E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; 7(8): 209-213
Received: 18-06-2024
Accepted: 25-07-2024

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The *Madhuca longifolia*: A multifaceted tree with rich in nutritional factors

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DOI: https://doi.org/10.33545/2618060X.2024.v7.i8c.1223

Abstract
Madhuca longifolia, commonly known as Mahua or the Indian Butter Tree, is a vital multipurpose tree with significant socioeconomic value, extensively found in the tropical and subtropical regions of the Indian subcontinent. This deciduous tree is resilient, thriving in dry, rocky, and saline conditions. Mahua is prized for its various parts, each offering numerous benefits. The fruit seeds yield mahua butter, rich in linoleic and unsaturated fatty acids beneficial for heart health. The flowers, rich in sugar and containing essential vitamins and minerals, are used for food, liquor production, and animal feed. The leaves and bark have notable antioxidant properties, while the oil extracted from seeds is used in making soap, lubricants, and candles. Despite its long gestation period, modern grafting techniques have enabled quicker cultivation. The tree's adaptability makes it valuable for arid and semiarid regions. Future breeding efforts should focus on enhancing horticultural traits, increasing flower shelf life, and leveraging biotechnological tools for rapid improvement.

Keywords: *Madhuca longifolia*, mahua tree, Indian butter tree, multipurpose tree, socioeconomic value

Introduction
Mahua, the Indian Butter Tree (*Madhuca longifolia* (Koenig) J.F. Macribide) is an important tree having vital socioeconomic value and growing throughout the tropical and subtropical region of the Indian subcontinent. It is a deciduous tree that grows widely under dry tropical and subtropical climatic conditions. It is very hardy and thrives well on rocky, gravely, saline and sodic soils, even in pockets of soil between crevices of barren rock (Singh, 1998) [7]. It is one of those multipurpose forest tree species that provide an answer for the three major Fs i.e food, fodder and fuel.

Mahua is a tree valued for its fruit, seeds, which are the largest source of natural hard fat commercially known as mahua butter or mowrah butter. Fruits are eaten as raw or cooked. The fruit pulp may be utilized as source of sugar, whereas the dry husk makes a good source of alcoholic fermentation. Seeds are good source of oil. The oil obtained from kernel which is said to be useful for heart patients is used for edible purpose and permitted for preparation of vegetable oil. Amount of oil obtained from seeds of the fruit is higher than many oil seed crops and oilbearing trees. In Mahua oil, linoleic and unsaturated fatty acids are found, which are useful for heart patients, because it reduces the cholesterol content in blood serum. Mahua oil is used in manufacture of soap, lubricating grease, fatty alcohols and candles. Flowers of the plant are edible. The corolla commonly called as mahua flowers is a rich source of sugar containing appreciable amount of vitamins and minerals. The flowers are also used in preparation of distilled liquor, portable spirits, vinegar and feed for livestock. Reported that the fresh flowers of Mahua (*B. latifolia* Roxb.), that emit fragrance contain 2acetyl1pyrroline (2AP), the compound responsible for pleasant aroma in basmati and other scented rice. It was found that 2AP gets synthesized only in fleshy corolla of mature flowers. The flowers show antibacterial activity against *E. coli* and also are used against rice pest diseases (Sujatha and Das, 1988) [8]. Next to sugarcane molasses, Mahua flowers contribute as most important raw material for alcohol production.

Enzyme Invertase, present in the flowers of *Madhuca longifolia* plays an important role during the preparation of fermented Ayurvedic drugs known as 'Arishta'

Table 1: Nutritional Value of Mahua Flower

Moisture (%)	19.8
Protein (%)	6.37
Fat (%)	0.50
Reducing Sugar (%)	50.62
Total Inverts (%)	54.24
Cane Sugar (%)	3.53
Total Sugar (%)	54.06
Ash (%)	4.46
Calcium (%)	8.00
Phosphorus (%)	2.00

The leaves are used for making plates for various purposes. Mahua seeds can also be used for preparation of defatted flour, which has great potentiality in bakery products. The saponin obtained after extraction has industrial and commercial application. Cake obtained after extraction of oil is used as manure and has insecticidal properties. It provides quality timber wood for various uses. Every part of Mahua yields an economic product of great potential value; hence it is very useful tree for tribal and poor people of India. People in small villages don't have sufficient money for various resources to earn their living that is why they are fully or partially dependent on the natural resources which are easily available, cheap and renewable. Mahua flower is having potential to satisfy few needs of rural people. High sugar content of Mahua flower allows it to be consumed as jam, jelly or raw. The dried Mahua flower can be sold to the local distillery and hence they can make good money from it. The fermentation waste can also be used as bio fertilizer which is ecofriendly and cheap in comparison to the expensive fertilisers. Bulbul and Begum (2014) revealed that the methanol extract of *M. indica* has got profound antioxidant activity. So the plants may be considered as good sources of natural antioxidants for medicinal uses such as against aging and other diseases related to free radical. Leaves and barks of *Madhuca indica* showed significant antioxidant activity with IC50 value 61.832 ìg/ml and 66.342 ìg/ml respectively. The phenolic content was found in leaf 62.43mg of GAE / gm of extractives and the amount of phenolic content was 61.08mg of GAE / gm of extractives for bark which correlated with good antioxidant potentiality. The ethanolic and aqueous leaf extracts of *Madhuca indica* has anti hyperglycemic activity, is able to ameliorate the diabetic state and is probably a source of hypoglycemic compound (Jebaseelan and Ramasubramanian, 2014) [9]. *M. longifolia* leaves are effective biosorbent for the removal of Pb(II) ions from aqueous media. So, these leaves can be used on industrial scale for removing Pb (II) ions effectively. The tree is very well known to rural folk since ages in India. The production in India is mainly concentrated in the drier states and the produce is collected by the villagers and sold in the local market. Its cultivation may be spread to arid and semiarid areas, resource poor areas and wastelands where other crops cannot be grown successfully.

Domestication

Mahua (*Madhuca indica*) is an oilseed tree which grows naturally on village common lands in India. The local people, particularly the tribal, collect the fallen corolla and consume it in the fresh or dehydrated form. Long gestation period and poor income are major constraints for cultivation of mahua. Techniques have now been developed to produce grafted plants of mahua which start bearing in the fourth year. Looking to the economics and short gestation period, farmers are now keen to establish plantation of mahua on their degraded lands as a commercial crop

Taxonomy

Mahua (*Bassia atifolia* Roxb) belongs to the family sapotaceae. The trees of *Bassia latifolia* and *B. longifolia* grow up to an altitude of 1,200 m. The *B. malabarica* grows in Western Ghats from Kanara to Travancore and also in the Himalayas. The trees of *Bassia butyracea* grow in the Himalayan regions up to an altitude of 4,500 m.

Centers of Origin/Centers of Diversity

The mahua introduced from India to Australia and Polynesia. The species *Madhuca longifolia* is distributed in northern, central and southern part of peninsular India, and *M. latifolia* is found in some parts of central and north India.

Mahua, a characteristic tree of the dry region, is found in almost all parts of India. It commonly grows in eastern Uttar Pradesh, Madhya Pradesh, Chhattisgarh, Maharashtra, Bihar, Jharkhand, Orissa, Andhra Pradesh and Gujarat. In Rajasthan, it is also found growing on the wastelands particularly in southern part of the state. Dense population of mahua trees can be seen in Dahod, Panchamahals and Vadodara districts of Gujarat

Objectives of Crop Improvement

'Farmers' preference and market demand should be kept in mind, while defining the breeding objectives. Mahua is generally preferred by farmers as multipurpose tree for the use of food, fodder, fruit, flower, timber and fuel wood. These intended uses help in defining the ideotypes of this tree. Donald (1968) [10] defined ideotype as "a biological model which is expected to perform predictably, leading to greater quantities and qualities of crop yield under defined environmental conditions".

1. To develop promising genotypes having high yield potential along with early and regularity in bearing.
2. To develop short stature, precocious (rapid juvenile growth i.e. precocious in bearing) and prolific bearer cultivars having high oil content in kernels.
3. Breeding for resistance against biotic and abiotic stresses may be the objective of mahua improvement.

Ideotype specification for *Maduca longifolia*

- **Crown:** Large with many branches for planting on common land, but narrow an dance canopy for farm and home planting.
- **Stem:** Single or multiple but with a long straight bole with branches high on the stem
- **Root:** Deep, strong taproot to withstand wind

Cytogenetics

Mahua belongs to the family sapotaceae, indigenous to India, having chromosome X = 7, 8

Inheritance Pattern

Correlation studies provide reliable information on nature and extent of relationship for bringing out improvement in yield and other traits. There was significant positive association of flowers and fruits per fascicle, flower weight and flower yield with fruit yield per plant. These traits may be observed for their

positive behaviour while selecting superior genotypes.n Found significant positive correlation between 100 seed weight with seed length, breadth and thickness. Kernel oil content was negatively correlated with all the above seed characters and found significant negative correlation with hilum breadth, indicating that the seed size is not a selection criterion for identifying a genotype with high oil content. Heteroblastic development associated with phyllotaxy of leaves is generally noticed in *Madhuca indica*. This heteroblastic development of leaves serves as marker character and will help in identification of the taxon from closely related species.

Problem in Breeding

1. It is cross pollinated species so leadingto heterozygous nature of the crop. Improvement of such crop require long period ascompared to the annual crops.
2. Mahua is generally associated with long gestation period of 8 to 10 years.
3. Variability is declining in mahua at faster rate due to deforestation and human interventions. Flowers and fruits drop is another major hindrance in breeding. Large number of predators is associated with mahua due to its sweet corollas leading to more flowers and fruit drop.
4. Self and hand pollination gives low fruit set as compared to natural pollinations.
5. As other forest crop mahua seed collection is difficult. Birds and animals eat the fleshy fruits
6. There is no commercial cultivar available in this crop but some of the promising genotypes are available at NBPGR, New Delhi and NDUAT, Faizabad. Such genotypes should be improved by using modern breeding techniques. Fruit or tree breeders should lead the improvement work by collaboration with genetics person, biotechnologist, botanist and taxonomist

Floral Biology

Flowering

M. latifolia is longlived and starts bearing from about the 10th year. A full grown tree can produce up to 90 kg of flowers in a year. Leaf fall occurs from February to April and the trees are often leafless at the time of flowering which takes place, once in a year, ie. during March - April. The flowering time varies with the local conditions. It is recorded that the peak period of flowering and fruit set commenced in the month of March April in different genotypes. Time taken for complete development of flower bud from its visible initiation to anthesis varies from 20 to 30 days identified four different flower developmental stages.

- **Stage 1.** Bud completely closed
- **Stage 2.** Bud closed with the style protruding
- **Stage 3.** Flower partly open with the style protruding
- **Stage 4.** Fully ripe flower with shedding corolla

Flower

Flowers are in dense clusters at the end of branches with long pedicels; calyx coriaceous (i.e. leathery; stiff and tough, but somewhat flexible.); corolla tublar, fleshy, cream coloured, scented, caduceus (i.e.falling off early). The corolla falls off before or with the appearance of new leaves. The copious fall of succulent corollas weave a cream coloured carpet on the ground. The stamens are very short and adhere to the inner surface of the corolla. The pistil is a long, protruding green tongue. The pedicel length, pedicel thickness, bud length and breadth at flower opening varied from 4.205.50 cm, 2.003.00 mm, 1.30-1.80 cm and 1.001.20 cm, respectively in different genotypes. Total number of sepals was noted four. The ovary and style length varied from 4.506.25 mm and 25.0035.00 mm, respectively.

Anthesis, Stigma Receptivity and Pollen Viability

Variable percentage of anthesis was registered in different genotypes. Peak period of anthesis was recorded from mid night till morning in all the genotypes. Anthers dehisced 2-4 days before the time of anthesis.

Study of floral biology o reported that flower anthesis pattern and time (h) is Midday (5.0012.00), Pollen anthesis time (h) is 6.0015.00and the type of pollen grain/aperture is 45colporate (i.e. having distinct furrow and pore). Maximum stigma receptive period is first day after anthesis. Pollen viability and pollen germination ranged from 90.0098.50 and 26.50-40.20 percent respectively, among the genotypes studied.

Pollen pistil interaction

Madhuca indica shows strong self incompatibility reactions. It showsa few characters of both sporophytic and gametophytic systems. It has trinucleate pollen which needs controlled hydration for germination, characteristic of sporophytic system. The pollen viability is retained for a longer period (about 5-6 days) which is gametophytic in nature. The stigma is covered with copious exudates at receptive stage as in a gametophytic system, but the pollen germination is inhibited on the stigma surface even though the grains are hydrated as in a sporophytic system. Since the genetics of the system is unknown, no conclusion can be drawn regarding the nature of the self incompatibility system in *Madhuca indica*.

Seed and Fruit Setting

The rate of seed setting in Mahua under normal environmental conditions is very low. Kuruvilla found that usually only one ovule out of eight ovules develops into seed per fruitand rarely two or upto seven ovules develop to seed. The seed setting rate is low even in hand pollinations due to lack of distribution of the pollen tubes in all the stylar canals and competition for stored resources between early fertilized ovules and late fertilized ovules. The fertilized ovule started its development within three days after pollination. As flowers are fully mature, the leaf initiation starts and the fruit development occur simultaneously along with vegetative bud sprouting. The vegetative sink dominates thereby resulting in the abscission of developing fruit. The matured fruits fall on the ground in May and July in the North India and August and September in the South India.

Botanical Description

Mahua is a medium sized to large deciduous tree, usually with a large rounded crown found up to an altitude of 1,200 meter and of 12 to 15 meter height. Bark grey to black with cracks, inner bark dark red, milk, trunk short, branches numerous. The tree matures from 8 to 15 years and fruits up to 60 years. Leaves are thick, leathery, pointed at the tip and clustered at the end of branches. It exudes a milky sap when broken. Young leaves pinkish and wooly underneath. Flowers are small and fleshy, dull or pale white in colour and in define fascicles near end of branches. Corolla tubular, freshly, pale yellow aromatic and caduceus. Fruits are green at maturity and turn pinkish yellow when ripe. Botanically fruit is fleshy berry. Fruits are 2-6 cm long, ovoid, fleshy and having 14 seeds coloured brown to black. Seed contains two kernels. Seed of Mahua is highly sensitive to desiccation and freezing, indicating

recalcitrant nature of seed. Edible part is Mesocarp (flesh) of fruit

Crop Improvement Methods

Introduction

Collection, introduction and evaluation of mahua variability was undertaken, thirtyfive genotypes were selected and evaluated for flowering, fruiting and fruit quality attributes. Highest number of fruits per cluster (14.00) was found in collection No.2. Corolla (Mahua flowers) of collection No.5 had maximum weight (2.5g) and Juice (68.00%). TSS (26.00%) and total sugar (22.10%) was also found to be highest in the same genotype. Ripening took place in the month of May and June in different genotypes. The weight of mahua fruits varied from12.50 to 40.00 g and seed weight from 5.67 to 22.50 g. Kernel weight ranged from 4.20 to 16.00 g. TSS percent of fruits varied 12.0016.30, total sugar 10.5014.00 percent and vitamin C content 42.0063.50 mg/100 g.

Variability in oil content and seed weight of 37 accessions of mahua (*Madhuca longifolia*) collected from different part of Tamil Nadu, India were assessed by and found the highest oil content in accessions IC556617 (61.5%) and was followed by IC554529 (58.7%). Out of the total 37 accessions, 14 accessions were having more than 55 percent kernel oil content, which is a desirable trait for industrial use of this tree. These accessions can be used as a rich source of fat for industrial purposes.

Selection

It is highly heterozygous, crosspollinated fruit crop and as such seedlings exhibit a wide range of variations, which aids in the selection of the superior desirable genotypes. Due to cross pollination and predomination of seed propagation over a long period of time, it gives immense opportunity to locate elite trees having positive horticultural traits. Wide variations were observed in sweetness, acidity, size, shape and bearing habits in Mahua under Uttar Pradesh and Gujarat conditions. It is important to study the variability existing in the species and to select superior genotypes for adoptability, fast growth, precociousness, oil content, sugar content, flower size and disease resistance. 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. Superior genotypes are then propagated clonally or by seed into special seed production areas or orchards where open or controlled pollination provide seed for planting and if needed, for further selection, testing and breeding.

Improvement was made through selection. Elite genotypes were earmarked among the existing population of mahua based on the horticultural traits and evaluated under field conditions. Generally, the trees of *B. latifolia*, *B. longifolia* are found in the North and South parts of the country, which bear flowers containing a large amount of sugar and seeds rich in quality oil

Hybridization

Crossing Technique

In this method, flower buds of the cultivars should be emasculated a day prior to anthesis and covered with butter paper bags. Next morning, emasculated flowers should be pollinated with the pollen of desired cultivars, after pollination, it should be covered again. These bags should be removed after ensuring that the fruit set is taken place

Future Thrust

Breeding work with respect to horticultural traits is limited due to limited interest in this crop by horticulturists. There is vast scope for the improvement of scion and rootstock in this crop. The dwarf scion with precocious bearing may helpful for closer planting leading to more number of plants per unit area and efficient cultural practices. Another area in scion improvement is through increasing the shelf life of flowers (Corolla) which is economic part of plant and deteriorate very quickly. Under high temperature during summer months (April to June) mahua flowers suffer postharvest losses. Spoilage is the most significant form of wastage that accounts for 20–25 percent of postharvest losses in mahua flowers, which become unsuitable for the liquor distillation units and as cattle feed.

Biotechnological tools must be utilized for fasten the breeding programme. Seedlings must be evaluated as rootstock for better encore, dwarfness and adaptability to different climate.

Studies on floral biology, inter and intra specific/generic hybridization, documentation of floral biology and crossing techniques, plantation of selected plants for ex situ conservation and screening trees for higher oil content, sugar content, high flower and fruit yield are some of the other breeding objectives which should be carried out for the improvement of mahua.

Conclusion

Madhuca longifolia (Mahua) is an invaluable tree with extensive socioeconomic benefits, thriving in harsh environments and providing vital resources such as food, oil, and medicinal products. Despite its long gestation period, advancements in grafting techniques have made cultivation more feasible, offering promising prospects for arid and semi-arid regions. The tree's diverse applications, from nutritional to industrial uses, underscore its importance. Future research and breeding programs should focus on enhancing its horticultural traits and utilizing biotechnological advancements to improve yield, resilience, and economic viability, ensuring its continued contribution to rural livelihoods and sustainable development.

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