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Mahua – A multipurpose tree for tribals

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FOREWORD

Mahua, botanically known as *Bassia latifolia* Roxb, is an economically multipurpose tree. Its flowers, fruits and oil are used in various ways. The corolla commonly called *mahua* flower is a rich source of sugar, containing appreciable amount of vitamins and minerals. Flowers are used for preparation of distilled liquor and as feed for livestock. Seed is a good source of oil. Amount of oil obtained from seeds of the fruit is higher than many oil seed crops and oil-bearing trees. The oil obtained from kernel is used for edible purpose and permitted for preparation of vegetable oil. *Mahua* oil is also used in manufacture of soap, lubricating grease, fatty alcohols and candles. Cake obtained after extraction of oil is used as manure and has insecticidal properties. It provides quality timber wood for various household articles.

A wide range of variability occurs in nature with regard to fruit size and quality owing to its sexual propagation, which needs to be conserved and exploited. India is emerging as major stakeholder in global horticulture scenario accounting for 10 per cent of world production of fruits. This has been made possible due to the concerted efforts of scientists and progressive farming community.

In recent years, there is considerable awareness about the nutritional security and food safety. More emphasis is being given to underutilized fruits due to their high nutraceutical and therapeutical value in addition to being resistant/tolerant to many biotic / abiotic stresses. The demand of *mahua* is increasing gradually because of enormous potential for commercial exploitation aiming to improve the economic status of the poor and marginal farmers.

An area, which needs immediate attention, is the collection, documentation, conservation and post harvest management for their sustained production and popularization. This bulletin deals with the package of practices of *mahua* cultivation. It is hoped that, it will be helpful to growers, traders, students, scientists and teachers in playing their role for the *mahua* production in India.

(Dr. T. A. More)
Director

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Introduction

Mahua, botanically known as *Bassia latifolia* Roxb, is an economically multipurpose tree. Its flowers, fruits and oil are used in various ways. The corolla commonly called as *mahua* flowers is a rich source of sugar containing appreciable amount of vitamins and minerals. Flowers are used for preparation of distilled liquor. Flowers (fresh and dried) and spent flowers (after fermentation) are also used as feed for livestock. Fruits are eaten as raw or cooked. The fruit pulp can be used as source of sugar for alcoholic fermentation. Seeds are good source of oil. Amount of oil obtained from seeds of the fruit is higher than many oil seed crops and oil-bearing trees. The oil obtained from kernel is used for edible purpose and permitted for preparation of vegetable oil. 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. 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 tribals and poor people of India.

Origin and distribution

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, Chattisgarh, 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. The tree is very well known to rural folk since ages in India

Area and production

Information regarding area and production of this fruit in India is not available, because it is not grown on plantation scale, but trees in patches are common in the villages and forests in many states. It can be seen growing on roadsides. 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 semi-arid

areas, resource-poor areas and wastelands where other crops can not be grown successfully.

Soil and climate

Mahua is very hardy and thrives well on rocky, gravelly red soils and also on saline and sodic soils. It can grow even in pockets of soil between crevices of barren rock. However, for its better growth and productivity, well-drained deep loam soil is ideal.

Mahua prefers tropical and sub-tropical climate and can withstand drought admirably. 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 4,500m.

Botany

Mahua (*Bassia latifolia* Roxb) belongs to the family sapotaceae. Some of the species of genus *Bassia* are described below.

Bassia latifolia

It is a deciduous tree having 12-15 meter height. Bark thick, dark-coloured, cracked, the inner bark red, milky, trunk short, branches numerous, spreading, forming a thick shady head. Leaves clustered near the ends of the branches, coriaceous, hard and firm, elliptic or elliptic-oblong, shortly acuminate, pubescent or tomentose when young, at length glabrous, base rounded or acute. Petioles long at first pubescent, ultimately glabrous or nearly so. Stipules long, subulate, densely pubescent, vary caducous. Flowers in dense fascicles near the ends of the branches, below the terminal leaf-bud. Pedicels long, drooping, fulvous or rusty-pubescent or tomentose. Calyx long, divided nearly to the base, segments ovate, subacute, rusty-tomentose, usually 4 (rarely 5), the two outer subvalvate and enclosing the others. Corolla cream coloured, tube long fleshy, rugose, when dry, lobes7-14 (usually 7-9), ovate-lanceolate, acute, erect. Stamens 20-30 (usually 24-26), anthers in 3 series, acuminate, hairy at the back. Ovary hirsute, style long and hairy at the base. Berry long, fleshy, ovoid, greenish. It flowers in January- April under different climatic conditions.

Bassia longifolia

It is commonly found in south India. A large tree, branches numerous, bark thick, dark brown, scaly, the inner dark red, milky, young parts pinkish-white silky-pubescent.

Leaves thin, clustered near the ends of the branches, linear-lanceolate, acute, glabrous when mature, much tapered towards the base, petioles long slender, stipules long, linear-subulate, hairy and caducous. Flowers appearing with the young leaves, in dense clusters near the ends of the branches below the leaves, pedicels long, glabrous, erect at first, afterwards more or less drooping. Calyx long divided nearly to the base, densely rusty-pubescent, segments usually 4, ovate-oblong, acuminate. Corolla long, tube fleshy, inflatted, glabrous, rugose when dried, lobes 6-12, lanceolate, subobtuse, glabrous. Stamens 16-20 in 2 rows one above the other, subsessile, anthers hairy, cordate at the base, the connective produced to a point. Ovary densely hairy. Berry oblong, the size of a plum, hirsute while young ultimately nearly glabrous, yellowish when ripe. Seeds 1-2, compressed, straight on one side, curved on the other. It flowers in November-January.

Bassia malabarica

It is a medium sized tree. Bark dark coloured, scaly. Leaves very coriaceous, oblong to lanceolate, sub-obtuse, glabrous, dark green and shining, base tapering, main nerves 15-25 pairs, very slender with closely reticulate veins between, petioles long. Flowers crowded towards the ends of the branches in dense fascicles. Calyx long, divided nearly to the base, segments 4, ovate, subacute, the 2 outer glabrous or nearly so, the 2 inner hairy. Corolla long, tube densely rufous-hairy, both inside and outside, slightly shorter than the lobes. Lobes 6 (rarely 7), oblong, obtuse, fulvous-hairy outside. Stamens 16-18 in 2 rows, filaments densely rufous-hairy, anther glabrous or with a very small tuft of hairs between the basal lobes, cordate at the base. Ovary glabrous. Berry oblong-lanceolate, glabrous while young. It flowers in November-January.

Reproductive biology

Singh *et al*, 2006, recorded that the peak period of flowering and fruit set commenced in the month of March-April in different genotypes. Number of flowers (42.00) and fruit set per fascicle (9.50) were found to be highest in MH 2, while it was registered least in MH 15. Variable percentage of anthesis was registered in different genotypes. Peak period of anthesis was recorded from mid night till

Flowering pattern in mahua

morning in all the genotypes. Anthers dehisced 2-4 days before the time of anthesis. The pedicel length, pedicel thickness, bud length and breadth at flower opening varied from 4.20-5.50 cm, 2.00-3.00 mm, 1.30-1.80 cm and 1.00-1.20 cm, respectively in different genotypes. Total number of sepals was noted four. The ovary and style length varied from 4.50-6.25 mm and 25.00-35.00 mm, respectively. Pollen viability and pollen germination ranged from 90.00-98.50 and 26.50-40.20 per cent respectively, among the genotypes studied. On the basis of different reproductive attributes studied, fruit set per panicle may be considered as one of the positive traits while screening the elite genotypes of *Mahua.*

Genetic diversity

It is highly heterozygous, cross-pollinated 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 large period of time, it gives immense opportunity to locate elite trees having horticultural traits. Wide range of variability were observed in sweetness, acidity, size, shape and bearing habits in *Mahua* under Uttar Pradesh conditions (Singh *et al*, 1999).

Variability in physico-chemical characters of *mahua* flowers (Singh *et. al.* 1999)

Maturity Group	Flower weight (g)	Juice (%)	Pomace (%)	Stamens (%)	TSS (%)	Acidity (%)
Early	1.5 - 2.8	66.4 - 69.6	28.3 - 30.8	0.8 - 1.4	25.0 - 26.7	0.09 - 1.0
Mid season	1.3 - 2.5	64.5 - 67.7	30.5 - 33.4	1.5 - 2.0	23.5 - 25.8	0.11 - 0.12
Late	1.2 - 2.6	62.8 - 64.1	34.1 - 35.0	1.3 - 1.8	21.0 - 26.0	0.10 - 0.12

Variability in physical characters of *mahua* fruits (Singh *et. al.* 1999)

Maturity group	Fruit wt. (g)	Husk (%)	Seed (%)	Total sugar (%)	Vit. C (mg/100g)
Early	16.8 – 35.3	58.0 – 71.7	28.3 – 42.0	13.0 – 13.8	47.5 – 59.2
Mid season	19.4 – 31.8	58.3 – 70.2	29.8 – 41.7	11.5 – 13.2	48.3 – 72.5
Late	18.5 – 20.5	70.8 – 71.9	28.1 – 29.2	11.0 – 11.4	51.2 – 65.5

Variability in physical characters of *mahua* seeds (Singh *et. al.* 1999)

Maturity group	Seed wt. (g)	Kernel (%)	Shell (%)
Early	7.2 – 10.0	73.7 – 77.2	22.8 –26.3
Mid season	8.1 – 9.5	73.9 – 83.6	16.4 – 26.1
Late	5.2 – 6.0	76.8 – 78.8	21.2 – 23.2

Variability in chemical characters of *mahua* kernels (Singh *et. al.* 1999)

Maturity group	Oil (%)	Free fatty acids (%)	Proteins (%)	Minerals (%)
Early	42 – 49	0.53 – 0.54	23.5 – 23.7	5.3 – 5.7
Mid season	42 – 45	0.59 – 0.62	22.6 – 22.7	3.9 – 6.4
Late	42 – 43	0.97 – 1.20	21.0 – 25.7	4.4 – 4.8

Description of some promising genotypes evaluated at CHES, Godhra:

MH-10

It was collected from Vejalpur village of Panchmahal district, Gujarat. Peak period of flowering is the second week of March. Flowers recorded 2.29 g weight, 65.00 % juice and 26.37 % TSS. It ripens in second week of May and recorded 30.50g fruit, 13.50g seed and 11.00g kernel weight.

MH-14

It was collected from Otala village (Baria Road) of Panchmahal district, Gujarat. Peak period of flowering is the second week of March. Flowers recorded 2.24 g weight, 66.00 % juice and 25.00 % TSS. It ripens in the second week of May and recorded 29.00 g fruit, 12.70g seed and 9.53g kernel weight.

MH-35

It was collected from Reechawani village (Baria Road) of Dahod district. Peak period of flowering is the second week of March. Flowers recorded 2.13 g weight, 64.12 % juice and 24.90 % TSS. It ripens in third week of June and recorded 28.50g, 12.23g and 10.08g fruit, seed and kernel weight, respectively.

MH-63

It was collected from Reechawani village (Baria Road) of Panchmahal district, Gujarat. Peak period of flowering is taken place in the 4th week of March. Flowers recorded 2.50 g weight, 68.00 % juice and 24.37 % TSS. It ripens in 4th week of May and recorded 23.50g fruit weight.

Singh and Singh, 2005, surveyed the area of diversity of Gujarat and identified twenty elite genotypes, among its population. Early flowering was observed in the 1st week of March in MH 1, MH 4, MH 5, while it was recorded late (2nd week of April) in MH 6. Number of flowers and fruits per fascicle ranged from 17.50 – 45.00 and 3.00-8.00 respectively. Dry flower yield varied from 30.00 to 46.00 kg / plant in different genotypes. Variation in fruit yield among the genotypes ranged from 35.00 kg to 82.00kg / plant. The highest total soluble solids (27.80 %), total sugar (24.24%) and vitamin C content (64.00mg/ 100g) was recorded in flowers of MH 4. Maximum weight of fruit (34.50), seed (14.50g), kernel oil (46.50%), minerals (4.90%) and protein content (24.00 %) were found in MH 2. Promising genotypes have been established in the field and are being further evaluated for their flowering and fruiting as potential parents to develop high yielding stable genotypes having positive horticultural traits. Variability for flowering and fruiting attributes among fifteen genotypes of *mahua* was also recorded under semi-arid ecosystem of Gujarat (Singh *et al,* 2005).

Variability in physico-chemical attributes of *mahua* flowers (Singh *et. al.* 2005)

Genotype	Flower weight	Juice (%)	Pomance (%)	Stamen (%)	TSS (%)	Acidity (%)	Total sugar	Vit-C (mg/100g)
MH -1	2.30	67.00	32.20	0.80	25.00	0.09	22.11	58.00
MH- 2	2.40	69.00	30.30	0.70	26.10	0.08	23.14	62.50
MH- 3	2.30	64.10	35.30	0.60	27.00	0.10	24.14	61.60
MH- 4	2.32	68.50	30.60	0.90	27.80	0.11	24.24	64.00
MH- 5	2.11	61.60	37.69	0.81	24.00	0.12	21.09	53.00
MH- 6	2.13	60.90	38.84	0.86	27.50	0.13	20.00	52.00
MH- 7	1.91	62.00	37.17	0.83	24.00	0.10	21.11	44.30
MH- 8	1.90	68.52	30.57	0.93	26.00	0.91	23.00	42.90
MH- 9	1.89	66.00	33.06	0.94	26.00	0.94	23.11	46.00
MH- 10	2.29	65.00	34.07	0.93	26.37	0.98	23.17	59.00
MH- 11	2.26	60.60	38.46	0.94	25.00	1.10	22.19	44.00

Genotype	Flower weight	Juice (%)	Pomance (%)	Stamen (%)	TSS (%)	Acidity (%)	Total sugar	Vit-C (mg/100g)
MH- 12	2.19	63.00	36.07	0.93	24.11	1.08	20.89	43.00
MH- 13	2.10	65.0	34.04	0.96	26.00	1.07	21.97	49.30
MH- 14	2.24	66.00	33.08	0.92	25.00	1.08	21.00	59.00
MH- 15	2.16	63.25	35.86	0.89	25.50	1.12	21.14	56.40
MH-16	2.25	62.50	36.62	0.88	25.00	1.13	21.00	58.00
MH -17	2.16	63.11	36.06	0.83	26.00	1.10	22.10	59.00
MH -18	2.19	65.00	34.07	0.93	24.00	1.07	21.34	56.13
MH- 19	2.00	61.00	38.06	0.94	24.90	1.06	20.99	56.12
MH- 20	2.10	60.00	39.02	0.98	26.10	1.07	23.00	59.14
CD (*P=0.05*)	0.11	1.39	1.92	NS	0.60	0.03	0.54	1.39

Variability in physico- chemical attributes of *mahua* fruits (Singh *et al*, 2005)

Genotype	Fruit weight (g)	Husk Weight (g)	Seed Weight (g)	Seed (%)	TSS (%)	Acidity (%)	Total sugar (%)	Vitamin-C (mg/100g)
MH -1	15.00	9.50	5.50	36.66	13.00	0.08	11.14	45.00
MH- 2	34.50	20.00	14.50	42.03	15.00	0.09	13.13	66.00
MH- 3	22.00	14.50	7.50	34.09	11.50	0.11	9.24	48.50
MH- 4	32.00	18.00	14.00	43.75	14.50	0.12	11.18	59.40
MH- 5	18.00	11.00	7.00	38.88	11.00	0.09	9.30	50.11
MH- 6	25.00	14.50	10.50	42.00	12.00	0.09	9.43	52.00
MH- 7	26.00	15.00	11.00	42.30	13.00	0.08	10.19	56.00
MH- 8	28.00	14.37	13.63	48.67	12.10	0.08	9.45	45.00
MH- 9	20.00	11.10	8.90	44.50	13.14	0.08	11.03	61.00
MH- 10	30.50	17.00	13.50	44.27	14.00	0.09	11.43	48.30
MH- 11	22.00	12.20	9.60	43.63	13.00	0.12	10.11	44.11
MH- 12	24.00	13.00	11.00	45.83	13.14	0.11	10.17	48.00
MH- 13	26.00	14.00	12.00	46.15	12.94	0.13	9.76	46.00
MH- 14	29.00	16.30	12.70	43.80	14.10	0.08	11.78	60.40
MH- 15	22.50	12.00	10.50	46.66	13.11	0.09	11.10	45.11
MH-16	20.10	11.00	9.10	45.27	13.41	0.11	11.21	44.00

Genotype	Fruit weight (g)	Husk Weight (g)	Seed Weight (g)	Seed (%)	TSS (%)	Acidity (%)	Total sugar (%)	Vitamin-C (mg/100g)
MH -17	21.00	12.00	9.00	42.86	12.00	0.12	9.08	43.00
MH -18	18.00	10.10	7.90	43.89	12.19	0.13	9.13	52.55
MH- 19	18.50	10.00	8.50	45.95	12.00	0.11	9.00	56.41
MH- 20	20.50	11.60	8.90	43.42	13.00	0.09	10.13	55.00
CD (*P=0.05*)	2.16	1.34	1.36	1.11	0.53	NS	0.64	2.67

Variability in physico- chemical attributes of *mahua* kernels (Singh *et al*, 2005)

Genotype	Kernel weight (g)	Kernel (%)	Shell weight (g)	Shell (%)	Oil (%)	Protein (%)	Minerals (%)
MH -1	4.20	76.36	1.30	23.64	41.00	20.00	4.11
MH- 2	12.10	83.45	2.38	16.55	46.50	24.00	4.90
MH- 3	5.14	68.53	2.36	31.47	43.00	21.00	4.15
MH- 4	12.00	85.71	2.00	14.29	45.00	23.00	4.68
MH- 5	5.10	72.86	1.90	27.40	43.00	22.10	3.93
MH- 6	8.13	77.44	2.37	22.56	40.00	21.30	3.98
MH- 7	9.00	81.81	2.00	18.19	42.00	20.14	3.90
MH- 8	11.14	81.73	2.46	18.27	43.50	21.13	4.11
MH- 9	7.11	79.88	1.79	20.12	44.80	22.30	4.09
MH- 10	11.00	81.48	2.50	18.52	46.00	24.10	4.83
MH- 11	7.14	74.38	2.46	25.62	41.90	23.00	4.15
MH- 12	9.03	82.09	1.97	17.91	42.00	21.30	4.30
MH- 13	9.43	78.58	2.57	21.42	44.00	20.11	3.93
MH- 14	9.53	74.92	3.17	25.08	45.50	23.50	4.73
MH- 15	8.73	83.14	1.77	16.86	41.50	20.80	3.94
MH-16	7.14	78.46	1.96	21.54	42.00	22.30	3.95
MH -17	7.10	78.88	1.90	21.12	43.00	23.10	4.09
MH -18	5.64	71.39	2.26	28.61	44.50	23.09	4.14
MH- 19	6.19	72.82	2.31	27.18	45.10	22.01	4.20
MH- 20	6.50	73.03	2.40	26.97	44.50	20.11	3.94
CD (*P=0.05*)	1.13	0.56	0.32	1.38	1.30	0.68	0.43

Varietal wealth

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. So for, there is no improved variety of *mahua* for an organized orcharding. However, a large variability exists in its fruits. Recently, some selections have been made by Singh, 1998 at N.D.University of Agriculture and Technology, Faizabad (Uttar Pradesh), which are discussed bellow.

NM – 2

Flowering is taken place in the first week of April. Average number of flowers / fascicle, weight of fresh flower, yield of flower (dry) were recorded 66, 2.8g, and 9.9 kg, respectively from 7-year-old grafted plants. Fresh flower had 25.50 % total sugar, 19.60% reducing sugar, 5.6 % non- reducing sugar, 60.90 mg/ 100 g Vitamin C, 650.70 IU Vitamin A and 0.60 % mineral content.

Total sugar content of dry flower was 58.70 % with reducing sugar 55.60 and non-reducing sugar 3.0 %. Mineral content of dry flower was found to be 2.20 per cent. Ripening of fruit took place by second week of June. Average fruit weight 16.80g, husk content 58.80 %, total sugar13.60 %, reducing sugar 7.8 %, non- reducing sugar 5.80 %, vitamin C 51.30 mg/ 100 g, vitamin A 586.70 IU and mineral content 1.90 % was recorded. Average seed weight and kernel weight was found to be 7.2 g and 5.50 g respectively. Oil content, 47.40 %, free fatty acid 0.53 %, protein content 23.60 % and mineral content 5.70 % was recorded. Unsaturated fatty acid 53.80 % with 40.30 oleic and 13.50 % linoleic and where as saturated fatty acid was recorded 45.40 % (palmitic 24.30, stearic 20.20 and archidic 0.90 %).

NM- 4

Flowering is taken place in the fourth week of April. Average number of flowers / fascicle 54.6, weight of fresh flower 2.6g and yield of flower (dry) of 7-year-old grafted plant is 8.5 kg. Fresh flower recorded 24.50 % total sugar, 19.60% reducing sugar, 4.80 % non- reducing sugar, 49.20 mg/ 100 g Vitamin C, 528.20 IU Vitamin A and 0.67 % mineral content.

Total sugar content of dry flower was 57.30 % with reducing sugar 53.80 and non-reducing sugar 3.30 %. Mineral content of dry flower was found to be 2.30 per cent. Ripening of fruit started by third week of June. Average fruit weight 19.50 g, husk content 65.30 %, total sugar 11.20 %, reducing sugar 8.20 %, non- reducing sugar 3.20 %, vitamin C 55.80 mg/ 100 g, vitamin A 860 IU and mineral content 2.1 % was recorded. Average seed weight and kernel weight were found to be 6.00 g and 4.70 g, respectively.

Oil content 45.20 per cent, free fatty acid 0.63 per cent, protein content 25.70 per cent and mineral content 4.40 per cent were recorded. Unsaturated fatty acid 50.60 % with oleic 38.00 and linoleic 12.60 % and saturated fatty acid 48.50 % (palmitic 19.90, stearic 27.00 and archidic 1.60 %).

NM-7

Flowering is taken place in the second week of April. Average number of flowers / fascicle 64.30, weight of fresh flower 2.50g and yield of flower (dry) of 7-year-old grafted plant is 10.00 kg. Fresh flower recorded 22.70 % total sugar, 19.50% reducing sugar, 3.00 % non- reducing sugar, 48.50 mg/ 100 g Vitamin C, 564.50 IU Vitamin A and 0.82 % mineral content.

Total sugar content of dry flower was 58.40 % with reducing sugar 56.60 and non-reducing sugar 1.50 % while mineral content of dry flower was found to be 3.00 per cent. Ripening of fruit took place by third week of June. Average fruit weight 21.8 g, husk content 55.00 %, total sugar 10.10 %, reducing sugar 8.00 %, non- reducing sugar 2.30 %, vitamin C 59.20 mg/ 100 g, vitamin A 620.70 IU and mineral content 2.4 % was recorded. Average seed weight and kernel weight was found to be 9.50 g and 7.20 g, respectively. Oil content 46.70 per cent, free fatty acid 0.55 %, protein content 22.40 % and mineral content 4.80 % was recorded. Unsaturated fatty acid 49.20% with oleic 34.40 % and linoleic 14.90 % and saturated fatty acid 47.90 % with palmitic 20.80, stearic 26.90 and archidic 1.20 % was recorded.

NM- 9

Flowering is started in the fourth week of April. Average number of flowers / fascicle 54.6, weight of fresh flower 2.2g and yield of flower (dry) of 5-year-old grafted plant is 6.80 kg. Fresh flower had 21.80 % total sugar, 20.00% reducing sugar, 2.10 % non- reducing sugar, 30.20 mg/ 100 g Vitamin C, 802.00 IU Vitamin A and 1.40 % mineral content.

Total sugar content of dry flower was 55.70 % with reducing sugar 54.30 and non-reducing sugar 1.60 %. Mineral content of dry flower was found to be2.90 percent.

Ripening of fruit initiated by third week of June. Average fruit weight 16.70 g, husk content 60.00 %, total sugar 15.40 %, reducing sugar 12.20 %, non- reducing sugar 3.70 %, vitamin C 72.50 mg/ 100 g, vitamin A 890.00 IU and mineral content 1.80 % was recorded.

Average seed and kernel weight was found to be 5.20 g and 4.0 g, respectively. Where as oil content 48.50 per cent, free fatty acid 0.48 %, protein content 16.80 % and mineral content 4.10% was recorded. Unsaturated fatty acid was recorded 51.60 % with oleic 37.60, linoleic 14.00 % while saturated fatty acid was found to be 47.60 % with 19.50, 27.50 and 0.60 % palmitic, stearic and archidic, respectively.

Plant propagation

Raising of seedlings

Generally, seedlings are raised to be used as rootstock. *Mahua* seeds have no dormancy. Fresh seeds after storage of 5-6 days at room temperature show 80% germination. Seeds can be sown on raised beds about 3 cm deep during June-July, therefore, they are shifted in polythene bags with 3-4 leaves. It may also be sown directly in polythene bags. Seeds germinate within 10-15 days. The seedlings become ready to use as rootstock after 9- 12 months. Polyembryony is found in *mahua* seeds. Therefore, 15-20% seeds produce nucellar seedlings.

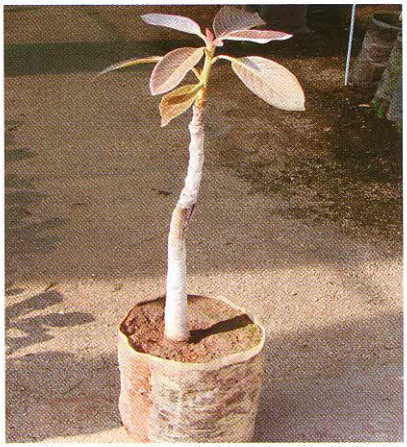
Raising of mahua rootstocks

Vegetative propagation

Soft wood grafting

Softwood grafting is practiced when one-year-old seedlings raised for rootstock commence putting on new growth and the leaves are of light green colour. Shoots of 3-4 months, which have prominent apical bud are taken as the scion material. Defoliation of such shoots is done 8-12 days before detaching from the parent tree for grafting operation. At the time of removal of these shoots, the apical buds should be remained intact. Naturally defoliated shoots (March-April) may be used for better success. These shoots are detached from the mother plant with the help of secateur or sharp grafting knife for grafting by cleft method. For this, seedling rootstock is cut at 20-35 cm height and the top portion is removed. With the help of knife, 5 cm long vertically downward incision is made in the center of the rootstock and on the base of the scion shoot; a sharp cut of 5 cm is made on both the sides. Thereafter, prepared scion is carefully inserted in vertical slit of the rootstock and tightly secured with the help of 200 gauge thick and 2

cm wide polythene strips. After grafting, the plants are observed regularly and any growth below the graft union is removed to encourage the sprouting and subsequent growth of the scion shoots. The polythene strips are carefully removed after completion of union. If the selection of scion and rootstock is proper, 60-70 % success may be obtained during the month of March, April, July and August. Anonymous, 2007 reported that softwood grafting recorded maximum success in the month of March (80%), followed by February (70%) and July (65%) under Uttar Pradesh conditions. Highest percentage of graft success in *Mahua* was recorded in the month of March (70.00) closely followed by April, July and August, while least percentage of success was noted in the month of September (8.33), (Singh, *et al*, 2008). Soft wood grafting may be practiced in the month of March, April, July and August for multiplication of *mahua* genotypes under semi arid environment of Western India.



Soft wood grafting

Effect of time on softwood grafting of *Mahua* (Singh, *et al*, 2008)

Months	Time taken for bud sprout (days)	Bud sprout (%)	Success (%)	Length of sprout (cm) at 150 days
July	30.50	66.25 (54.45)	64.20 (53.25)	24.20
August	30.00	64.50(53.43)	62.00 (51.94)	23.10
September	34.00	9.25(17.66)	08.33 (16.74)	18.50
October	32.00	22.10(28.04)	20.10 (26.64)	16.00
November	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00
January	0.00	0.00	0.00	0.00
February	0.00	0.00	0.00	0.00
March	26.00	73.25(58.82)	70.00 (56.79)	28.00
April	27.33	67.50(55.24)	65.50 (54.03)	27.10
May	28.00	63.50(52.83)	60.00 (50.77)	20.10
June	29.00	57.10(49.08)	55.00 (47.87)	20.00
C.D (P=0.05)	2.11	3.55	2.14	1.25

Figures in parentheses are transformed values.

Soft wood grafting *in-situ*

In-situ softwood grafting was found to be better for establishing *in- situ Mahua* orchard in gravelly soils and drier tracts where mortality of nursery raised grafts is very high. Freshly extracted seeds are sown in the polythene bags for germination. After attaining age of one year, it should be directly planted (June- July) in the field at the desired distance. These vigorous seedlings are soft wood grafted with scion sticks of the suitable genotypes. If irrigation water is enough, grafting may also be performed in the month of March- April provided rootstocks attain pencil thickness. Such plants grow very fast and attain a stature in few years.

Wedge grafting *in- situ*

Result of study in optimization of period for *in- situ* wedge grafting revealed that naturally defoliated shoots may be used for grafting in the month of March and April with highest percentage of graft success when grafting is done in the month of March (75.00 %). Better graft success is recorded in the month of March and April because of faster establishment of vascular connection with rootstock and scion. March and April months may be the ideal for multiplication of elite *mahua* genotypes under semi-arid environment of western India.

Wedge grafting

Veneer grafting

Veneer grafting is a successful method for multiplication of *Mahua* on one-year-old rootstock. The shoots are taken from spring flush and the operation is done in the month of July and August. July is the ideal time for veneer grafting. Plants become ready for planting in September, just 2 months after grafting. Anonymous (2007) reported that veneer grafting recorded 60 and 40% success in the month of February and March, respectively.

Air layering

Shukla (2005) reported that one year old shoots on *mahua* trees were ringed and upper end of the cuts were treated with IBA 1000 ppm. The ringed portion after hormonal operation was wrapped with moist moss grass. Rooted shoots were removed from the mother plant 60 days after the treatment and planted in polythene bags having size of 15 x 30 cm and filled with soil and FYM mixture (1:1). This method needs to be standardized under various climatic conditions.

Growing structures

Growing structures are special structures and design of protected houses fabricated with glass, polyethylene fibres, shedding nets, plastic materials and provided with environmental monitoring equipments / devices for regulation of optimal conditions required for regeneration of plants, growth and hardening of propagating materials.

Mist house: It is used for multiplication of plants through soft wood grafting, in which controlled misting system is provided to maintain the adequate humidity throughout the growing period of plants to avoid the loss of water.

Net house: It is used for protection of grafted plants during the hot summer months. It is fabricated with 25, 50, and 75 % shedding nets of nylon and provided with micro sprinkler system to maintain the humidity and temperature.

Use of polycontainers

Grafted plants ready for planting

Raising of rootstocks in nursery beds and lifting budded plants with earth ball in highly sandy soils is practically not feasible. Transportation of plants from long distance may also cause high mortality particularly under semi-arid and arid environment. To reduce the time for raising rootstock and to avoid damage during handling and transportation, polyethylene bags may be used on commercial scale. Generally polyethylene bags having size of 15cm x 25cm or 20x30 cm are used for raising the rootstocks. Small holes are made in the bottom and sides of polyethylene bags for drainage and aeration and filled with porous rooting medium or pot mixture for raising rootstocks. Generally 1-2 seeds are sown in each poly bags and then placed in trench bed, so that it can be irrigated easily. Some times coiling of root is become problem, hence root pruner is also used for trimming of roots.

Orchard establishment

Once the climate and soil requirements of *mahua* have been taken in to consideration, the next step is to layout the orchard. The land may be prepared by usual ploughing, harrowing and levelling. There should be a gentle slope to facilitate proper irrigation

Experimental block

Mahua at farmer's field

and prompt drainage to avoid the harmful effects of water stagnation during rainy season. *Mahua* may be grown under various cropping systems i.e. as an orchard crop in a pure land, as an agro-forestry species in mixed cropping systems or as a hedgerow tree. After marking the places for the plants, pits of 1x1x1m are usually dug out during summer months. Digging of pits is very essential for heavy type of soil with shallow hard pan. While digging, it is necessary to keep the top soil and sub soil separately in two heaps near each pit for about 2-4 weeks. This helps in exposing harmful soil organisms to weathering agencies, providing better aeration in the future rooting zone and making provision for the nutritional requirements for the healthy development of the plants. Well-decomposed organic matter (25 kg farmyard manure) is mixed with soil and pits are filled up just above from the ground level. Planting is done in the center of the pit during the rainy season when the soil is already settled. While planting one should be

careful that the earth ball does not break and graft union remains well above the ground level. The planting should preferably be done during cloudy weather and in the evening. The plants should be irrigated immediately after planting. In the initial 2-3 years, it is advisable to protect plants against low temperature injury by covering plants with some short of cover, leaving the eastern side open for entrance of light. *Mahua* is planted at the distance of 10 x10 m. It is frequently planted along land borders, on field boundaries and in village groves as individual tree.

Canopy management (training and pruning)

Canopy management of the crop deals with the development and maintenance of their structure in relation to the size and shape for the maximum productivity and quality. The basic concept in canopy management of a perennial tree is to make the best use of the land and the climatic factors for an increased productivity. Tree vigour, light, temperature and humidity play a vital role in the production and quality of the fruits. The crux of the canopy management lies in the fact, as to how best we manipulate the tree vigour and use the available sunlight and temperature to increase the productivity and quality and also to minimize the adverse effects of weather parameters. Some of the basic principles in canopy management are (1) maximum utilization of the light (2) avoidance of the build up of microclimate congenial for the disease and pest (3) convenience in carrying out the cultural operations (4) maximizing the productivity and quality. Basically, the training is a potential tool to manage the canopy architecture of the plant. Training is very essential to develop the framework of *mahua* plants. Plants are allowed to grow straight with the help of stakes. Young plants

MH-2

MH-18

MH-14

should be allowed 3-5 well spaced branches to develop in to the main scaffold structure of the tree. Framework of branches is allowed to develop above 60-100 cm from the ground level. Pruning is a tool to regulate tree size and shape to achieve a desired architecture of the canopy and also to reduce the foliage density by removing the unproductive branches of the tree. Regular pruning in *mahua* plant is not required, however dry, week and diseased branches should be removed.

Nutrient management

Generally *mahua* trees are not manured however, a dose of 10 kg farmyard manure, 100g N, 50g P and 75g K/plant approximately should be given to one-year-old plant. It should be increased every year in the same proportion up to the age of 10 years. Thus fully-grown up trees require 100 kg farmyard manure, 1 kg N, 0.5kg P and 0.75 kg K Farmyard manure should be applied during July-August. Half dose of N and full dose of P and K should be applied in the month of July and remaining half dose of N should be applied by the end of August or first week of September under rain fed conditions. The exact dose of N P K needs to be standardized under various climatic conditions. The manure and mixture of fertilizer should be spread under the canopy of plants and incorporated in the soil. Mahua leaf litter is available in the canopy of the plant which is an integral part of the soil fertility management. It may be managed with earthworm culture in plant basin with the degradation of the biomass. However, such type of studies is required to be carried out in different climatic conditions. In soil application method, fertilizer should be applied in active root zone.

Intercropping

Intercropping is intended to maximize land and space use efficiency to generate supplemental income particularly during the initial unproductive phase of the orchard to protect the inter space from losses through weeds, erosion, impact of radiation, temperature, wind and water and enriching it by nitrogen fixing legume crops. Compatible crop combination is necessary with regard to species, cultivars, planting method and sequence. Cucurbitaceous crop like pumpkin, bittergourd, bottlegourd, cucumber, black gram, cowpea, cluster been may be grown as inter crops in the orchard under rainfed condition. Green manuring is useful if planted on poor soils. Experimental evidences are, however, not available. *Mahua* based cropping system needs to be standardized.

Weed management

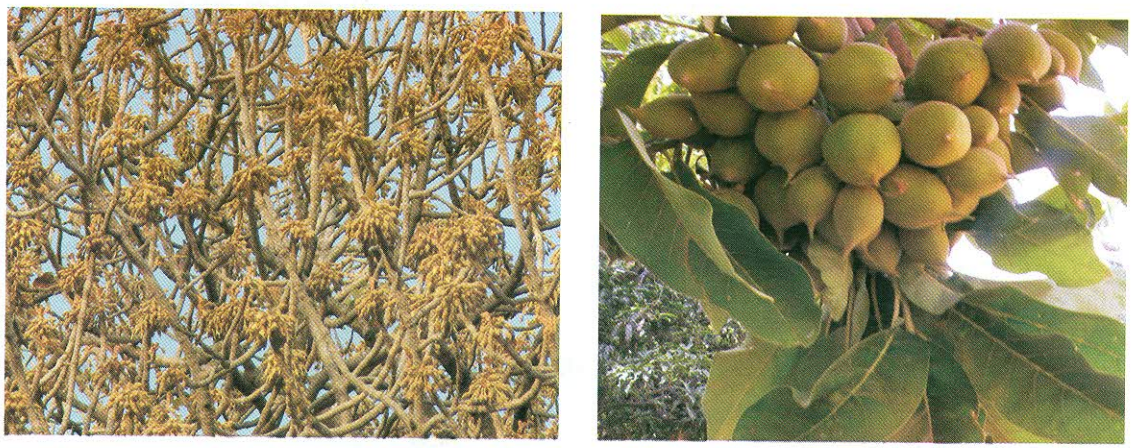
Weeds injure crops very slowly in a subtle way. Most weeds complete their life cycle in a shorter time compared to the fruit trees and compete for light, water and mineral nutrients and reduce yield. In new and old orchard, hoeing, hand weeding and ploughing the land 2-3 times a year is done to suppress weed growth. Intercropping and mulching may also be followed to control weeds.

Irrigation

In general, irrigation is required during establishment of the orchard. No irrigation is required for well grown up trees.

Flowering and fruit set

In *Mahua*, flowers appear just after leaf fall (from February to April) in different agro climatic zone of the country (Singh *et al*, 2005). The time taken for complete development of flower bud from its visible initiation to anthesis varies from 20 to 30 days. The average number of flowers per fascicle varies from 10 to 60. Young plantation of grafted *Mahua* (7- year old) shows heavy flowering with very poor fruit set (1.6-4.0 %). Dropping of young fruit lets have been observed and only 8-13 % of set fruits reached to maturity. The cause of poor fruit set may be due to pollination problem or self-incompatibility. Seedling trees of higher age have better fruit set than the tree of lower age group (Singh, 1998).



Flowering and fruiting in *mahua*

Maturity, harvesting, yield and post harvest management

Singh *et al*, 2006 studied maturity standards in different genotypes of *Mahua* under semi arid conditions of Gujarat and observed that the fruit growth was faster initially and slowed down while reaching towards maturity. Total soluble solids, total and reducing sugars increased as the fruits reached towards the maturity. Titratable acidity increased during initial period of fruit development then declined. It may be concluded that fruits of MH-1 and MH-5 may be ready for harvest by 2nd week of May and that of MH-4 and MH-6 by 4th week of May. However, MH-2 and MH-3 may be harvested by 3rd week of May and 1st week of June, respectively. *Mahua* yields both flowers and seeds. The creamy coloured, fleshy corolla (flowers) falls in early hours of morning. They should be collected. Falling of corolla continues for 15-20 days. The ripe fruits shed from trees during May -July. They are collected by hand for storage and in heaps for seed extraction. The yield of flowers (dry) varies from 100-150 kg and kernel 60-80kg/tree/year. The flowers before storage are dried. As soon as they are collected they should be dried on polythene sheet and should not be stored in

Dried *Mahua* flowers

Variability in *Mahua* seeds

bulk in moist condition. Flowers should be stored in thin layers. They should be turned over from time-to-time to bring the lower layers to the top. Dried flowers after packing in gunny bags are stored in a dry place up to 1 year under ordinary conditions. Seeds are extracted from ripe fruits and are shelled within a week otherwise it will germinate. Once the seeds are germinated, they become unfit for oil extraction. Kernels obtained after shelling should be dried up to a moisture content of 8%, because seeds containing more than 7-8% moisture are liable to fungal attack. Dried kernels can be utilized for extraction of oil. The kernels can be packed in gunny bags and stored for a year.

Both fresh and dried flowers are used for preparation of various nutritive food products, which form an article of diet. *Mahua* flowers are largely used in preparation of distilled liquors. It is also used for preparation of cake, vinegar, jam, syrup and honey. Flowers and spent flowers (after fermentation) are utilized as feed for livestock. The fruit pulp can be used as a source of sugar for alcoholic fermentation. Seeds processed for oil are used to manufacture vanaspati ghee, soap, greases and cosmetics. Seeds are also used for preparation of seed flour having a great potential in bakery products. The saponin obtained after extraction has industrial and commercial applications. *Mahua* cake obtained is used as manure and has insecticidal properties. Every part of *mahua* yields economic products of great potential value; hence *mahua* constitutes most important raw materials for various industries.

Marketing

About 75% of the farmers sell their produce at the farm level to the village merchants and retailers. They can not afford to transport their produce to distant markets on account of the non availability of transport facilities, expensive transport, mal practices in the market. Information regarding demand, supply, price, market outlook, knowledge of the consumer's preference, marketing channels are important for marketing of produce.

Plant protection

Pest management

Bark eating caterpillar (*Inderbela spp.*): It has been observed as the most serious pest of *Mahua*. Larvae of this moth feed on bark of stem, interrupting translocation of sap and thus the tree becomes weak and unproductive. Pest is very active from February to March. It can be controlled by maintaining sanitary situation in the orchard and petrol or dichlorovos (0.1%) should be injected in the hole and be plugged. Foliar sprays with Dimethoate (0.05 %) at tri weekly interval control the pest effectively.

Mahua leaf roller (*Polychorosis cellifera*)

The larvae web the leaves by folding the tip downwards on both the margins parallel to the mid-rib and feed inside. In case of severe attack 1/4th of the lamina is eaten up. Regular clipping and burning of affected leaves can keep the population under control. In case of severe attack, spraying with Chlorpyriphos 20 EC (2ml/liter water) or Endosulfan 35 EC (2ml/liter water) is recommended.

Future research needs

There is considerable potential for the expansion of *Mahua* cultivation in India. Therefore, some suggestions for future research priorities are given below:

1. The plant genetic resource (PGR) research needs to be undertaken on the classification of the genetic diversity through use of the morphological, biochemical and molecular techniques. Efforts may be made in using the molecular techniques for understanding the genetic structure of the crop. Promising genotypes having tolerance to the biotic and a biotic stress should be selected.
2. Model nurseries for the local supply of quality plant material should also be established.
3. Information should be made available on *Mahua* based cropping system for different normal and problematic soils.
4. Agro-techniques like integrated nutrient management, diversified farming system, high density planting system, weed management, canopy management and irrigation management should be standardized under different ecosystem of the country.
5. Maturity, harvesting, grading, packaging and storage system should also be standardized.
6. There is need to develop new products from *Mahua* flowers and popularize them not only in domestic market but also in international market.
7. Research information on integrated pest management should also be made available.

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