201.08	8 to 16	260
	9	STMBA 9	Chandbil	Mayurbhanj	86°27'2.9"	22°6'4.4"	141.8	15.0	6.8	103.88	11 to 18	275
	10	STMBA10	Chandbil	Mayurbhanj	86°27'16.4"	22°6'3.1"	141.2	11.5	6.2	85.40	4 to12	260

Annexure-3: Geocoordinates and morphometric attributes of CPT (Candidate Plus Tree) of *M. latifolia* in Agroclimatic Zone (ACZ)-3

Land Type	Sample Tree No.	Sample Tree Code	Place of collection	District	Longitude	Latitude	Altitude (Ft.)	Tree Height (m)	GBH (Ft.)	Crown area (m^2)	No. of fruits /bunch	Bunches/tree
Forest Land												
	1	STBSF 1	Tinikosia	Blasore	86°41.8'47"	21°29.3'13"	285.2	8.5	2.7	30.78	8 to 26	150
	2	STBSF 2	Tinikosia	Blasore	86°41.8'3.2"	21°29.3'09"	260.0	8.0	2.3	35.56	4 o 15	70
	3	STBSF 3	Kuladhia	Blasore	86°38.9'5.5"	21°29.0'05"	286.5	11.0	5.0	70.89	5 to 14	200
	4	STBSF 4	Kuladhia	Blasore	86°38.9'7.6"	21°29.0'13"	274.7	12.3	5.3	110.20	3 to 11	240
	5	STBSF 5	Kuladhia	Blasore	86°38.9'12.5"	21°29.0'17.2"	268.5	11.0	4.9	98.70	6 to 13	190
	6	STBSF 6	Kuladhia	Blasore	86°38.9'11.1"	21°29.0'13.4"	279.8	9.5	4.7	91.00	7 to 15	185
	7	STBSF 7	Kuladhia	Blasore	86°38.9'21.4"	21°29.0'18.9"	271.6	11.5	5.2	100.47	6 to 14	210
	8	STBSF 8	Kuladhia	Blasore	86°38.9'19.5"	21°29.0'15"	270.0	12.0	5.3	110.30	3 to 10	250
	9	STBSF 9	Tinikosia	Blasore	86°41.8'35.7"	21°29.3'21.4"	274.7	9.0	4.3	110.60	4 to 12	190
	10	STBSF 10	Tinikosia	Blasore	86°41.8'24.6"	21°29.3'17.5"	273.6	9.5	4.5	89.90	4 to 10	160
Agricultural Land												
	1	STBSA 1	Sialimada	Blasore	86°40.7'2.1"	21°29.3'3.4"	217.5	11.0	6.0	44.18	6 to 12	325
	2	STBSA 2	Sialimada	Blasore	86°40.7',4.5"	21°29.3'4.1"	211.7	12.0	7.5	78.55	3 to 11	300
	3	STBSA 3	Sialimada	Blasore	86°40.7',3.8"	21°29.3'14.1"	214.0	13.5	7.4	120.56	8 to 16	210
	4	STBSA 4	Sialimada	Blasore	86°40.7',14.5"	21°29.3'17.1"	218.4	10.5	5.1	132.12	7 to 20	170
	5	STBSA 5	Sialimada	Blasore	86°40.7',7.5"	21°29.3'8.1"	216.5	11.5	5.5	110.45	4 to13	190
	6	STBSA 6	Sialimada	Blasore	86°40.7',9.5"	21°29.3'7.1"	212.9	12.5	5.2	125.67	6 to 16	130
	7	STBSA 7	Sialimada	Blasore	86°40.7',11.5"	21°29.3'5.4"	216.7	10.0	4.8	113.80	9 to 15	160
	8	STBSA 8	Sialimada	Blasore	86°40.7',17.5"	21°29.3'19.1"	221.3	14.5	7.8	145.65	5 to 15	230
	9	STBSA 9	Sialimada	Blasore	86°40.7',21.5"	21°29.3'14.8"	217.8	14.0	7.0	131.72	7 to 17	220
	10	STBSA 10	Sialimada	Blasore	86°40.7',24.5"	21°29.3'17.1"	213.4	13.0	5.2	107.34	4 to 18	180

Annexure-4: Geocoordinates and morphometric attributes of CPT (Candidate Plus Tree) of *M. latifolia* in Agroclimatic Zone (ACZ)-4

Land Type	Sample Tree No.	Sample Tree Code	Place of collection	District	Longitude	Latitude	Altitude (Ft.)	Tree Height (m)	GBH (Ft.)	Crown area (m^2)	No. of fruits /bunch	Bunches/tree
Forest Land												
	1	STNGF 1	Saliagocha	Nayagarh	84°47'44.4"	20°21'53.5"	451.3	16.0	6.5	69.63	5 to 12	130
	2	STNGF 2	Saliagocha	Nayagarh	84°45'2.3"	20°23'25.6"	435.0	7.0	7.0	57.06	2 to 11	140
	3	STNGF 3	Baguda	Nayagarh	84°43'51.2"	20°24'5.6"	508.5	13.0	7.3	38.48	3 to 11	160
	4	STNGF 4	Gurah	Nayagarh	84°38'21.0"	20°23'59.4"	569.4	10.0	10.7	78.55	3 to 14	350
	5	STNGF 5	Pankua	Nayagarh	84°49'35.7"	20°16'21.1"	565.4	18.5	8.5	113.11	4 to 21	300
	6	STNGF 6	Neliguda	Nayagarh	84°48'37.7"	20°21'32.5"	453.0	12.5	10.0	56.75	6 to 16	220
	7	STNGF 7	Neliguda	Nayagarh	84°48'36.9"	20°21'34.1"	473.3	17.5	8.0	78.55	8 to 31	350
	8	STNGF 8	Neliguda	Nayagarh	84°48'37.4"	20°21'32.8"	449.8	15.5	8.5	110.87	3 to 17	240
	9	STNGF 9	Neliguda	Nayagarh	84°48'36.3"	20°21'46.1"	451.6	14.5	7.7	90.56	4 to15	200
	10	STNGF 10	Neliguda	Nayagarh	84°48'37.2"	20°21'54.7"	463.3	12.5	7.6	87.65	2 to13	155
Agricultural Land												
	1	STNGA 1	Burusahi	Nayagarh	84°45'1.0"	20°23'23.4"	402.7	14.0	10.7	132.74	2 to 12	350
	2	STNGA 2	Baribiri	Nayagarh	84°38'22.1"	20°24'19.7"	575.5	11.5	10.7	98.55	3 to 13	200
	3	STNGA 3	Baribiri	Nayagarh	84°38'25.3"	20°24'20.1"	605.6	10.0	9.0	76.75	2 to 12	150
	4	STNGA 4	Gurah	Nayagarh	84°38'1.7"	20°24'1.1"	565.1	10.5	6.3	58.48	3 to 14	250
	5	STNGA 5	Gurah	Nayagarh	84°38'7.4"	20°24'21.3"	568.7	12.5	9.1	78.43	2 to11	160
	6	STNGA 6	Gurah	Nayagarh	84°38'4.3"	20°24'12.1"	556.3	11.5	10.5	110.87	3 to 12	235
	7	STNGA 7	Gurah	Nayagarh	84°38'8.9"	20°24'17.6"	564.6	9.4	9.4	96.45	2 to13	210
	8	STNGA 8	Gurah	Nayagarh	84°38'5.7"	20°24'4.7"	560.8	12.5	8.7	75.84	4 to 15	164
	9	STNGA 9	Baribiri	Nayagarh	84°38'41.1"	20°24'9.2"	587.6	10.5	9.8	86.52	3 to 15	196
	10	STNGA 10	Baribiri	Nayagarh	84°38'29.1"	20°24'24.7"	577.3	12.0	7.5	70.78	2 to14	156

Annexure-5: Geocoordinates and morphometric attributes of CPT (Candidate Plus Tree) of *M. latifolia* in Agroclimatic Zone (ACZ)-5

Land Type	Sample Tree No.	Sample Tree Code	Place of collection	District	Longitude	Latitude	Altitude (Ft.)	Tree Height (m)	GBH (Ft.)	Crown area (m^2)	No. of fruits /bunch	Bunches/tree
Forest Land												
	1	STKMF1	Srirampur	Kandhamal	83°59'46.5"	20°8'14.5"	2082.0	12.0	5.5	67.11	4 to 18	120
	2	STKMF2	Srirampur	Kandhamal	83°59'41.7"	20°8'12.4"	2106.0	15.0	9.3	132.74	3 to 18	160
	3	STKMF3	Srirampur	Kandhamal	84°00'36.5"	20°8'25.6"	1896.0	17.0	11.3	188.71	2 to14	120
	4	STKMF4	Srirampur	Kandhamal	*84*°00'34.8"	*20*°8'27"	1923.0	18.0	7.5	176.73	2 to 17	80
	5	STKMF5	Srirampur	Kandhamal	84°00'33.3"	20°8'30.2"	1934.0	21.0	9.0	153.95	2 to 20	68
	6	STKMF6	Srirampur	Kandhamal	84°00'34.3"	20°8'42.3"	1906.0	15.0	9.3	165.15	2 to 12	64
	7	STKMF7	Srirampur	Kandhamal	84°00'43.5"	20°8'42"	1909.0	15.0	8.0	33.18	4 to 14	75
	8	STKMF8	Srirampur	Kandhamal	84°00'46.4"	20°8'42.1"	1884.0	13.0	11.3	95.04	2 to 12	100
	9	STKMF9	Srirampur	Kandhamal	84°00'46.1"	20°8'42.6"	1903.0	16.0	7.3	56.75	4 to 18	95
	10	STKMF10	Srirampur	Kandhamal	84°00'50.7"	20°8'44.3"	1892.0	18.0	5.3	86.60	5 to 16	160
Agricultural Land												
	1	STKMA1	Kanjamendi	Kandhamal	84°00'19"	20°8'19.1"	2002.0	13.0	7.3	70.89	2 to 13	110
	2	STKMA2	Kanjamendi	Kandhamal	84°00'17.9"	20°8'21.7"	2023.0	14.0	5.3	55.42	2 to15	90
	3	STKMA3	Kanjamendi	Kandhamal	84°00'16.5"	20°8'24"	2023.0	11.0	6.1	122.73	2 to 18	120
	4	STKMA4	Kanjamendi	Kandhamal	84°00'9.3"	20°8'24.8"	2050.0	10.0	5.0	38.48	2 to12	80
	5	STKMA5	Kanjamendi	Kandhamal	83°59'56.4"	20°8'20.2"	2088.0	15.0	10.3	207.42	5 to 22	210
	6	STKMA6	Kanjamendi	Kandhamal	83°59'55"	20°8'19.2"	2086.0	14.0	10.7	132.74	4 to14	440
	7	STKMA7	Kanjamendi	Kandhamal	83°59'55.4"	20°8'18.8"	2127.0	12.0	5.2	25.97	4 to 15	240
	8	STKMA8	Kanjamendi	Kandhamal	83°59'55.5"	20°8'16.8"	2052.0	13.0	6.7	78.55	3 to 20	160
	9	STKMA9	Kanjamendi	Kandhamal	83°59'54"	20°8'16.2"	2058.0	10.0	9.3	201.08	2 to14	120
	10	STKMA10	Kanjamendi	Kandhamal	83°59'49.8"	20°8'14.9"	2052.0	8.0	4.0	44.18	3 to15	80

Annexure-6: Geocoordinates and morphometric attributes of CPT (Candidate Plus Tree) of *M. latifolia* in Agroclimatic Zone (ACZ)-6

Land Type	Sample Tree No.	Sample Tree Code	Place of collection	District	Longitude	Latitude	Altitude (Ft.)	Tree Height (m)	GBH (Ft.)	Crown area (m^2)	No. of fruits /bunch	Bunches/ tree
Forest Land												
	1	STNPF1	Kelia	Nabarangpur	82°27.3'53"	19°31.1'47"	2040.0	12.0	13.7	188.71	6 to 14	720
	2	STNPF2	Kelia	Nabarangpur	82°27.3'15"	19°31.1'40"	2037.0	11.0	8.3	78.55	4 to 11	340
	3	STNPF3	Kelia	Nabarangpur	82°27.3'25.3"	19°31.1'42.5"	2012.0	11.0	5.9	90.12	4 to 14	175
	4	STNPF4	Kelia	Nabarangpur	82°27.3' 36"	19°31.1'13"	1998.0	10.0	6.7	87.65	5 to 20	160
	5	STNPF5	Kelia	Nabarangpur	82°27.5' 42"	19°33.2'41.5"	2023.0	10.0	6.0	74.35	3 to 15	200
	6	STNPF6	Kelia	Nabarangpur	82°27.5'27.8"	19°31.2'24"	1991.0	12.0	7.5	125.64	3 to 11	190
	7	STNPF7	Kelia	Nabarangpur	82°27.3'15.9"	19°31.7'36"	1970.0	11.0	6.8	110.82	5 to 17	220
	8	STNPF8	Kelia	Nabarangpur	82°27.6'23.9"	19°31.6'40"	2027.0	13.0	8.1	98.54	9 to 16	200
	9	STNPF9	Kelia	Nabarangpur	82°27.8'27"	19°31.3'32"	1981.0	15.0	10.4	175.65	7 to 17	230
	10	STNPF10	Kelia	Nabarangpur	82°27.8"31"	19°31.4'28"	2021.0	12.0	6.5	104.89	5 to 12	170
Agricultural Land												
	1	STNPA1	Cheschetiguda	Nabarangpur	82°24'13.4"	19°30'3.0"	2013.0	12.0	5.7	43.76	2 to 10	160
	2	STNPA2	Chichibari	Nabarangpur	82°27'27.8"	19°33'8.9"	2097.0	11.0	5.9	58.48	2 to 10	200
	3	STNPA3	Dhamnaguda	Nabarangpur	82°21.42'5.3"	19°30.7'2.5"	1990.0	14.0	8.3	95.04	4 to 11	650
	4	STNPA4	Dabugaon	Nabarangpur	82°26.4'02"	19°29.87'7"	2020.0	11.0	4.5	35.65	3 to 10	250
	5	STNPA5	Dabugaon	Nabarangpur	82°26.4'36"	19°27.9'01"	2072.0	14.0	10.3	95.04	6 to 13	450
	6	STNPA6	Dabugaon	Nabarangpur	82°26.4'51.2"	19°27.9'15.6"	2036.0	12.0	5.7	110.45	5 to 17	270
	7	STNPA7	Dabugaon	Nabarangpur	82°26.4'17.5"	19°27.9'13.1"	1995.0	13.0	5.9	98.56	4 to 14	240
	8	STNPA8	Dabugaon	Nabarangpur	82°26.4'45"	19°27.9'01"	2031.0	14.0	6.3	134.65	7 to 20	220
	9	STNPA9	Dabugaon	Nabarangpur	82°26.4'36"	19°27.9'42"	2045.0	13.0	5.4	120.72	5 to 12	170
	10	STNPA10	Dabugaon	Nabarangpur	82°26.4'36"	19°27.9'57"	1985.0	14.0	6.2	140.57	5 to 11	320

Annexure-7 Geocoordinates and morphometric attributes of CPT (Candidate Plus Tree) of *M. latifolia* in Agroclimatic Zone (ACZ)-7

Land Type	Sample Tree No.	Sample Tree Code	Place of collection	District	Longitude	Latitude	Altitude (Ft.)	Tree Height (m)	GBH (Ft.)	Crown area (m^2)	No. of fruits /bunch	Bunches/tree
Forest Land												
	1	STMGF1	Boipariguda	Koraput	82°31.0'45"	18°46.1'22"	1902.0	14.0	8.7	95.04	5 to 11	480
	2	STMGF2	Boipariguda	Koraput	82°31.1'23"	18°46.1'12'	1876.0	13.0	7.4	94.67	4 to 12	210
	3	STMGF3	Boipariguda	Koraput	82°31.4'55"	18°46.1'43"	1890.0	11.0	6.3	90.65	6 to 14	170
	4	STMGF4	Boipariguda	Koraput	82°31.5'9"	18°46.1'37"	1875.0	12.0	6.8	93.67	6 to 10	140
	5	STMGF5	Boipariguda	Koraput	82°32.0'5"	18°46.4'32"	1884.0	11.5	6.5	110.45	4 to 13	200
	6	STMGF6	Boipariguda	Koraput	82°32.0' 29"	18°46.3'48'	1895.0	12.0	6.8	105.67	5 to 11	230
	7	STMGF7	Boipariguda	Koraput	82°32.3'47"	18°46.3 29'	1879.0	14.5	8.6	155.78	4 to 13	280
	8	STMGF8	Boipariguda	Koraput	82°32.3'28"	18°46.5'19"	1892.0	13.0	7.4	120.65	7 to 12	220
	9	STMGF9	Boipariguda	Koraput	82°32.5'33"	18°46.5'25"	1887.0	13.5	6.1	115.78	8 to 13	190
	10	STMGF10	Boipariguda	Koraput	82°31.4'49"	18°46.1'33"	1893.0	11.5	6.0	110.90	7 to12	210
Agricultural Land												
	1	STMGA1	Gurudiput	Malkangiri	82°28'18.1"	18°47'26.2"	1873.0	12.0	7.0	49.85	2 to 10	100
	2	STMGA2	Sugriguda	Malkangiri	82°16'10.2"	18°33'12.8"	866.9	9.0	6.3	56.75	3 to 11	300
	3	STMGA3	Sugriguda	Malkangiri	82°16'7.4"	18°33'17.6"	916.2	10.0	7.0	38.48	6 to 16	450
	4	STMGA4	Sugriguda	Malkangiri	82°16'8.3"	18°33'18.1"	903.2	12.0	7.3	78.55	3 to 11	150
	5	STMGA5	Sugriguda	Malkangiri	82°16'4.2"	18°33'27.1"	921.6	11.0	6.3	28.27	4 to 12	260
	6	STMGA6	Boipariguda	Koraput	82°30.9'9"	18°45.9'21"	1880.0	11.0	9.3	63.62	3 to11	200
	7	STMGA7	Boipariguda	Koraput	82°31.0'07"	18°46.0'4.8'	1895.0	15.0	10.7	38.48	3 to11	150
	8	STMGA8	Boipariguda	Koraput	82°31.0'51"	18°46.'8.8"	1884.0	12.0	9.3	50.27	4 to 13	320
	9	STMGA9	Boipariguda	Koraput	82°30.9'31"	18°46.9'8.1"	1889.0	13.0	6.4	31.23	6 to 17	140
	10	STMGA10	Boipariguda	Koraput	82°30.9'31"	18°45.9'41'	1891.0	12.5	5.9	37.86	5 to 14	160

Annexure-8: Geocoordinates and morphometric attributes of CPT (Candidate Plus Tree) of *M. latifolia* in Agroclimatic Zone (ACZ)-8

Land Type	Sample Tree No.	Sample Tree Code	Place of collection	District	Longitude	Latitude	Altitude (Ft.)	Tee Height (m)	GBH (Ft.)	Crown area (m^2)	No. of fruits /bunch	Bunches/tree
Forest Land												
	1	STNWF1	Tanwat	Nawapara	82°32'16.8"	20°44'39.3"	1270.0	12.0	9.3	38.48	3 to 10	300
	2	STNWF2	Tanwat	Nawapara	82°32'17.5"	20°44'40.8"	1304.0	8.0	6.0	41.32	2 to 11	160
	3	STNWF3	Tanwat	Nawapara	82°32'17.1"	20°44'41.8"	1273.0	11.0	7.0	35.67	6 to 13	600
	4	STNWF4	Tanwat	Nawapara	82°32'20.5"	20°44'53.6"	1270.0	10.0	14.0	38.48	2 to 12	180
	5	STNWF5	Gobara	Nawapara	82°32'31.8"	20°43'8.7"	1254.0	12.0	12.7	38.48	4 to 14	320
	6	STNWF6	*Tanwat*	Nawapara	*82*°33'43.99"	*20*°46'0.3"	1218.0	10.0	6.0	63.62	3 to 14	260
	7	STNWF7	*Tanwat*	Nawapara	*82*°34'28.1"	*20*°45'2.1"	1383.0	10.0	10.3	63.62	8 to 17	850
	8	STNWFF8	Gobara	Nawapara	82°32'31.1"	20°43'21"	1245.0	11.0	5.9	74,85	5 to 15	320
	9	STNWF9	Gobara	Nawapara	82°32'31.5"	20°43'41"	1265.0	11.0	6.0	82.56	4 to 16	210
	10	STNWF10	Gobara	Nawapara	82°32'31.3"	20°43'35"	1236.0	12.0	6.1	76.21	5 to 17	260
Agricultural Land												
	1	STNWA1	Tadiba	Nawapara	82°37'24.6"	20°35'1.8"	962.0	12.0	10.3	113.11	3 to 11	320
	2	STNWA2	Tadiba	Nawapara	82°37'24.3"	20°35'3.8"	960.0	11.0	8.0	86.60	3 to 10	240
	3	STNWA3	Tadiba	Nawapara	82°37'4.2"	20°35'33.7"	972.0	11.0	12.7	78.55	4 to 11	300
	4	STNWA4	Tadiba	Nawapara	82°37'5.4"	20°35'34.9"	1028.0	8.0	2.8	19.63	3 to 12	160
	5	STNWA5	Tadiba	Nawapara	82°37'0.7"	20°35'37.1"	1007.0	8.0	3.0	28.27	3 to 10	200
	6	STNWA6	Tanwat	Nawapara	82°34'0.731"	20°45'20.722"	1253.0	12.0	9.3	50.27	4 to 13	310
	7	STNWA7	Bhaludongri	Nawapara	82°46.102'	20°19.222'	820.0	12.0	11.3	95.04	4 to 11	350
	8	STNWA8	Bhaludongri	Nawapara	82°46.1'02"	20°19.2'22"	845.0	11.0	6.3	110.50	5 to 16	270
	9	STNWA9	Bhaludongri	Nawapara	82°46.1'42"	20°19.2'53'	860.0	10.0	5.7	87.54	2 to 15	210
	10	STNWA10	Tanwat	Nawapara	82°34'23.2"	20°45'45.4"	1236.0	9.0	5.9	70.30	3 to 13	160

Annexure-9: Geocoordinates and morphometric attributes of CPT (Candidate Plus Tree) of *M. latifolia* in Agroclimatic Zone (ACZ)-9

Land Type	Sample Tree No.	Sample Tree Code	Place of collection	District	Longitude	Latitude	Altitude (Ft.)	Tee Height (m)	GBH (Ft.)	Crown area (m^2)	No. of fruits /bunch	Bunches/tree
Forest Land												
	1	STBGF1	Matikhai	Bolangir	82°58'53.5"	20°44'15.8"	958.7	5.0	6.0	38.65	2 to 10	180
	2	STBGF2	Khaprakhol	Bolangir	82°52'44.5"	20°45'12.3"	1056.0	8.0	9.3	45.67	2 to 11	80
	3	STBGF3	Harishankar	Bolangir	82°52'12.1"	20°50'36.7"	1150.0	12.0	10.7	95.04	2 to 13	200
	4	STBGF4	Harishankar	Bolangir	82°52'15.7"	20°50'37.0"	1049.0	5.0	4.7	33.67	2 to10	260
	5	STBGF5	Harishankar	Bolangir	82°52'15.7"	20°50'44.3"	1037.0	7.0	3.2	35.21	2 to 14	160
	6	STBGF6	Kantabanjhi	Bolangir	82°59'37.9"	20°36'9.9"	904.3	9.0	4.3	40.11	5 to 14	240
	7	STBGF7	Kantabanjhi	Bolangir	82°59'31.2"	20°36'7.4"	888.6	11.0	9.3	78.55	4 to 12	420
	8	STBGF8	Kantabanjhi	Bolangir	82°59'38.9"	20°36'23"	895.0	8.0	5.5	56.45	5 to16	190
	9	STBGF9	Kantabanjhi	Bolangir	82°59'48.4"	20°36'34.2"	899.0	9.0	6.1	51.43	3 to17	210
	10	STBGF10	Kantabanjhi	Bolangir	82°59'55.7"	20°36'47.2"	907.0	10.0	8.1	65.67	4 to 10	250
Agricultural Land												
	1	STBGA1	Bhainsa	Bolangir	83°17'6.0"	20°42'55.1"	725.2	16.0	10.7	28.27	3 to 12	600
	2	STBGA2	Bhainsa	Bolangir	83°17'5.3"	20°42'51.2"	697.2	7.0	5.0	33.18	3 to 10	300
	3	STBGA3	Bhainsa	Bolangir	83°17'1.7"	20°42'54.2"	754.0	14.0	14.0	188.71	5 to 14	1000
	4	STBGA4	Kusamgani	Bolangir	83°10'23.2"	20°42'44.1"	821.4	11.0	10.3	122.73	3 to 12	600
	5	STBGA5	Matikhai	Bolangir	82°58'50.8"	20°44'14.3"	978.1	8.0	6.5	56.75	4 to15	160
	6	STBGA6	Nunhad	Bolangir	82°56.622'	20°34.187'	860.0	16.0	15.3	188.71	5 to 14	720
	7	STBGA7	Nunhad	Bolangir	82°56.649'	20°34.104'	800.0	14.0	14.0	153.95	3 to 15	640
	8	STBGA8	Hudapath	Bolangir	83°17'1.7"	20°42'54.2"	754.0	14.0	14.0	188.71	5 to 14	1000
	9	STBGA9	Hudapath	Bolangir	83°17'27"	20°42'43.6"	759.0	13.0	9.5	113.45	3 to 17	320
	10	STBGA10	Hudapath	Bolangir	83°17'13"	20°42'35.1"	751.0	12.0	9.0	110.78	4 to 11	340

Annexure-10: Geocoordinates and morphometric attributes of CPT (Candidate Plus Tree) of *M. latifolia* in Agroclimatic Zone (ACZ)-10

Land Type	Sample Tree No.	Sample Tree Code	Place of collection	District	Longitude	Latitude	Altitude (Ft.)	Tee Height (m)	GBH (Ft.)	Crown area (m^2)	No. of fruits /bunch	Bunches/tree
Forest Land												
	1	STAGF1	Raibahal	Angul	84°27'28.2"	20°54'52.7"	204.9	21.5	6.7	103.88	7 to 18	420
	2	STAGF2	Raibahal	Angul	84°27'32.0"	20°54'51.6"	140.0	17.0	8.2	113.11	8 to 21	580
	3	STAGF3	Raibahal	Angul	84°27'32.1"	20°54'50.9"	141.0	17.5	9.2	63.62	9 to 12	140
	4	STAGF4	Raibahal	Angul	84°27'30.9"	20°54'47.8"	143.2	15.5	14.7	86.60	8 to 10	270
	5	STAGF5	Bhagabanpur	Angul	84°27'32.4"	20°50'40.8"	155.8	14.0	9.7	86.60	8 to 10	140
	6	STAGF6	Bhagabanpur	Angul	84°27'32.8"	20°50'45.3"	133.2	14.0	7.5	38.49	10 to 14	120
	7	STAGF7	Bhagabanpur	Angul	84°27'34.1"	20°50'51.9"	152.5	16.5	7.3	86.60	8 to 10	160
	8	STAGF8	Bhagabanpur	Angul	84°27'41.5"	20°50'53.4"	149.0	14.0	7.9	95.40	4 to 14	220
	9	STAGF9	Bhagabanpur	Angul	84°27'47.2"	20°50'55.7"	151.0	13.5	7.1	76.85	3 to 13	180
	10	STAGF10	Bhagabanpur	Angul	84°27'53.4"	20°50'58.4"	147.0	13.0	10.2	130.45	3 to 15	310
Agricultural Land												
	1	STAGA1	Kasturba	Angul	84°26'57.5"	20°55'44.9"	140.9	16.0	6.7	70.90	7 to 15	140
	2	STAGA2	Kasturba	Angul	84°26'55.7"	20°55'44.5"	137.7	18.0	9.0	122.73	8 to 17	350
	3	STAGA3	Kasturba	Angul	84°26'53.1"	20°55'48.2"	135.9	17.0	8.0	113.11	8 to 18	230
	4	STAGA4	Kasturba	Angul	84°26'52,6"	20°55'49.4"	136.3	17.0	6.7	70.89	12 to 22	270
	5	STAGA5	Baniadohali	Angul	84°26'24.8"	20°55'48.7"	132.0	16.5	5.9	44.18	10 to 17	140
	6	STAGA6	Baniadohali	Angul	84°26'24.2"	20°55'48.4"	134.2	14.5	6.5	50.27	8 to 16	165
	7	STAGA7	Baniadohali	Angul	84°26'24.7"	20°55'46.8"	139.3	17.0	4.0	70.89	8 to 14	150
	8	STAGA8	Baniadohali	Angul	84°25'55.1"	20°55'49.2"	139.6	14.5	6.4	50.27	6 to 18	160
	9	STAGA9	Baniadohali	Angul	84°25'31.5"	20°55'53.5"	138.2	11.0	7.1	28.27	8 to 14	110
	10	STAGA10	Baniadohali	Angul	84°25'50.3"	20°55'53.1"	138.0	12.0	6.7	44.18	8 to 16	90

Annexure-11(A)

VILLAGE LEVEL QUESTIONNAIRE

Name of the interviewer: **Date of Interview:**

General Information:

1. Name of the respondent:
2. Name of the Village/hamlet:
3. Name of the Block/Mandal:
4. Household size: Large/Small/Medium
5. No. of male/female/Children:

Male	Female	Children

6. Primary occupation of Household:
7. Total monthly household income:
8. Percentage of household income obtained from mahua :

Collection:

9.Whether madhuca seeds/flowers she/he collects and in which time/season of the year?

S. no	Items	Season	How many hours a day	Days per season		
				Summer	Winter	rainy

10. How far s/he goes to collect and Methods of extraction (For each item):

Sl no	Items	How far s/he walks to collect	Who else in the family goes with	Time taken to reach	Methods of extractio n/harvest ing	Major Problems in collection. (Distance/Reducing Resources/Problems with FD/any other)

11. After collection how are the items used?

Item	Household Consumption (Qty)	Selling (Qty)

Storage:

12. Whether storage is done, if yes, why and which items?

Items	Quantity (unit)	Stored for (Days)	Season	Major problems in storage	Additional cost incurred

Processing:

13. Whether processing is done, if yes, why and which items?

Items	Why s/he does processing	Quantity	Time taken for processing	Other resources used for processing	Major problems in processing

14. How processing is done for each item?

Value addition:

15. Whether value addition is done or not, if yes, why?

Items	Quantity	Time taken for value addition	Individually/ in group	Cost incurred	Major problems in Value addition	How much additional income it provides

16. How value addition is done?

Transport:

17. Where s/he transports the items to sell?

Items	Mode of transport	Quantity transported at a time	Distance being transported	Cost involved	Major problems in transport

Market Information:

18. Where is the market? How far?
19. Whom does s/he sell the items?
    a) Small trader b) Middle man c) Any other
20. How does s/he identify the potential buyer?
    a) Personal contacts b) From fellow sellers c) Any other source
21. How often they go to sell in the market?
22. Price Information:

Item	Unit of selling (kg/any other)	Current Price/unit	Quantity sold at a time	Major problems in marketing

Annexure 11(B)

QUESTIONNAIRE FOR THE SMALL TRADERS

Name of the interviewer: **Date of interview:**

1. Name of the respondent:
2. Name of the village/hamlet he belongs to:
3. Since when he has been involved in this trade:
4. Any other profession he is involved in:

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5. Criteria of selecting items for trading:

6. Where he goes to buy?
7. He goes to the collector or the collectors come to him or both ways?
8. How often in a month/week?

Trading: (Season, Items, Quantity and Price)

Item	Season	Unit of trade	Price/unit	Qty he buys at a time	Total qty per season	Reasons of fluctuation in price

9.How does he fix prices, grade (within the items) and keep a track of the prevailing market price?

10. To whom he sells? How he identifies them?

11. How much of area (no. of villages) he covers?

12. What are the modes of transport and the cost involved?

13.Does he need to store or process items, if yes, why and the cost involved?

Processed and Value added items:

14. Does he trade with processed or value added items? What's the price difference?

Items	Unprocessed Price/ Unit	Processed Price/Unit	Raw items (Price)	Value added items(Price)

15. His opinion about collectors and major problems in Mahua seeds /flowers trading:

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BIO DATA

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7. **ACADEMIC QUALIFICATIONS :**

Examinations Passed	Name of the Board University	Year of Passing	Subjects taken	Division
H.S.C.	CBSE	1987	English, Hindi, Maths, G.Sc., Social	1st
+2 Science	CHSE,Orissa	1989	Physics, Chemistry, Mathematics, Biology, English, MIL	1st
B.Sc (Forestry)	Orissa University of Agriculture & Technology Bhubaneswar	1994	Silviculture, Forest Products, Tree improvement, Agro forestry, social forestry, forest management, Horticulture, Agronomy, etc.	1st
M.Sc. (Forestry) with Specialisation (Forest products)	Dr.Y.S.Parmar University of Horticulture & Forestry, Solan (HP)	1997	Forest Products, Silviculture and Agroforestry, Forest Breeding and tree improvement, Plant Physiology Biochemistry etc. **M.Sc. Thesis** :"Studies on the astringent principle of *spilanthes acmella* murr".	1st
NET-1997	ICAR	1998	Forestry	passed
NET-1998	ICAR	2000	Forestry	passed
NET-2001	ICAR	2002	Forestry	passed

8. Distinction gained in Academics

i. In examination conducted by Indian Association of Physics Teachers in 1989.
ii. Silver Medalist in National Talent Search Contest in Mathematics.

9. Publications :

1.	Sahoo, P. K., Nayak, S., Behera, L. K., Rout, S. and Biswal, D.2016. Influence of storage condition and duration on oil content of Physic-Nut seeds. *Multilogic in Science.*
2.	Sahoo, P. K. , Behera , L. K. and Nayak, S. K.. 2015.Storage conditions and durational effect on seed germination of physic nut (*Jatropha curcas* L.) . *Res. Environ. Life Sci.* 8(1): 57-60 .
3.	Rout,S. and Nayak,S.2015. Effect of Storage Condition and Duration on Seed Germination of *Pongamia pinnata* L.Pierre. *Research Journal of Agriculture and Forestry Sciences .* 3(4): 19-24.
4.	Rout,S. and Nayak,S.2015. Vegetative Propagation of *Pongamia pinnata* through grafting. *Journal of International Academic Research for multidisciplinary.* 3(3) :180-186.
5.	Rout,S. and Nayak,S.2015. Influence Of Storage Condition and Duration on Oil Content of *Pongamia pinnata* L.Pierre. Seeds. *Online International Interdisciplinary Research Journal*. 5 : 139-144 .
6.	P. K. Sahoo, L. K. Behera and S. K. Nayak. 2014. Vegetative propagation of physic nut (*Jatropha curcas* L.) through stem cuttings . *Journal of Applied and Natural Science* 6 (2): 467-472.
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11.	Nayak,S. and Chand,R. 2002.Dynamics of Spilanthol in *Spilanthes acmella* Murr. in plant growth and development .*Indian Drugs* . 39(8):419-421.
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13	Extension Bulletin on Teak cultivation in oriya.
14	Extension literature on Bamboo cultivation in oriya.
15	Extension literature on *Acacia mangium* cultivation in oriya
16	Leaflet on patalgaruda.
17	Leaflet on Neem
18	Leaflet on Pipali
19	Booklet on Mahua
20	Publication on Intervention of Agroforestry systems in Nayagarh district and its prospects

10. EXPERIENCE (if any) :

(i) TEACHING :

Designation	Period (From - To)	Courses Taken	Nature of Work
Assistant Professor, Department of forestry , College of Agriculture , OUAT, BBSR	**23.09.2009** to Till date	**UG Programme** Wood science and Technology , Wood anatomy, NTFP, Wood based Industry, , Forest work experience **PG Programme** Chemistry of medicinal and aromatic plants , Cultivation of medicinal and aromatic plants, Forest products laboratory technique, Paper - pulp technology and Composite wood, PG research	Contact (Instruction) Preparation of teaching including library use Admnistration Evaluation Research Guidance Counseling Developmental activities .

Student'sGuided

Advisor : 14 (PG students)

Co-advisor : 15 (PG students)

List of PG Thesis Guided

Year	Thesis Title
2012	Studies on propagation and evaluation of post harvest changes in oil content of *Pongamia pinnata* L.Pierre.
2012	Studies on Propagation and evaluation of post harvest changes in oil content of *Jatropha curcas*
2013	Studies on seed variability of candidate plus trees and evaluation of post-harvest changes in oil content of *Madhucaindica* Gmel
2013	Studies on seed variabilityevaluationof postCPT'sharvestchangesandin the oil content of *Terminalia bellerica* (Gaertn.) Roxb.
2014	Seed variability and post harvest changes in the oil content of *Calophyllum inophyllum* L.
2015	Studies on propagation through stem cuttings and effect of biofertilizers on growth of *Stevia rebaudiana.*
2015	Studies on propagation through stem cuttings and effect of biofertilizers on growth of *Ocimum kilimandscharicum* G.
2016	**S**eed variability and post-harvest changes in oil content of *Schleichera oleosa* (Lour.) Oken.
2017	**S**tudies on variation in oil content and physicochemical properties of *Milletia pinnata* (L.) Panigrahi seed oil under different storage conditions and durations.
2017	Dynamics of Curcumin with various growth and development stages of *Curcuma caesia*and its variation with different storage conditions and durations.
2018	Studies on physical, anatomical and chemical characteristics of Eucalyptus hybrid wood from two agro-climatic zones of Odisha**.**
2018	**S**tudies on variation in oil content and physico-chemical properties of *Buchanania lanzan Spreng* seed oil under different storage conditions and

	durations.
2019	Assessment of Wedelolactone with growth and development of *Wedelia chinensis (*Osbeck*)* Merr. and its variation with storage.
2019	Dynamics of Berberine and Tinosporaside from *Tinospora cordifolia* (Willd.) Miers with seasonal changes and their variation in content with storage.

(ii) EXTENSION :

Designation	Name of the Organization	Period (From - To)	Nature of Work
Subject Matter Specialist Forestry	KVK Nayagarh , OUAT	22.12.2006 to 22.09.2009	Conducting Trainings, Front Line Demonstrations , Onfarm Trials in forestry related crops/ enterprises.
Subject Matter Specialist Forestry	KVK Sonepur , OUAT	06.02.2006 to 21.12.2006	Conducting Trainings, Front Line Demonstrations , Onfarm Trials in forestry related crops/ enterprises
Research Associate	ZARS-KVK Nabrangpur, RRTTSS, Umerkote	04.01.2001 to 03.07.2003	Conducting Trainings, Front Line Demonstrations , Onfarm Trials in forestry related crops/ enterprises

(iii) RESEARCH :

Designation	Name of the Organization	Period (From - To)	Nature of Work
Junior Research Fellow	In project "Integrated Tree Improvement in Neem", Forestry,College of Agriculture,OUAT, Bhubaneswar. Funded by ICFRE , Dehradun	01.07.1998 - 30.06.1999	Selection of Candidate plus trees of Neem from different provinances of Orissa , characterization and selection of elite trees through oil content study and progeny trial.
Research Associate	In project through agroforestry intervention in the Supercyclone affected districts of Orissa, C.A.,Dept. of Forestry, OUAT, Bhubaneswar. Funded By Deptt. Of Land Resources , Govt. Of India.	04.07.2003 to 04.02.2006	Reclamation of Saline &Waterlogged aste Lands by Conducting Plantations in Govt., community , institutional and farmers land through various Agroforestry systems.
Co- Principal Investigator	In Projec Germplasm collection , evaluation and integrated tree	December 2009 to March 2013	Germplasm collection , evaluation and integrated tree improvement of Jatropha and karanj for enhancing seed yield and oil content

	improvement of Jatropha and karanj for enhancing seed yield and oil content . Department of Forestry , College of Agriculture , OUAT, BBSR		

BIO DATA

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4. **PRESENT ADDRESS** : **ASSISTANT PROFESSOR**
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7. **ACADEMIC QUALIFICATIONS :**

Examinations Passed	Name of the Board University	Year of Passing	Subjects taken	Division
H.S.C.	CBSE	1987	English, Hindi, Maths, G.Sc., Social	1st
+2 Science	CHSE,Orissa	1989	Physics, Chemistry, Mathematics, Biology, English, MIL	1st
B.Sc (Forestry)	Orissa University of Agriculture & Technology Bhubaneswar	1994	Silviculture, Forest Products, Tree improvement, Agro forestry, social forestry, forest management, Horticulture, Agronomy, etc.	1st
M.Sc. (Forestry) with Specialisation (Forest products)	Dr.Y.S.Parmar University of Horticulture & Forestry, Solan (HP)	1997	Forest Products, Silviculture and Agroforestry, Forest Breeding and tree improvement, Plant Physiology Biochemistry etc. **M.Sc. Thesis** :"Studies on the astringent principle of *spilanthes acmella* murr".	1st
NET-1997	ICAR	1998	Forestry	passed
NET-1998	ICAR	2000	Forestry	passed
NET-2001	ICAR	2002	Forestry	passed

Date : 30/01/2020

30/01/2020
SASWAT NAYAK

PARTICULARS OF THE CANDIDATE

NAME OF THE CANDIDATE:	SASWAT NAYAK
DEGREE:	PH.D
DEPARTMENT:	FORESTRY
TITLE OF THE THESIS:	EFFECTS OF SEED SOURCE, STORAGE CONDITIONS AND DURATION ON GERMINATION, SEEDLING TRAITS AND OIL CONTENT IN *Madhuca latifolia* Macbride IN ODISHA
DATE OF ADMISSION:	01.08.2014
APPROVAL OF RESEARCH PROPOSAL:	
(1) BOARD OF STUDIES:	08.05.2015
(2) SCHOOL BOARD:	19.05.2015
REGISTRATION NO & DATE:	MZU/Ph.D./781 OF 19.05.2015
EXTENSION (IF ANY):	N/A

Head

Department of Forestry

EFFECTS OF SEED SOURCE, STORAGE CONDITIONS AND DURATION ON GERMINATION, SEEDLING TRAITS AND OIL CONTENT IN *Madhuca latifolia* Macbride IN ODISHA

THESIS SUBMITTED IN FULFILMENT OF THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN FORESTRY

ABSTRACT

BY

SASWAT NAYAK

MZU/Ph.D./781 OF 19.05.2015

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2020

The present investigation entitled "Effects of seed source, storage conditions and duration on germination, seedling traits and oil content in *Madhuca latifolia* Macbride in Odisha" was carried out in the experimental sites, laboratory of College of Forestry and laboratory of Department of Soil Science, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha during the period 2016-2018. The main objectives of the study were:

(i) To assess the extent of variability in seed characters and oil content of *Madhuca latifolia* Macbride from different provenances of Odisha

(ii) To determine the effect of different storage conditions and duration on oil content of *M. latifolia*

(iii) To study the economic importance of fruits and flowers of *M. latifolia* on the livelihood of the local people

Seven experiments were conducted in total to meet these objectives and these were:

1. Studies on variation in morphometric characters of fruits of *M. latifolia* Macb.
2. Studies on variation in physico-chemical properties of oil from seeds of *M. latifolia*
3. Studies on soil chemical properties of provenances of *M. latifolia*
4. Studies on ecological characters of *M. latifolia* in different agrocimatic zones
5. Studies on variation in morphometric characters of seedlings of *M. latifolia.*
6. Effect of different storage conditions and durations on seed oil Content and its physico-chemical properties of stored seeds of *M. latifolia*
7. To assess the economic importance of fruits and flowers of *M. latifolia* on the livelihoods of the local people.

In the **first experiment**, fruits were collected from both from forest area and agricultural land area separately from all ten agroclimatic zones (ACZ) of Odisha. The fruit length (cm), fruit width (cm), fruit thickness (cm), seed length (cm), seed width (cm), seed thickness (cm), seed helium length (cm), kernel length (cm), kernel width (cm), kernel thickness (cm), 100 fruit weight (gm), 100 seed weight (gm), 100 kernel weight (gm) and 100 oven dry kernel weight (gm) of the sample trees were found to have significant variation.

The highest Fruit length (8.14cm), Seed length (5.24 cm), seed hilum length (4.69 cm), 100 seed weight (583 g), 100 kernel weight (397 g) and 100 oven dry kernel weight (273.3 g) in case of sample tree STMBA8 under ACZ – 2, fruit width (4.10 cm) and fruit thickness (3.90 cm) in case of sample tree STBSA8 under ACZ– 3, seed width (1.99 cm) in case of sample tree STAGA 2 under ACZ– 10, seed thickness (1.84 cm) in case of sample tree STNPF1 under ACZ– 6 , kernel length (4.02 cm)) in case of sample tree STNPF2 under ACZ– 6 , kernel width (1.64 cm) in case of sample tree STNWF1 under ACZ– 8 , kernel thickness (1.63 cm)) in case of sample tree STNPA1 under ACZ– 6 and 100 fruit weight (2310 g) in case of sample tree STMGA8 under ACZ– 7. The seeds from the above trees can be collected as per the required seed trait to raise seedlings of better quality for future plantation and for research purposes. It was also found that the sample tree showing higher values for important morphometric characters was STMBA8.

Analyzing the variation of fruit characters under individual ACZ, the morphological characters showed higher value of coefficient of variations are seed thickness (10.64) in ACZ-10, seed helium length (10.22) in ACZ-3 and 100 fruit weight (11.25)in ACZ-9in case of forest lands . It helps for selection of a character with higher coefficient of variation in a particular ACZ. The above mentioned zones can be considered for selection purposes of that particular character for further improvement studies of the species. Similarly, from agricultural lands also morphological characters that showed higher value of coefficient of variations are seed length (11.21) in ACZ-6, kernel length (11.55) in ACZ-6 and 100 fresh kernel weight (13.96) in ACZ-1which can be considered for selection purposes for further improvement studies of the species. In some of the ACZ various morphological characters showed significant differences between the mean values of fruits collected from forest lands and agricultural land. It was also found that the coefficient of variation of a particular character within a ACZ is higher than the coefficient of variation of the same seed character among the ACZ.

Comparing among different agroclimatic zones, higher value of coefficient of variation were recorded for morphological characters of the fruits collected from forest lands like 100 fruit weight (5.28) , fruit length (4.77), kernel width (4.46) and kernel thickness (4.31). Similarly, Higher value of coefficient of variation were found for morphological characters of the fruits collected from agricultural lands like kernel width (4.75), kernel thickness (4.50), 100 kernel weight (3.63) and kernel length. It signifies that these characters can be useful for selection purposes when selection is carried out from the *M. latifolia* population present throughout the state (i.e from all agroclimatic zones) not in a particular ACZ.

The mean values of morphometric characters of fruits collected from forest lands and agricultural lands under different ACZ will be helpful for collection of seeds of desirous trait in large scale (for industrial or other utilization aspects) from zone recording higher mean value . For the seeds collected from forest lands, the highest mean kernel length (3.12 cm) , kernel width (1.51 cm) and hilum length (3.18 cm) were found in ACZ-3, seed thickness (1.75 cm) and kernel thickness (1.52 cm) was found in ACZ-6 , seed length (3.50 cm) and 100 fresh kernel weight (283.59 g) was found in ACZ-5, fruit length (5.32 cm) was found in ACZ-1 and 100 fruit weight (1711.39 g) was found in ACZ-10. Similarly for the seeds collected from agricultural lands highest value were found in fruit width (3.55 cm) , fruit thickness (3.48 cm) and 100 seed weight (410.75 g) was found in ACZ-3, seed weight (1.82 cm)) was found in ACZ-1, kernel length (3.12 cm) in) was found in ACZ-6 and 100 oven dry kernel weight (195.44 g) was found in ACZ-5.

In the **second experiment**, seeds of *M. latifolia* Macb. collected from 10 ACZ of Odisha and observations were recorded for physico-chemical properties like Oil content (%), acid value, saponification value, ester value, FFA (%), iodine value , specific gravity and specific gravity . All characters except density and specific gravity of oil found to have significant variation among the sample trees under each zone.

The highest Oil content (51.84 %) was observed in case of sample tree STSGF 7 under ACZ– 1 from the seeds collected from forests lands. However, in case of seeds collected from agricultural lands the highest Oil yield (125.08 g) was observed in sample tree STMBA 8 under ACZ– 2, saponification value (271.20) and ester value (268.12) in case of sample tree STKMA9 under ACZ– 5, iodine value (68.07) in case of sample tree STBSA 8 under ACZ–3 and lowest acid value (0.67) and free fatty acid content (0.34) in case of sample tree STAGA4 and STAGA7 under ACZ–10. The seeds from the above trees can be collected as per the required oil trait to raise seedlings of better quality for future plantation to meet the food and industrial requirement and for research purposes. It was also found that the sample tree showing higher values for some important oil characters was STMBA8.

Analysing the oil content and physico-chemical properties of oil derived from fruits collected from forests and agricultural lands from different ACZ higher value of coefficient of variations are found in the agricultural lands than forest lands. Higher variation were found for FFA in ACZ-6 (28.82%), acid value in agroclimatic zone-3 (15.43), Saponification value in ACZ-10 (10.55) and oil content in ACZ-6 (9.36). The above mentioned zones can be considered for selection purposes of that particular character for further improvement studies on the species.

In some of the ACZ various oil characters showed significant differences between the mean values of fruits collected from forest lands and agricultural land.It was also found that the coefficient of variation of a particular oil character within a ACZ is higher than the coefficient of variation of the same oil character among the ACZ.

Comparing among different ACZ,, higher value of coefficient of variation were recorded for oil characters of the seeds collected from forest lands like acid value (13.72) and Iodine value (5.27), whereas, higher value of coefficient of variation were recorded for oil characters of the seeds collected from agricultural lands are free fatty acid content (12.71), oil content (7.92), saponification value (5.71) and oil yield (4.11).

The mean values of oil characters of seeds collected from forest lands and agricultural lands under different agroclimatic zones will be helpful for collection of seeds of desirous trait in large scale (for industrial or other utilization aspects) from zone recording higher mean value .Basing on the oil characters , seeds collected from forest land under agroclimatic zone -8 may be collected for both food and industrial value as it has higher oil content (43.21%), oil yield (80.91g), saponification value (212.17) and lesser free fatty acid content (1.92) and iodine value (55.42).

In the **third experiment,** soil profiles were exposed in both natural forest and agricultural lands having *M. latifolia* distribution under different ACZ. The soil were then collected for each profile from four zones i.e. 0-25cm, 25-50cm, 50-75cm and 75-100cm and tested for soil pH, soil electrical conductivity, soil organic carbon , available soil nitrogen, available phosphorus and available potassium.

It was found that pH value of soil in case of both forest as well as agricultural land in most of the ACZto be acidic and pH was found to be increasing from top to the bottom layer of profile in most of the ACZ. The mean pH of agricultural land was found to be more than mean pH of forest land in all ACZ. The mean pH of soil profile of forest lands from different ACZ ound to be acidic-neutral ranged between 5.51 – 6.97, whereas, of agricultural land found to be acidic-alkali ranged between 6.03 – 7.59.

It was found that EC value of soil in case of both forest as well as agricultural land in most of the agroclimatic zone found to be in normal range and decreasing from top to the bottom layer of profile . In case of forest land the mean EC ranged between 0.024 - 0.118 whereas for agricultural land it ranged between 0.044 -0.169. The mean EC of agricultural land was found to be more than mean EC of forest land in most of the ACZ.

Organic Carbon (SOC) Concentration of soil found to be decreasing from top to the bottom layer of profile in case of both forest as well as agricultural land in most of the ACZ.In case of forest land the mean SOC concentration ranged between 0.24 - 1.04where as for agricultural land it ranged between 0.29-0.66 .The mean SOC concentration of forest land was found to be more than that of agricultural land in most of the ACZ.

Available nitrogen of soil found to be decreasing from top to the bottom layer of profile in case of both forest and agricultural lands in most of the ACZ. In case of forest land the mean available nitrogen ranged between 71.88 kg/ha–140.63kg/ha whereas for agricultural land it ranged between 65.63 kg/ha - 156.25 kg/ha .The mean available nitrogen of agricultural land was found to be more than that of forest land in most of the ACZ except ACZ3, 9 and 10.

Available phosphorus of soil found to be decreasing from top to the bottom layer of profile in case of both forest and agricultural lands in most of the ACZ. In case of forest land the mean available phosphorus ranged between 2.49 kg/ha–8.25 kg/ha whereas for agricultural land it ranged between 6.14kg/ha–21.70 kg/ha .The mean available phosphorus in soil agricultural land was found to be more than that of forest land in most of the ACZ. In both forest and agricultural lands, the available potassium of soil found to be increasing from top to the bottom layer of profile in some ACZ and decreasing in other zones. The mean available potassium ranged between 135.40 kg/ha–901.78 kg/ha in forest land where as for agricultural land it ranged between 73.46 kg/ha–145.15 kg/ha.

Besides that the mean available Potassium was found higher in some ACZ n the soil of agricultural land and other ACZ in the soil of forest land.

The available Sulphur is found with higher values in the top layer of soil profile in some agroclimatic zones and higher in other layers of profile in rest of the ACZ. The mean available potassium ranged between 12.40 kg/ha – 48.00 kg/ha in forest land where as for agricultural land it ranged between 8.97 kg/ha –14.99 kg/ha. The mean available Sulphur was found higher in all ACZ in the soil of forest lands.

In the **fourth experiment**, tree associate study of *Madhuca latifolia* in under taken in different natural forest 10 agroclimatic zones of Odisha . The study was carried out in the outer fringe of the natural forest which are mostly protected by villagers through Joint forest Management and from where the dependents collect the Non Timber Forest Products including Mahua flowers and seeds .

The Shannon-Wiener index (H′) for all the natural forests studied under different ACZ ranges from 1.592–2.560 (Table: 37-46) with maximum in agroclimatic zone- 9 and minimum in ACZ- 5. *M. latifolia* showed higher density in ACZ2 (137.5 stems/ha), ACZ3 (127.25 stems/ha) and agroclimatic zone 5 (123.25 stems/ha) and contributes alone 17.41 %, 17.91% and 26.63% respectively of their total tree density. The relative frequency of *M. latifolia* was recorded maximum in forest under ACZ5 (20.83) and minimum in forest under ACZ10 (11.53) and it showed random dispersal pattern in most of the agroclimatic zones and contiguous dispersal pattern in few ACZ. In most of the ACZ, *Shorea robusta*, *Madhuca latifolia* and *Buchnania lanza*n are found to be associated with each other in natural distribution. The IVI for *M. latifolia* was found between 84.27-28.25 with maximum in ACZ5 and minimum in ACZ10.

In the **fifth experiment**, the seeds collected from different sample trees under various agroclimatic zones were evaluated by nursery testing, seedlings were raised from seeds of *M. latifolia* Macb**.** collected from all agroclimatic zones of Odisha and observations were recorded for germination percentage, seedling length, collar diameter, fresh seedling biomass , oven dry seedling biomass, mean daily germination, peak value, germination value, moisture content and shoot vigour index.

The germination percentage of all ACZ varies from 27 % -100 % in case of seeds collected from forest lands where as the germination of all provenances varies from 37 % -100 % in case of seeds collected from agricultural lands. The shoot vigour index of all agroclimatic zone varies from 394.2-2962.0 in case of seeds collected from forest lands where as the shoot vigour index of all ACZ varies from 2.57g-4.83g in case of seeds collected from agricultural lands. The seedling oven dry biomass of all ACZ varies from 394.2-2962.0 in case of seeds collected from forest lands where as the seedling oven dry biomass of all ACZ varies from 1.88g-4.81g in case of seeds collected from agricultural lands.

For the seedlings raised from the seeds collected from forest lands, higher variations within each zone were found for all the germination traits with highest in germination value. ACZ-10 showed maximum variations with in the ACZ for the germination traits like germination value (PCV-88.29, GCV-87.97 and CV-6.99), germination percentage (PCV-49.57, GCV-49.02 and CV-7.39), mean daily germination (PCV-49.06, GCV-48.91 and CV-5.22) and peak value (PCV-46.54 , GCV-46.37 and CV-4.68). Seedling traits like shoot vigour index, seedling length, fresh seedling biomass and oven dry seedling biomass showed higher variations with highest in shoot vigour index. ACZ-5 showed maximum variations wit in the ACZ for the seedling traits like shoot vigour index (PCV-50.57, GCV-50.44 and CV-3.68), oven dry seedling biomass (PCV-17.39, GCV-15.67 and CV-7.59) and fresh seedling biomass (PCV-17.18, GCV-14.10 and CV-9.83).

Similarly, in case of seedlings raised from the seeds collected from trees on agricultural lands, ACZ-3 showed maximum variations (PCV, GCV and CV values) with in the ACZfor most of the germination traits except germination value which has second highest variation after ACZ-10. Seedling traits showed maximum variation in for most of the traits in agroclimatic zone-8 except shoot vigour index which found second highest after ACZ-5.

These germinating and seedling traits has a scope for further assessment of variability in their respective ACZ mentioned above that will helpful for the improvement of the species. From seedlings raised from all the sample trees seeds , maximum germination percentage (100%) and other germination characters were found in sample tree -STAGA 6 where as important seedling characters like shoot vigour index (2962.00) and seedling oven dry biomass (15.34 g) were found to have maximum value in sample tree -STKMF1 in ACZ-5.

In the **sixth experiment**, the oven dried seed samples of *M. latifolia* were stored in different containers (Polybags, Cotton bags and Plastic containers) under various storage conditions (open light, closed light, closed dark and dark) for 180 days. The oil was extracted and its physico-chemical properties were studied at different intervals (at the time of storage, 30 days , 60 days, 90 days, 120 days, 150 days and 180 days after storage) for each sample. The observations recorded were for the oil content (percentage), acid value, saponification value, iodine value, oil density and specific gravity.

The mean oil content (averaged for all storage containers and storage conditions) was maximum (51.23%) at the time of storage of seeds and decreased to minimum (40.25%) after 180 days of storage with maximum degradation (21.43%). Maximum oil was extracted from seeds stored under closed light condition irrespective of container. Irrespective of storage conditions and storage durations, seeds stored in container like polythene bags gave maximum oil than other containers. After 180 days of storage the maximum oil content (48.01%) was found in the seeds stored in closed polythene bags kept in light.

The acid value and FFA % of the oil extracted from stored seeds found to be increased from the time of storage (6.45; 3.24) till 180 days of storage period (75.15; 37.77) irrespective of storage container and conditions. Irrespective of storage conditions and storage durations, seeds stored in container like plastic containers gave minimum acid value and FFA% of oil than other containers. Similarly, irrespective of storage containers and storage durations, seeds stored in closed dark condition recoded low acid value and fatty acid %. After 180 days of storage, the best storage condition with least acid value (40.17) and FFA% (20.19%) was the seeds stored in closed dark plastic container.

The saponification value of oil extracted from stored seeds decreased irrespectively of storage containers and storage durations from the day of packing (162.90) till 180 days of storage (68.17). Irrespective of storage conditions and storage durations, seeds stored in container like polythene bags gave maximum saponification value of oil than other containers. Similarly, irrespective of storage containers and storage durations, seeds stored in closed dark condition recorded higher saponification value of oil. After 180 days of storage the maximum saponification value of extracted oil (89.83) was found in the seeds stored in closed polythene bags kept in dark.

The Iodine value of oil extracted from the seeds at the time storage (62.70) was low The Iodine value of oil from the stored seeds decreased irrespective of storage containers and storage durations from the day of packing till 180 days of storage (39.83). Irrespective of storage conditions and storage durations, seeds stored in container like polythene bags gave maximum Iodine value of oil than other containers. Similarly, irrespective of storage containers and storage durations, seeds stored in closed dark condition recoded higher iodine value of oil. After 180 days of storage the maximum iodine value of extracted oil (43.60) was found in the seeds stored in closed polythene bags and plastic containers kept in dark.

Density and specific gravity of oil extracted from stored seeds increased irrespectively of storage containers and storage durations from the day of packing (0.891; 0.898) till 180 days of storage (0.897; 0.904). Seeds stored in container like polythene bags gave maximum density and specific gravity of oil than other containers irrespective of storage conditions and storage durations. Similarly, irrespective of storage containers and storage durations, seeds stored in closed dark condition recoded higher density and specific gravity of oil. After 180 days of storage the maximum density and specific gravity of extracted oil (0.901; 0.908) was found in the seeds stored in closed polythene bags and plastic containers kept in dark.

In the **seventh experiment**, this investigation was carried out in the villages near to forests and also having *M. latifolia* trees under traditional agroforestry systems like field bunds and homesteads on which local people depend to certain extent for their livelihoods. The study was carried out in 2-3 villages with total of forty respondents under each ACZ.

It was found that more than 80% of the respondents' size belongs to medium and small-sized family in all agro climatic zones. It was found that 58.50 % of respondents had medium sized family, 32.25 % had small families and 9.25 % of respondents had large families. The average land holding of respondents in the study area over all ACZ ranged 1.8 – 7.9 acre (0.72 – 3.16 ha) with an average of 3.88 acre (1.55 ha).Contribution of Mahua products to the total income generated from NTFPs it was found that maximum contribution was found in case of agroclimatic zone -9 (95.49%) and minimum contribution in case of ACZ-8 (60.23%) . Similarly, Contribution of Mahua products to the total income generated from all sources was found maximum (21.94%) in ACZ-1 and minimum (14.12%) in ACZ-3. The selling rate of dried mahua flowers at primary collector level varies from place to place and ranges between Rs 22.60-Rs 29.00 / kg over all ACZ of Odisha with maximum in ACZ-1 and minimum in ACZ-9. The mean collection of mahua flowers and mahua seeds per household across all agroclimatic zones of Odisha was about 3.67 Qtls and 82.98 kg respectively. The trade of Mahua flowers is approximately 7,92,000 Quintals in the state of Odisha contributing about Rs 1.93 crore to the primary collectors engaged in the activities in the state.

On the basis of the various results obtained the following conclusions can be drawn:

1. Higher variations in seed characteristics like seed thickness , seed helium length , 100 fruit weight , seed length, kernel length and 100 fresh kernel weight of *Madhuca latifolia* Macbride occurs in the germplasm collected from various agroclimatic zones and these can be taken up for improvement of the species .
2. More variation occurs within sample trees of agroclimatic zone than among the agroclimatic zones in both morphometric characters of *M. latifolia* seed and its seed oil characters.
3. Sample tree of *M. latifolia* showing higher values for important morphometric characters and oil characters was STMBA8 .
4. Higher variation were found for oil characters of *M. latifolia* like Free fatty acid , acid value, Saponification value and oil content in the germplasm collected from various ACZ which can be taken up for improvement of the species .
5. *M. latifolia* has higher IVI values along with *Shorea robusta* in most of the forests under different ACZ.
6. Higher variation occurs in germination traits like germination value, germination percentage, mean daily germination and seedling traits like shoot vigour index, oven dry seedling biomass and fresh seedling biomass.
7. In order to extract maximum oil, seeds should be stored in closed polythene bag in light.

8. In order to maintain the quality of oil with higher oil content, seeds should be stored in closed dark condition.
9. Flowers and fruits of *M. latifolia* contributes about 21.94% - 14.12% of the total income of tribal people dependent on it.

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(Saswat Nayak)

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