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Printed: March 2015

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Citation:
Dhyani, S. K., Vimala Devi, S. and Handa, A. K. (2015): Tree Borne Oilseeds for Oil and Biofuel. Technical Bulletin 2/2015. ICAR-CAFRI, Jhansi. pp: 50.

Published by the Director, ICAR-Central Agroforestry Research Institute (CAFRI), Gwalior Road, Near Pahuj Dam, Jhansi-284 003 (U.P.)

Printed at Army Printing Press, 33 Nehru Road, Sadar, Cantt., Lucknow-226 002 Tel : 0522-2481164

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Preface

Biofuels are important renewable and alternate source of petroleum fossil fuels. India has a rich potential, with more than 100 diverse tree species producing seed oil suitable for biodiesel. These oil tree species can be grown on non-agricultural lands and hence does not compete for food and fodder. With both National Biofuel policy (2009) and National Agroforestry Policy (2014) being launched in the country, the first policy targets the replacement of fossil fuels by biofuel to the extent of 5% by 2012, 10% by 2017 and above 10% beyond 2017 and the second policy aims at integrated land use option for livelihood, environment and energy security. Some of the important TBOs like Jatropha, Karanj, Mahua, Simarouba etc., are efficiently included in the agroforestry systems and resulted in beneficial results, thus providing a large source of non-edible tree borne oilseeds.

Central Agroforestry Research Institute (CAFRI), Jhansi has initiated R & D on biofuel in 2003. Later, as partner in NOVOD network project on integrated development of Jatropha and Karanj, systematic work is being done on development of agroforestry systems integrating TBOs. A large collection of germplasm accessions for Neem, Jatropha and Karanj are being maintained and evaluated at CAFRI research farm, Jhansi. The studies conducted include genetic variability at morphological, biochemical and molecular level; reproductive biology; nutritional analysis; propagation and silviculture techniques; agroforestry systems, etc. In addition, the institute coordinates "All India Coordinated Research Project (AICRP) on Agroforestry" with 37 centres located in different agroclimates of the country. Ten centres of the AICRP on Agroforestry are working on TBOs for the last one decade. CAFRI and its AICRP on AF have conducted several trainings and extension programs for farmers, agricultural officers and scientists. Currently under the 12th plan, a Mini Mission –component III on tree borne oilseeds has been setup. This compilation will help in taking forward this mission.

We acknowledge the initiatives, continuous guidance and encouragement by the Director(s) of the CAFRI (erstwhile NRCAF) for the R & D on biofuels. The hard work and dedication of researchers of the institute led by Dr. V. K. Gupta, Dr. R. V. Kumar, Dr. S. P. Ahlawat, Dr. Sudhir Kumar and technical personnel and research scholars along with the scientists of AICRP centres working on biofuels deserve our appreciation and gratitude. We are grateful for the whole hearted support in research and extension by the AICRP on AF centres and other stakeholders who are involved in this effort. The support for the funding by the ICAR and NOVOD Board under Department of Agriculture and Co-operation, Ministry of Agriculture, Govt. of India is duly acknowledged. The authors express their appreciations to Dr. R K Tewari, Dr. Inder Dev, Dr. Rajeev Tiwari and Dr. Ramesh Singh, members of Publication Committee, for timely editing the bulletin.

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Abbreviations and Acronyms

AICRPAF	All India Coordinated Research Project on Agroforestry
AICRP-RES	AICRP on Renewable Energy Sources (AICRP-RES)
B:C	Benefit Cost Ratio
CAFRI	Central Agroforestry Research Institute
CAZRI	Central Arid Zone Research Institute
CFTRI	Centre for Food & Technology Research Institute
CIMAP	Central Institute of Medicinal and Aromatic Plants
CRIDA	Central Research Institute for Dryland Agriculture
CSIR	Council of Scientific & Industrial Research
DAC	Department of Agriculture & Co-operation
DARE	Department of Agricultural Research and Education
DBT	Department of Biotechnology
DoLR	Department of Land Resources
DRDO	Defense Research & Development Organization
DST	Department of Science and Technology
EFC	Expenditure Finance Committee
FICCI	Federation of Indian Chambers of Commerce and Industry
FRI	Forest Research Institute
GoI	Government of India
ICAR	Indian Council of Agricultural Research
IASRI	Indian Agricultural Statistics Research Institute
ICFRE	Indian Council of Forestry Research and Education
ICRAF	International Centre for Research on Agroforestry
ICRISAT	International Crop Research Institute for the Semi-Arid Tropics
IFGTB	Institute of Forest Genetics and Tree Breeding
IGFRI	Indian Grassland and Fodder Research Institute
IINR&G	Indian Institute of Natural Gum and Resins
IPCC	Intergovernmental Panel on Climate Change

IRR	Internal Rate of Return
IIT	Indian Institute of Technology
KVK	Krishi Vigyan Kendra
MNRE	Ministry of New and Renewable Energy
MoRD	Ministry of Rural Development
NABARD	National Bank for Agriculture and Rural Development
NARS	National Agricultural Research System
NBPGR	National Bureau of Plant Genetic Resources
NBRI	National Botanical Research Institute
NGO	Non-Government Organization
NMOOP	National Mission on Oil Seeds and Oil Palm
NOVOD Board	National Oilseed and Vegetable Development Board
NRCAF	National Research Centre for Agroforestry
PC	Project Coordinator
PC Unit	Project Coordinating Unit
SAU	State Agricultural University
R&D	Research & Development
TBOs	Tree Borne Oil seeds
TERI	The Energy Research Institute
TNAU	Tamil Nadu Agriculture University

Background

The need of alternatives of fossil fuel is pressing hard for several reasons especially to the countries like India with vibrant economy, which consumes large amount of fossil fuels and rely heavily on import for the same. Bio-fuels are renewable liquid fuels extracted from biological raw material and have proven to be good substitutes for oil in the energy sector. As oil from the food crops like corn, sweet sorghum, soybean, *etc.*, cannot be diverted for biodiesel in India, the concentration of alternate biofuel source is on non-edible oils obtained from seeds of tree species, some of which were being traditionally used as fuel source in rural areas. Tree Borne Oilseeds (TBOs) are cultivated/grown in the country under different agro-climatic conditions in a scattered form in forest and non-forest areas as well as in waste land /deserts/hilly areas. The country has enormous potential of oilseeds of tree origin like Mahua (*Madhuca indica*), Neem (*Azadirachta indica*), Simarouba (*Simarouba glauca*), Karanja (*Pongamia pinnata*), Ratanjyot (*Jatropha curcas*), Jojoba (*Simmondsia chinesis*), Cheura (*Diploknema butyracea*), Kokum (*Garcinia indica*), wild Apricot (*Prunus armeniaca*), wild Walnut (*Aleurites molucana*), Kusum (*Schleichera oleosa*), Tung (*Vernicia fordii*) *etc.* which can be grown and established in the wasteland and varied agro-climatic conditions. These have domestic and industrial utility like agriculture, cosmetic, pharmaceutical, diesel and substitute, cocoa-butter substitute *etc.,* but it is not being utilised fully due to lack of awareness of their uses, collection, proper processing facilities, organized marketing sector and others. Besides, lack of proper facility for storage, seed collection, long gestation period, fruiting/maturity season coinciding with rain are main constraints limiting collection and utilization of above TBOs.

Concerted R&D works on bio-fuel species started in 2003 after the committee constituted for bio-fuel development in India presented its report to Planning Commission and then several organizations like ICAR, NOVOD Board, DBT, DST, DRDO, and CSIR started funding R&D of TBOs to several research institutions including SAUs. The scheme 'Integrated Development of Tree Borne Oilseeds' has been initiated during the 10th Plan period to harness the existing potential and augment the future potential of TBOs like Jatropha, Karanja, Mahua, Neem, Jojoba, Wild Apricot, Cheura, Kokum, Simarouba *etc.* Besides, many states like Chhattisgarh, Uttarakhand, Karnataka and Andhra Pradesh started their own network programmes for encouraging R&D on bio-fuels. Two National Networks *viz.*, 'National Network on Jatropha and Karanja' and 'National Network on Wild Apricot and Cheura' were constituted by involving State Agricultural Universities, Institutions of CSIR, ICFRE, ICAR, CFTRI, TERI and IIT to address different researchable issues under the banner of National Oilseed and Vegetable Development Board, Gurgaon (MoA). The main focus of these network programmes was germplasm collection and evaluation, standardization of agro-techniques & crop improvement.

The R&D efforts were focused on collection, evaluation and conservation of its germplasm, understanding its breeding behaviour, standardization of nursery and propagation techniques, development of cultivation packages for different soil and climatic conditions, machines for bio-diesel production *etc.* A large number of accessions from almost all the areas of its distribution in the country for different biofuels have been collected by research organizations. Good amount of variability has been recorded in morphological traits, seed yield and oil content. Genotypes having high seed yield and oil content have been selected from germplasm evaluation trials. The agro-techniques for raising plantation has been standardized.

A National Biodiesel Mission was launched by the Planning Commission to cover 2.5 million ha area in the country, to meet 5 % replacement of the diesel requirement of the country. GoI had fixed the target to replace 20 % petrodiesel with biodiesel up to 2011-12 by producing 13.38 million tons of biodiesel annually through plantations of Jatropha alone in 11.19 million ha. The Ministry of Petroleum and Natural Gas has launched biodiesel procurement policy w.e.f. 01.01.2006 @ ₹ 25 per litre through state owned petroleum companies in 12 states. However, recently for the XIIth Plan, the Department of Agriculture and Co-operation, Ministry of Agriculture, has formulated the Mini Mission III to promote the oil seeds in addition to TBOs for biofuel. The aim of Mini Mission III of National Mission on Oil Seeds and Oil Palm (NMOOP) from the current year is to promote 11 tree borne oilseeds (Simarouba, Neem, Jojoba, Karanja, Mahua, Wild Apricot, Jatropha, Cheura, Kokum, Tung & Olive). The tree borne oilseeds (TBO's) at present, contribute an insignificant portion of vegetable oil production in the country mainly due to lack of improved varieties, elite planting material and agronomic practices.

Under the umbrella of Indian Council of Agriculture Research, Central Agroforestry Research Institute (CAFRI), Jhansi coordinates an All India Coordinated Research Project (AICRP) on Agroforestry which was initiated on April 1st, 1983. The ICAR R&D activities on biofuels are being conducted at ten centres of AICRP on AF; seven centres of the Network Project on Tree Born Oilseeds; four centres of AICRP on Renewable Energy Sources (AICRP-RES) and at the Centre of Excellence on Biofuels at TNAU, Coimbatore.

The Research work across the different Institute's and Organizations has resulted in developing information on availability of elite germplasm, its source and package of practice for the important TBOs. This has been summarized here for their promotion to achieve the objectives of the Mini Mission III.

Introduction to Biofuel: A Renewable Source*

Bio-fuels are renewable liquid fuels extracted from biological raw material and have proven to be good substitutes for oil in the energy sector. Bio-fuels such as bio-diesel and ethanol are gaining world wide acceptance as a solution for problems of environmental degradation, energy security, restricting imports, rural employment and agricultural economy. India due to the growing oil intensification of its economy, as more than 70% of the oil used in the country is imported has taken initiatives to search for alternatives to the fossil fuels. Bio-fuels derived from plant-based resources assume importance in this context.

International Scenario

All countries including India are grappling with the problem of meeting the ever-increasing demand of fuel within the constraints of international commitments, legal requirements, environmental concerns and limited resources. In this connection fuels of biological origin have drawn a great deal of attention during the last two decades. A number of countries in the world took up initiatives for development of bio-fuels to meet the growing demands for energy. The focus has been on bio-diesel and bio-ethanol. Among the major countries in the world in bio-ethanol production, Brazil is a frontrunner. USA uses corn as the main source of bio-ethanol. Thailand uses sugarcane as well as cassava for ethanol. Japan, Germany, Canada, Australia, Indonesia, South Africa, Sweden are the other leading countries using ethanol blends. Bio-diesel is being used in USA, Austria, Finland, France, Germany, Greece, Czech Republic, Ireland, Italy, Spain and Sweden. The main sources of bio-diesel in these countries are rapeseed, sunflower, olive oils, which are, however edible oils and are not appropriate in Indian context, as we are also importing nearly half of our edible oil requirements.

Indian Scenario

India took initiative for use of Bio-diesel and ethanol for blending with petro-diesel and petrol. In India, oil provides energy for 95% of transportation and the demand for transport fuel continues to rise. As per the third assessment of IPCC, the global oil demand will rise by 1.68% from 75 MB/day in the year 2002 to 120 MB/day in 2030 *i.e.* a ten-fold increase. Energy input in agriculture is also increasing. Part of this energy should come from bio-based fuel, which is short term renewable.

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*Modified from Dhyani,S.K.(2014), Introduction to biofuels-a renewable source. In: **Training manual on 'Agroforestry for Biofuels and Bioenergy. eds: Vimala Devi, S., Sridhar, K.B., Chavan, S., Handa, A. K. & Dhyani, S.K. 2014. ICAR-NRC for Agroforestry, Jhansi, U.P., pp: 229**

Use of ethanol as automotive fuel was first made in Mysore in 1938. Dual fuel operation in diesel engines was experimented at the Indian Institute of Science (IISc.), Bangalore, in 1950. Oil crisis in the 1970s, prompted the Government to test performance of ethanol-gasoline blends in cars, scooters, three wheelers and tractors in the 1980s. Methanol diesel blends were successfully demonstrated in DTC buses during 1986-92, followed by 93 Government vehicles using 10% gasohol during 1993-95 under a MNES R&D project. R&D in bio-diesel has been taken up by a number of Institutions, SAUs among many others.

TBOs of Potential Value

The major source of bio-diesel in India is non-edible oil seeds and the technology for its production is indigenously available. Bio-diesel provides bio-degradability, non-toxicity and is sulphur-free. The oxygen content is about 10%, which gives better emission characteristics in terms of CO, HC & PM. The production potential for bio-diesel is nearly 20 million t per annum. Only a few million tonnes have been utilized (due to lack of demand). Estimated potential varies from 0.1 to 20 million tonnes, out of which 20 to 25% has been utilized. About 150 non-edible tree borne oilseeds (TBOs) exist in India. Some of the important TBOs used in India are Neem (*Azadirachta indica*), Karanj (*Pongamia pinnata*), Mahua (*Madhuca indica*), Jatropha (*Jatropha curcas*), Kusum (*Schleichera),* Pilu *(Salvadora oleoides),* Bhikal (*Prinsepia utilis),* Undi (*Calophyllum inophyllum*), Thumba (*Citrullus colocynanthis*), Sal (*Shorea robusta)* and Jojoba (*Simmondsia chinensis)*. The oil content varies between 21 to 73% in these species. All these species have multipurpose uses like domestic and industrial utility such as agriculture, cosmetic, pharmaceutical, diesel and its substitute, *etc.* Most of these TBOs are abundantly found in forest and non-forest areas but are scattered and are not properly collected, what so ever collected is of poor quality due to the lack of awareness of their uses. Among the various Tree Borne Oilseeds (TBOs), *Jatropha curcas* and *Pongamia pinnata* have been found most suitable for biodiesel production on the basis of various characters like hardy nature, easy handling and satisfactory growth in varied agro-climatic conditions. The cultivation of these species is possible under varied soil and climatic conditions and the oil of these species is most suitable for biodiesel production. Before going for large scale plantation, availability of quality planting material must be ensured because these species are perennial in nature and once established continue to yield for next 30 – 40 years. To make the cultivation of these species more profitable, value addition in the product is of immense use. By adding value through processing, in main product and byproduct, additional income can be generated.

National Bio-diesel Strategy

Bio-diesel needs no separate infrastructure for storage and dispensing as the existing facilities can be used and handling bio-diesel is also safer. In addition, plantations of *Jatropha*

and *Pongomia* would lead to gainful utilization of wasteland. At the national level, a bio-diesel programme has the potential to create employment opportunities on a large scale, particularly in rural areas in the various activities along the production-use chain, such as growing plants, collection of oil-bearing seeds, extracting oil from the seeds through expeller units, trans-esterification for making bio-diesel for blending and use with conventional diesels for distribution at retail outlets. A systems approach is necessary for ensuring that the different components of bio-diesel programme are effectively coordinated and bio-diesel becomes a cost effective alternative.

National Policy on Bio-fuel

The union cabinet approved the National Policy on biofuels and its implementation on 24.12.2009. It also approved setting up of a National Biofuel Coordination Committee chaired by the Prime Minister to provide policy guidance and coordination. The Ministry of New and Renewable Energy has been designated as the coordinating Ministry for biofuel development and utilization, while specific roles have been assigned to other ministries concerned.

Salient features of the National Policy on Bio-fuel

- Bio-diesel production will be taken up from non-edible oil seeds in waste/degraded/ marginal lands.
- An indicative target of 20 % blending of biofuels, both for biodiesel and bio-ethanol by 2017 has been proposed.
- Minimum support price (MSP) for non-edible oil seeds would be announced with periodic revision to provide fair price to the growers.
- Minimum Purchase Price (MPP) for purchase of bio-ethanol and bio-diesel would be announced with periodic revision.
- Major thrust will be given to research, development and demonstration with focus on plantations, processing and production of biofuels, including second generation biofuels and financial incentives, including subsidies and grants.
- If it becomes necessary, a national Bio-fuel Fund could be considered.

Research, Extension and Demonstrations

The yields from the petro-plants need to be significantly increased and the efficiency of trans-esterification also has to be significantly enhanced, so that the biodiesel production becomes economically viable. An integrated action among various Government Departments and research organizations, NGOs and other stakeholders is needed for successful implementation of the programme. The following areas and the nodal agencies to carry out the programme are identified.

Sl.No.	Areas of work	Nodal agency
1.	Identification of seeds and developing suitable methods for extraction of oil and processing them to convert into biofuels, blending of bio-fuels; and modification in engine technology, use of biofuel as transport fuel, evolving methods to use rotten and excess food grains for ethanol production, developing policy frame work	ICAR, CSIR, MNRE, MoST
2.	Pricing of bio-fuels including taxation	Ministry of Finance and State Governments
3.	Storage of seeds and biofuels	Ministry of Food and Consumer Affairs and Ministry of Petroleum and Natural Gas
4.	Distribution network and use in automobiles and other oil based engines	Ministry of Petroleum and Natural Gas
5.	Availability of land and cultivation of crops to produce feedstock for biofuels	Ministry of Rural Development/ Ministry of Agriculture and Ministry of Environment and Forest (MoEF)
6.	Production of biofuels	Ministry of Food-processing, Ministry of Industry and Small Scale Industry
7.	Plant genetics for increasing yield and quality	ICAR, DBT
8.	Environmental issues	MoEF
9.	Field Action Plan	State Governments

Estimation of biofuel requirement in the country

The requirement of biofuels have been worked out for blending ratios of 5, 10 and 20 % by the committee on development of biofuels setup by the Planning Commission and the scenario is presented as under.

Scenario on requirement of Bio-fuel in India at various blending levels

Year	Diesel Demand (M T)	Biodiesel requirement for blending (M T)		
		@5%	@ 10%	@ 20%
2006-07	52.33	2.62	5.24	10.48

Source: Report of the Committee on development of Bio-fuel, GOI, 2003

However, presently bio-fuel plantations are scattered and production units are located away from the farms. Absence of clearly defined high yielding varieties and marketing channels result in inefficiencies in production, which further results in increase in cost of

production of biofuel. According to the Biodiesel Producers Association, the cost of producing a litre of biofuel is about ₹ 45 and other state and excise taxes add another 7-8 ₹ litre^{-1}. Therefore, biofuel is more or less of the same cost as diesel. This is true even in developed countries like US, Germany, *etc.* However, tax incentives in those countries have closed the gap between cost of biofuel and fossil fuels. It is for this reason that no tax is being levied on biodiesel production in Germany and Italy. In US, the fuel blender receives incentives based on percentage of biodiesel per gallon.

Therefore, biofuel sector needs concession in both direct and indirect tax fronts to attract investments in plantation, collection, processing and blending. The concession can be in the form of reduction in duty on imported materials and machineries used in production of biofuels, revise the MSP formula for fixing the price of biodiesel in view of higher cost of production.

FICCI Core Group on biofuels has suggested that, amongst other steps, the government should grant a 10 year exemption of excise and custom duties, as well as all Central and State levies on biodiesel, FDI for Jatropha cultivation and production of biodiesel and combining Jatropha cultivation with MNREG scheme as it is labour intensive activity. Besides this, it is also necessary to keep a safeguard similar to that of Tamil Nadu, where no more than 25% biodiesel can be exported.

Faced with irregular and insufficient oilseed supply only a few production units currently exist in the country. These units now depend on traders instead of farmers for oilseed purchase. The traders typically buy from farmers at a price of ₹ 5-6 a kg of Jatropha oil seed and sell to producers with an unrealistic price margin of over 100 % at ₹ 10-12 a kg. This translates into higher biofuel costs and the benefit of biofuel plantation is more to the trader than to the primary producer. Sincere efforts are, therefore needed so that additional income generated must reach the farmer.

Ensuring the sustainability and success of the biofuel programme

Farmers need to be assisted to undertake farming of crops used in ethanol and other bio-fuels, by ensuring purchase of these products at a minimum support price by government and industrial units, educating them about the species for biofuels, and cultivation techniques and providing them with high quality seeds/saplings *etc.* Quality control and certification of the planting material are urgently needed. Suitable mechanisms need to be developed to collect and store agri-residues such as rice straw, so that these wastes which are otherwise burnt, become a commercial commodity for farmers and would be available for ethanol production This should be supported by developing the necessary industrial infrastructure to process the collected biomass for production of ethanol/other biofuels and the by product industrial wastes so generated, could be used as manure.

Use of wasteland may be encouraged to develop plantations of Neem, Karanja, Jatropha and other such species for bio-diesel production. Mechanisms need to be developed to collect oilseeds from forests. The wood generated from plantations could be utilized as feedstock for wood gasification to generate electricity. Wasteland should be used as collection centres for agri-residue. This process will have multiple benefits like land reclamation, employment generation, decentralized electricity generation *etc.*

Extensive support needs to be provided to R&D institutions to work on developing suitable process development for biofuels from various feedstocks and for developing agronomic practices for growing crops for biofuels in wasteland. ICAR and CSIR should jointly undertake this function in cooperation with State Agricultural Universities.

Panchayati Raj institutions have a major role to play in creating awareness among people about *Jatropha* and other species, for cultivation in wasteland, common land and farm hedges. Panchayats/clusters of Panchayats have to be identified for this purpose. There is need for collaboration with State and Central Government organizations - National Seed and Vegetable Oil Development Board, National Dairy Development Board *etc.*

Industrial sector needs to be encouraged to increase ethanol production from all available feedstock such as cereals, agri-residues, and starch-based crops besides optimizing the present level of production from molasses. The production of bio-diesel from various non-edible oil seeds also need to be encouraged. For this purpose, necessary incentives such as soft loans for establishing new industries, updating existing industry and tax holiday, need to be provided.

Farmers' perceptions

Farmers do not have experience of growing biofuel crops and are getting confused signals about the economic viability of the programmes. They are not sure about the quality of seeds / planting material given to them. They are not yet clear whether there will be a buy back arrangement on terms favourable to the growers. Factors relating to cost, risk and return determine farmers' acceptance and enthusiasm in relation to new programmes. Experts have argued for creation of a National Biofuel Board. Sooner a farmer-centric National Biofuel Board is established with the active support and participation of all stakeholders, including farmers' and women's organizations, the greater will be the prospect for speedy progress at desired pace that country needs urgently to ensure economically affordable energy security. The success or failure of the biofuels programme will depend on our ability to ensure supply of required quantity of raw material at the right time, in right quantities and at economically viable prices. Many dendro-thermal plants have failed because of inadequate linkages with raw material supply. The feedstock for the biofuel industry has to come from agriculture. Unless the interests of the biofuel farmers are protected, the investment made at the processing end will go waste.

National Mission on Oil Seeds

In the XIIth Plan, the Government of India launched a Mini Mission III. The aim of Mini Mission III of National Mission on Oil Seeds and Oil Palm (NMOOP) being implemented by the Department of Agriculture & Cooperation from the current year is to promote 11 tree borne oilseeds (Simarouba, Neem, Jojoba, Karanja, Mahua, wild Apricot, Jatropha, cheura, Kokum, Tung, Olive). The tree borne oilseeds (TBOs) at present, contribute an insignificant portion of vegetable oil production in the country mainly due to lack of improved varieties, elite planting material and agronomic practices.

The Government of India policy on promoting tree-based bio-fuel plantations is focused on promoting use of wastelands and less productive lands. The country has enormous potential of oilseeds of tree origin like Mahua, Neem, Simarouba, Karanja, Ratanjyot, Jojoba, Cheura, Kokum, wild Apricot, Bhikal, wild Walnut, Kusum, Tung *etc.* which can be grown and established in the wasteland and varied agro-climatic conditions. These have domestic and industrial utility like agriculture, cosmetic, pharmaceutical, diesel and substitute, cocoa-butter substitute *etc.* But it is not being utilised fully due to lack of awareness of their uses, collection and marketing *etc.* Besides, lack of proper facility for storage, seed collection, long gestation period, fruiting/maturity season coinciding with rain *etc.* are main constraints limiting to the collection and utilization of above TBOs.

Biofuel Programme at CAFRI, Jhansi

CAFRI (erstwhile NRCAF) is actively involved in designing and conducting R&D programmes on agroforestry models suitable for different edapho-climatic conditions of India through its research institute at Jhansi and AICRP on Agroforestry centres all over the country.

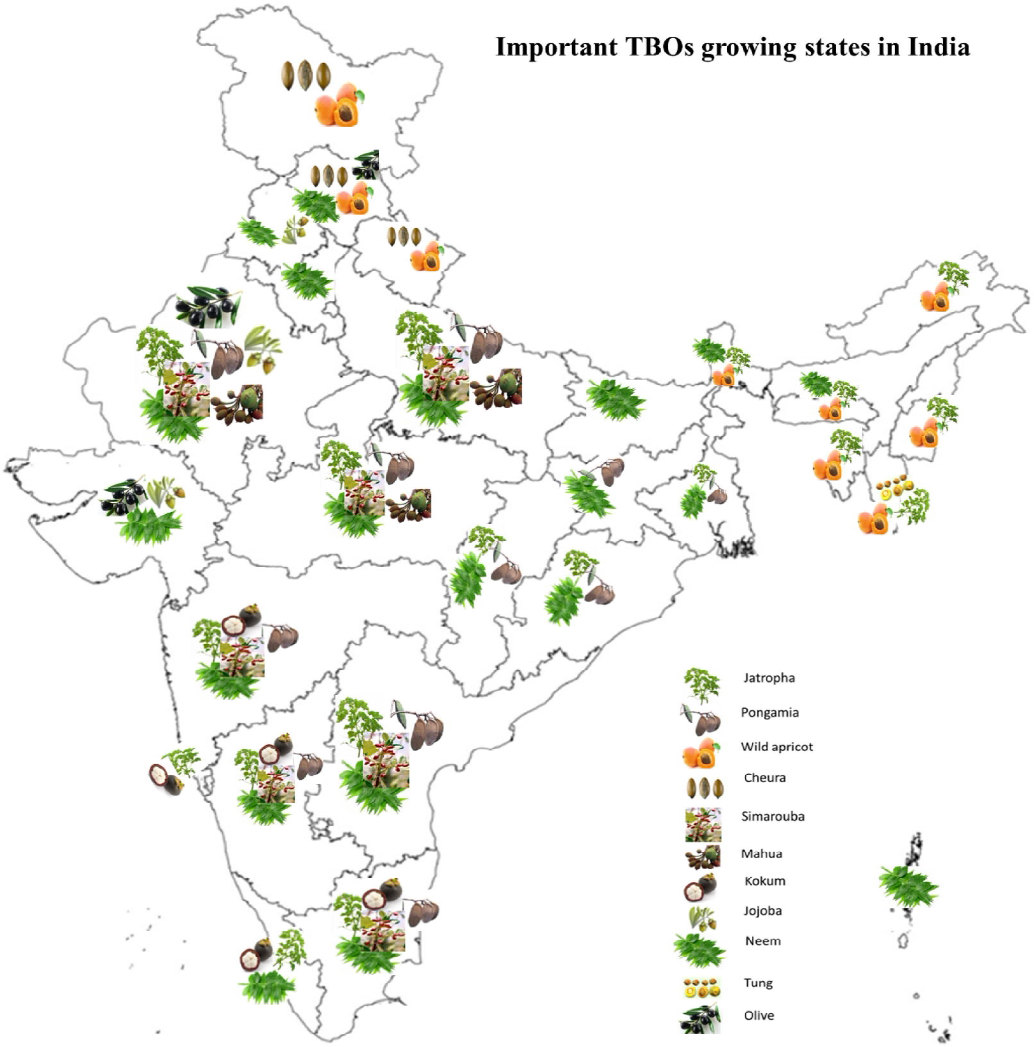
Quality planting material is prerequisite for any successful large scale plantation. Biofuel plant species are perennial in nature and once established they can yield for next 40-50 years hence, care must be taken to start the plantation programme with quality planting material. Keeping these objectives in mind, research activities on bio-fuel species started at CAFRI, Jhansi from November, 2003. From the beginning, the work was initiated with one of the bio-fuel species *i.e. Jatropha curcas*. Through exploration centre has collected 284 accessions of *Jatropha curcas* from diverse agro-climatic zones of states like Uttrakhand, Uttar Pradesh, Madhya Pradesh, Chhattishgarh, Maharashtra, Rajasthan and Gujarat. These accessions are in the process of evaluation for growth, yield and oil content in the centre at Jhansi and some promising accessions are further evaluated in different agroclimatic zones. These accessions were also evaluated for seed oil content and 87 accessions recorded more than 35 % oil content on seed basis. Accessions are being maintained as a cryo preserved at NBPGR, New Delhi and simultaneously being maintained at the farm of CAFRI, Jhansi. Ninety intra-specific crosses have been developed and

being evaluated in fields conditions. Some of the germplasm have been assessed for biochemical activities and interrelationship between morphology, nutritional content and enzymatic activity (ADF, NDF, cellulose, hemicellulose, lignin, crude protein, peroxidase and polyphenol oxidase). Accessions are characterized on molecular level using molecular markers. Study on reproductive biology and cytology has also been done. Field experiments on cultivation of *J. curcas* under agroforestry systems were also conducted to see the feasibility of growing crops in the initial years when the canopy of *J. curcas* is not affecting growth of understorey crop significantly. Simultaneously, *J. curcas* plants are maintained by pruning for more number of secondary branches as well as optimum tree canopy. Experiments on seed viability, germination, storage conditions, clonal propagation and nursery techniques were also standardized for mass multiplication of elite genotypes. Evaluation and characterization of Jatropha breeding material using molecular breeding technique and mass multiplication of elite lines through tissue culture for large scale plantation needs to be taken on priority.

Karanj (*Pongammia pinnata*), a leguminous tree has many traditional uses and is one of the important species in this category. This tree is known by many names *viz.*, Indian Beech, Pongam, Honge, Ponge and Karanj, *etc.* and mostly used for landscaping purposes as a wind break or for shade due to the large canopy and showy fragrant flowers. The seed oil is an important component of this tree being used as lamp oil, in soap making, and as a lubricant for thousands of years. This oil is rapidly gaining popularity as an important source of biofuel. Exploration trips were arranged to collect the accessions of this species and a total of 143 accessions were collected from diverse agro-climatic zones of states like Uttar Pradesh, Madhya Pradesh, Rajsathan and Haryana. These accessions are in the process of evaluation for growth, yield and oil content. Evaluation trials are being conducted at institute's farm as well as on different locations. 51 accessions have recorded for more than 35 % oil content on kernel basis. In the initial years of evaluation, some promising entries were identified for their precocity (2.5 years). Further, these accessions are evaluated for growth and yield.

In Neem (*Azadirachta indica*), 220 accessions from diverse agro-climatic zones of states like Uttar Pradesh, Madhya Pradesh, Andhra Pradesh, Maharashtra and Orissa have been collected. Evaluation trials are being conducted at institute's farm as well as on farmers' fields. 16 accessions have recorded for more than 50 % oil content on kernel basis. Accessions are being evaluated for azadirachtin content also. Ten accessions have been sent for multi-location trial in different states. Work of other Tree Borne Oil Seeds (TBOs) *viz.* Mahua and Simarouba are in progress at this centre. More than 15 ha area at this Centre is under plantation having different TBOs *viz.* Jatropha, Karanja, Neem, Mahua and Simarouba. The Institute has installed a small biodiesel plant unit at its farm and one litre batch lab glassware bio-diesel unit for training and demonstration.

The Centre has developed, demonstrated and disseminated agroforestry technologies based on natural resource management. The Centre has also provided technical support to the State Departments *viz.*, Agriculture; Forest; Rural development and Soil Conservation; KVK; Bundelkhand University; District Administration and others including the stakeholders.



Tree Borne Oilseeds cultivation across different agro-climatic zones of India

Jatropha curcas

Jatropha is a fast growing multi-purpose deciduous large shrub capable to grow and establish in tropical and subtropical region of the country and even on wasteland. It has the capacity to rehabilitate degraded or dry lands by improving water retention capacity. It has various advantageous characteristic features *viz.*, not browsed by cattle, best hedge plant, less gestation period (two years), capable to grow and establish in various biotic and abiotic stress conditions, high oil content (30-42% in seed), which has multiple uses as biodiesel, direct fuel, lubricant, medicine, besides other industrial uses. The by-product of biodiesel are also quite useful for industrial application such as glycerine and biofertilizers. The residue is a good substrate for biogas production

Origin	:	Central America
Family	:	Euphorbiaceae
Species	:	*Jatropha curcas*
Vernacular name	:	Ratanjyot, Danti, Physic nut, Purging nut

Improved varieties/accessions

Agroclimatic zone	Improved varieties/accessions
Eastern Himalayan Region	TFRI 01 (49.2%), MNJ-017(42.89 %), MNJ-017(42.89%), TCR-1(32.87%)
West Coast Plains & Hills Region	PAT-1 (32.83%), ALP-1(32.10%)
Upper Gangetic Plains Region	Bhimari, (36.10%), CSJ-3 (31.48 %), CSJ-6 from Allahabad (30.58 %), collection from Kanpur CSJ-10 (31.75 %), CSJ-11 (31.36 %), CSJ-23 (31.72 %), CSJ-24 (33.10 %), Collections from Lalitpur i.e. CSJ-14 (33.30 %), CSJ-15 (31.53 %), CSJ-16 (31.87 %), CSJ-17 (31.38 %), CSJ-20 (32.57 %)
Central Plateau & Hills Region	NRCJ158, NRCJ159, NRCJ124, NRCJ144, NRCJ145Raksla, Panna; Chapara,Seoni; Kherwani Chhindwara-1;Gessani Shivpuri -2; Gessani Shivpuri -1
Southern Plateau & Hills Region	TNMC 22, TNMC 33, TNMC 19,5 hybrids of TNAU Coimbatore
Frost tolerant genotype for H.P.	Jwalaji Local , Haryana: JR-17

Package of Practices

Direct sowing: The disease free and bold seedlings of Jatropha are transplanted in rows at spacing of 3m x 2m under irrigated condition accommodating 1666 plants ha^{-1}. On rainfed wasteland, a high density planting at 2 m x 2 m accommodating 2500 plants ha^{-1} is recommended. FYM (2-3 kg) and fertilizer (20 g urea, 120 g single super phosphate and 16 g Murate of potash) are mixed during ploughing to the soil and two seeds per pit are

dibbled with the onset of monsoon. When the seedlings are four weeks old, the weaker seedlings can be removed and the other bold seedlings can be used for gap filling.

Transplanting: Eight to ten weeks old seedlings are to be planted in 30 cm x 30 cm pits dug in the field at required spacing and filled with a mixture of soil, FYM (2-3 kg.) and fertilizer (20 gm Urea, 120 g Single Super Phosphate and 16 g Murate of Potash).

Fertilizer recommendations: The fertilizer in the ratio of 46:48:24 (N:P:K) kg ha^{-1} are to be applied in split doses from second year onwards so as to obtain economic yields and high oil content in seeds.

Inter cropping: Since, the gestation period of Jatropha is 2 years, the inter-cropping may be taken initially for two years, which will yield additional income to the grower. The intercrops selected by various institutions for intercropping in Jatropha depending upon soil and climatic requirements are chickpea, rice, green gram, black gram, sesamum, ginger, turmeric, arhar, masoor, lentil, ragi, kulthi, niger, soybean, moong, urad, wheat, cowpea, cluster bean, water melon, mustard, guar and dhaincha as well as mothbean for green manuring. In addition, in assured irrigation and wide spacing in between the rows, some leafy and fodder and short duration shade loving crops may be under taken after two years.

Inter-culturing and weeding: Inter-culturing should be carried out whenever necessary. Annually, 3-4 weedings may be carried out manually for keeping weed free field during initial growth period.

Irrigation: During dry period only life saving irrigations should be applied to the plants as and when required. Usually from second year onwards irrigation is not required unless soils are shallow and sandy. Two irrigations in a year if applied at both the flowering stages will enhance the yield.

Plant protection: Jatropha plants are less prone to attack by diseases and insects. Following few common diseases and insects are to be checked from time to time for better seed yields.

(A) Diseases

1. Damping off : Control: Spraying of Keptan 50% @ 0.2%
2. Collar rot : Control: Drenching with Baurdeax mixture (1%)
3. Root rot : Control: Spray Thiram @ 0.2%
4. Leaf spot : Control: Spray Blitox @ 0.2%

(B) Insects

1. Leaf miner : Control: Spray 1.5 ml lt^{-1} of water of Metasystox 25 CC
2. Blue Bug : Control: Spray Phosphomedin/ Dimethoate @ 2.0 ml/3 lt. of water
3. Green bug : Control: Spray 2 ml/3 lt. water of Phosphomedin

Flowering and fruiting: Flowering occurs two times a year, between September-December and March-April. The fruiting extends from September to December. The fruits mature 2-4 months after flowering.

Yield : With proper care, an average seed yield under rainfed condition is : 4^{th} year : 1000-1500; 5^{th} : 1600-2000; 6^{th} and onwards : 2500-4000 (kg ha^{-1} yr^{-1}).

Collection and processing: The ripe fruits are plucked from short trees. The collected seeds are sun dried and decorticated manually or by decorticators. One person can collect and decorticate 25-30 kg seed per day. Kernels are sold in the market in small quantities. This is an income generating village level activity and can be integrated with the rural development programme and along with collection of other non-traditional oilseeds like mango stones, karanj and neem.

Source of planting material

Important Research Institutions working on Jatropha:

Biofuel Park, Madenur, Hassan, Karnataka, http://biofuelkarnataka.in/jaivika-indana-udyana

Birsa Agriculture University, Ranchi, www.bauranchi.org

Central Salt and Marine Chemicals Research Institute, Bhavnagar, www.csmcri.org

Chandra Shekhar Azad University of Agriculture and Technology, Kanpur; www.csauk.ac.in

Chaudhary Charan Singh Haryana Agricultural University, Hisar; www.hau.ernet.in

CSK Himachal Pradesh Krishi Vishva Vidyalaya, Palampur; www.hillagric.ac.in

Forest College & Research Institute, Coimbatore, http://www.tnau.ac.in/fcri/About.html

ICAR-Central Agroforestry Research Institute, Jhansi; www.nrcaf.res.in

ICAR Research Complex for North Eastern Hill Region, Manipur; www.icarneh.ernet.in

ICAR-Central Research Institue on Dryland Agriculture, Hyderabad, Telangana, www.crida.in

ICAR-Central Arid Zone Research Institute, Jodhpur, Rajasthan, www.cazri.res.in

ICFRE-Tropical Forest Research Institute, Jabalpur; tfri.icfre.gov.in

Maharana Pratap University of Agriculture and Technology, Udaipur; www.mpuat.ac.in

Punjab Agricultural University, Ludhiana; www.pau.edu

SRM University, Chennai, www.srmuniv.ac.in

The Institute of Minerals and Materials Technology, Bhubaneswar; www.immt.res.in

UAS GKVK, Bengaluru, www.uasbangalore.edu.in

Uttar Banga Krishi Viswavidyalaya, West Bengal; www.ubkv.ac.in

Pongamia pinnata

Pongamia is a drought tolerant, semi-deciduous medium sized tree with short bole and spreading crown. It is widely grown from tropical dry to sub-tropical dry forest zones. It is a good shade bearer, suitable for planting in pastures, for afforestation in watershed areas and drier part of the country. It grows under a wide range of climate and soil conditions and can grow even in dry areas with poor, marginal, sandy and rocky soils. In addition to drought, it can tolerate saline conditions. *Pongamia pinnata* is a preferred species for controlling soil erosion and binding sand dunes because of its dense network of lateral roots. Root, bark, leaves, flower and seeds of this plant also have medicinal properties and traditionally used as medicinal plants.

Origin	:	Tropical and Temperate Asia
Family	:	Fabaceae
Species	:	*Pongamia pinnata*
Vernacular name	:	Karanj, Beech, Pongam, Honge, Kanji

Improved varieties/accessions

Agroclimatic zone	Improved varieties/accessions
Eastern Plateaus & Hills Region	Baramunda , Mancheswar
Southern Plateau & Hills Region	KNR1-(29.31 %), KSR1(27.34%) and TCR-MD(27.2 %), TCR-Cl-1, PT 1 and PT 2 of Dharwad,
Central Plateau & Hills Region	NRCP-13(early flowering), NRCP 24, NRCP 26 (high yielding), IC 527952 (34 %)
Eastern Plateaus & Hills Region	KKVPP-02(31.7%), KKVPP-17(42%)
Central Plateau & Hills Region	RPK 14
Western Plateau & Hills Region	RHRAK 50, RHRAK 44

% Oil content in parenthesis

Package of Practices

Sowing: Bold and healthy seeds are either sown in polybags or directly in field during July-August. The soaking of seeds for 24 hours in IBA (30 ppm) or GA_3 (20 ppm) enhances germination and vigour. Vegetative propagules developed through semi-hardwood cutting, air layering or cleft grafting can also be used.

Plantation: Pits of 60cm x 60cm x 60cm are dug for planting at the spacing 5m x 4m to accommodate 500 plants ha^{-1}. Addition of 5kg FYM pit^{-1} is recommended. One year old seedlings are transplanted at the onset of monsoon.

Irrigation: Three irrigations may be given in a year as and when required for better growth and development of plants

Inter cropping: The dwarf and short duration oilseed and pulse crops i.e., mustard, groundnut, sesamum, chickpea, blackgram, cowpea, horsegram, soybean and millets like maize, bajra etc can be grown successfully as intercrops upto 4-5 yrs after planting without affecting karanja plants to increase the economic feasibility.

Plant Protection

(A) Diseases

1. Damping off : Control: Seed treatment/soil drenching with Bavistin @ 0.1% or Thiram @ 0.3%
2. Rust : Control: Spray Dithane Z-78 or Dithane M-45 @ 0.3 %
3. Altenaria leaf spot : Spray Mancozeb @ 0.3%
4. Colletotrichum leaf spot : Spray Mancozed @ 0.3 %
5. Cercospora leaf spot : Spray of Fytolam @0.3 %
6. Susicladium leaf spot : Spray Dithane M-45 or Fytolam @ 0.3 %

(B) Insects

1. Leaf miner : Control: Spray Monocrotophos 0.01 %

Flowering and Fruiting: Grafted tree starts bearing fruits at the age of 4 years and seedling raised trees at the age of 5-6 years. In different parts of the country, the harvest period varies from Nov-Dec and May-June months.

Yield: The kernel yield varies between 8-24 kg $plant^{-1}$.

Source of planting material

Important Research Institutions working on Pongamia:

Biofuel Park, Madenur, Hassan, Karnataka, http://biofuelkarnataka.in/jaivika-indana-udyana

Chaudhary Charan Singh Haryana Agricultural University, Hisar; www.hau.ernet.in

Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, www.dbskkv.org

Forest College & Research Institute, Coimbatore, http://www.tnau.ac.in/fcri/About.html

ICAR-Central Agroforestry Research Institute, Jhansi; www.nrcaf.res.in

ICAR-Central Research Institue on Dryland Agriculture, Hyderabad, Telangana, www.crida.in

ICAR-Central Arid Zone Research Institute, Jodhpur, Rajasthan, www.cazri.res.in

Kerala Agricultural University, Kerala; www.kau.edu

Maharana Pratap University of Agriculture and Technology, Udaipur; www.mpuat.ac.in

Mahatma Phule Krishi Vidyapeeth, Rahuri; www.mpkv.ac.in

Tree Oils India Limited,Telangana, www.treesoilsindia.com

UAS GKVK, Bengaluru , www.uasbangalore.edu.in

University of Agricultural Sciences, Dharwad ; www.uasd.edu

Wild Apricot (*Prunus armeniaca*)

Wild apricot, locally called as chulu, is an important oilseed of tree origin. It is a hardy plant species and can be grown in most of the deep well drained soils. The wild apricot tree grows to a height of 10-15m and found in the dry temperate regions of North-western Himalaya particularly in the valleys of Jammu & Kashmir, Chenab, Kullu and Shimla regions of Himachal Pradesh, Garhwal hills of Uttarakhand and in Nainital, Almora and Pithoragarh of Kumaon region. The oil is used for medicinal, cosmetic, confectionary purpose and also as biodiesel source. The cake extraction of oil can be used as manure and as cattle feed after detoxification of hydro-cyanic acid.

Origin	:	North-Eastern China
Family	:	Rosaceae
Species	:	*Prunus Armeniaca*
Vernacular name	:	Chuari, Zardalu, Khubani, Chola

Improved varieties/accessions

Agroclimatic zone	Improved varieties/accessions
Western Himalayan Region & in some Eastern Himalayan Region	Shipley Early, Kaisha, New Castle, St. Ambroise and Royal and improved CPTS collection from Kumaun University

Package of Practices

Plantation: Vegetative propagation through T-budding in June or in September and tongue grafting in winter on wild apricot / peach/plum rootstocks. Well grown plants of 1-4 years old are planted in pits dug at spacing of 4-5 m x 4-5 m depending upon the variety grown and topography of the land. Planting is done during late autumn or early winter as growth starts early *i.e.* ,October to November. It can also be propagated by shield budding on wild apricot stock, *i.e.*, zardalu or peach stock.

Fertilizer: 50 Kg FYM in Dec-Jan, 20 g N + 15 g P + 15 g K per plant at initial planting and doubling the dose each year till a stabilised yield is reached at 6 years is recommended. It thrives best on sandy and chalky soil at 1000m above msl on sunny and frost free sites.

Pruning: Late autumn mid winter for pruning *i.e*, end of October – December. During the first year, leaving three to five well placed branches, all unwanted laterals are removed to form the framework. In subsequent years, thinning of branches which are either crossing or crowding one another is practiced to admit light into the centre and encourage the growth of spurs. The pruning of old trees should aim at producing new spurs to replace those broken during picking. If new growth is less than 40 to 80 cm each year, resort to severe pruning.

Flowering and fruiting: The tree starts flowering after a gestation period of 4 years. The cultivation needs specific chilling hours ranging from 350-900 hrs below 7°C (45°F), for proper foliation and bloom in spring. Bears fruit on one year old shoots and on older spurs. It comes to full bearing from 5-6 years onwards.

Plant Protection:

(A) Diseases

1. Gummosis and leaf curl: spray copper oxy-chloride @ 3 g lt^{-1} of water or carbendazin @ 5 g lt^{-1} of water in January.

(B) Insects

1. Peach fruit fly, plum fruit moth : spray 0.1 % Malathion or Carbaryl
2. borers, *etc.*: spray 0.1% methylparathion

Yield: Potential seed yield is 2-4 t ha^{-1}.

Source of planting material

Important Research Institutions working on wild apricot:

Kumaun University, Uttarakhand www.kunainital.ac.in

Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu and Kashmir; www.skuastkashmir.ac.in



Cheura (*Diploknema butyracea*)

Cheura is an important source of tree oil seed, which is mainly distributed in the sub-Himalayan tracts and outer Himalayan ranges, also sporadically found in tropical moist deciduous, semi-deciduous and ever green forests of Andaman Islands. It is a medium sized, hardy plant species with economic age of 80-100 years. The large and fleshy fruits are traded for edible purpose. The oil content of seed, known as phulwa or phulwara ghee is used as substitute for ghee and butter in cooking. It is also used in preparing medicines and cosmetic creams. The defatted cake can be used as manure as it has pesticide properties.

Origin	:	Nepal and adjoining parts of India
Family	:	Sapotaceae
Species	:	*Diploknema butyracea*
Vernacular name	:	Cheura, Phulware

Improved varieties/accessions

Agroclimatic zone	Improved varieties/accessions
Western Himalayan Region	Improved CPTS collection from Kumaun University

Package of Practices

Plantation: Propagated through seeds or cuttings in poly bags. Pits of 60cm x 60cm x 60cm are dug for planting at the spacing of 6m x 6m to accommodate 250 plants ha^{-1}. One year old healthy seedlings are transplanted in the monsoon season.

Flowering and fruiting: Cheura starts flowering in Oct-Nov at the age of 8-10 years. Generally, it is an alternate bearer and the fruit ripens in June-July.

Yield: Potential seed yield is 5-7 t ha^{-1}.

Source of planting material

Important Research Institutions working on Cheura:

Kumaun University, Uttarakhand, www.kunainital.ac.in

Simarouba (*Simarouba glauca*)

Simarouba or the paradise tree, is an ever green multi utility tree of medium size. It is both a source of edible oil and also biofuels. The oil can be used as cocoa butter substitute/ extenders in confectionary and bakery industry. The oil cake is valued organic manure. The plants are polygamodioecious with varying percentage of staminate, pistillate, male and few bisexual flowers in the population. It can grow well in tropical climate and can withstand scanty to high rainfall. All types of well drained soil are suitable for simarouba cultivation.

Origin	:	Florida (United States)
Family	:	Simroubaceae
Species	:	*Simarouba glauca*
Vernacular name	:	Simarouba, Paradise tree, Aceituno, Bitterwood

Improved varieties/accessions

Agroclimatic zone	Improved varieties/accessions
Southern Plateau & Hills Region	Palem-1, 2, 3,4
Central Plateau & Hills Region	HAUP-09, 13, 22, 28 ,
Western Plateau & Hills Region	PDKV SG-23, 25, 27, 30

Package of Practices

Plantation: Propagated through seeds or cuttings in poly bags. The seed has viability till three months. Pits of 45cm x 45cm x 45cm are dug for planting at the spacing of 6m x 6m or 8m x 8m depending on the rainfall in the area. Healthy seedlings are transplanted in the monsoon season. Right geometry of male and female plants is advised for effective pollination and good bearing. 500 g of compost/pit and after a month 10g urea + 10g superphosphate in first year and in second and third years 50 g of fertilizer mixture (17N:17P:17K) along with 500g compost is recommended.

Inter-cropping: The short term annual crops such as sunflower, soybean, groundnut, pulses are chosen depending on the soil type during gestation period. Shade loving crops may also be grown as intercrops after gestation period. During the bearing period 2kg of organic matter and 200g of fertilizer mixture in two equal doses is recommended.

Irrigation: Life saving irrigation is recommended for establishment. In the first two years, necessary protective irrigation in summer or preferably through micro irrigation is advisable.

Flowering and fruiting: Gestation period is 6-7 years (3-4 yrs in case of grafts).Flowers occur annually from Dec-Feb. Fruits are harvested during April-May.

Plant protection:

(A) Diseases:

In Nursery, damping off or wilt is controlled with seed treatment of Pseudomonas fluorescence @ 10g/kg.

(B) Insects:

In plantations mites are of serious concern. In severe attack condition, spraying of 0.25 % dicofol or guinaphos is effective.

Yield: Potential seed yield is 1-1.5 t ha^{-1}.

Source of planting material

Important Research Institutions working on Simarouba:

Biofuel Park, Madenur, Hassan, Karnataka, http://biofuelkarnataka.in/jaivika-indana-udyana

Chaudhary Charan Singh Haryana Agricultural University, Hisar, www.hau.ernet.in

Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, www.pdkv.ac.in

Professor Jayashankar Telangana State Agricultural University; Hyderabad,Telangana, www.pjtsau.ac.in

UAS GKVK, Bengaluru, www.uasbangalore.edu.in



Mahua (*Madhuca indica*)

Mahua is one of the important tree species in central India, as it produces abundant delicious and nutritive flowers. This is used for edible purpose either fresh or dried and stored for indefinite period. It is fast growing with 20 m height, ever green tree cultivated in warm regions for its oleaginous seeds. Its oil is used by tribal as vegetable butter in addition it is used in skin care products, soaps, detergents, *etc.* It serves as an important fuel oil, hence a good source of biodiesel. The seed cake is used as manure. The flowers are used to produce an alcoholic drink in several parts of India.

Origin	:	Central and North India
Family	:	Sapotaceae
Species	:	*Madhuca indica*
Vernacular name	:	Mahua, Mahwa, Mowra, Illpai, Hippe, Yappa

Improved varieties/accessions

Agroclimatic zone	Improved varieties/accessions
Central Plateau & Hills Region	NDMC9, NDMC 7, NDMC 10 & NDMC 3

Package of Practices

Plantation: Propagated through seeds or cuttings as common practice. However, air-layering has successfully been demonstrated (semi-hardwood/ air-layering). Pits of 45cm x 45cm x 45cm or 60cm x 60 cm x 60cm are dug at a spacing of 7m x 7m. 25 kg of FYM is recommended before plantation in July-September. Till 10 years, 10 kg FYM, 100g N, 50g P and 75g K and in fully grown plants 100kg FYM, 1kg N and 500g K is recommended during July-August.

Training and pruning: Training is essential in mahua plants. Plants are allowed to grow straight with the help of stakes and framework should be developed by encouraging growth of 4-6 well spaced branches on trunk at a height of 90 cm from ground level. Pruning is not recommended in mahua. However plucking of fruits with twig meets pruning requirement.

Irrigation: Young plantation requires irrigation at an interval of 5-6 days. Irrigation after fruit set is also important for retention and development of fruits.

Intercropping: Vegetables like bottle gourd, lady's finger, cucumber and ridge gourd may be grown in inter spaces up to 6-8 yrs.

Flowering and fruiting: Flower appears from Feb- April and it takes 20 -30 days from flower initiation to anthesis. Heavy flower and young fruit drop is observed and only 8-13 % of set fruits reach maturity. Fruits are harvested by 3rd week of May to 3rd week of June.

Plant Protection:

(A) Disease:

1. Leaf rust is observed in nursery and mature stage and it is controlled by spraying of carbendazim @ 0.1 % or 0.25 % manocozeb.
2. Wood decaying fungi - spray carbendazim @ 0.1 %

(B) Insects:

1. Bark eating caterpillar in mahua is controlled by inserting cotton soaked with dichlorovos (76 EC) @ 0.06% and spraying of monocrotophos @ 0.05%.
2. Leaf roller and is managed by spraying carbendazim @ 0.1 %.
3. Formation of inflorescence has serious attack of phanerogamic plant parasite and it is managed by weedicide like 2,4-D,Gramoxone or sulfosulfuron.

Yield: Flower yield varies from 100-150 kg tree^{-1} year^{-1} and kernel 60-80 kg tree^{-1} year^{-1}.

Source of planting material

Important Research Institutions working on Mahua:

Biofuel Park, Madenur, Hassan, Karnataka, http://biofuelkarnataka.in/jaivika-indana-udyana

Chaudhary Charan Singh Haryana Agricultural University, Hisar; www.hau.ernet.in

Indira Gandhi Agricultural University, Raipur; www.igau.edu.in

Narendra Dev University of Agriculture and Technology, Faizabad, www.nduat.in

UAS GKVK, Bengaluru, www.uasbangalore.edu.in



Kokum (*Garcinia indica*)

Kokum is an important minor fruit, besides seed oil source for edible and non-edible applications. It is reported to be imported from Zanzibar to India. It is found to be grown widely in tropical rain forests of Western ghats in Konkan, Goa, Southern Karnataka and Kerala. It is a slender ever green tree with dropping branches. Kokum fruit is a promising industrial raw material for commercial exploitation in view of its interesting chemical constituents. The seed yield a valuable edible fat known as kokum butter, used in chocolate and confectionary preparations and also in manufacture of soap, candle and ointments. It is an important source for biodiesel.

Origin	:	Asia and Africa
Family	:	Clusioideae
Species	:	*Garcinia indica*
Vernacular name	:	Kokum, Mangosteen, Kokum butter tree, Aamsol

Improved varieties/accessions

Agroclimatic zone	Improved varieties/accessions
West coast plains & Hills Region	IC342301, Konkon Amrita (S-8) Other common varieties : Plain kokum, Salted kokum, Lonawala kokum, Pakali kokum, Khane kokum, Khola kokum

Package of Practices

Plantation: Propagated through seeds or soft cuttings. Pits of 60cm x 60cm x 60cm are dug at a spacing of 6m x 6m. 10 kg of FYM with 1 kg Single super phosphate or bone meal is recommended before plantation in May-June. Till 10 years, 10 kg FYM, 100g N, 50g P and 75g K and in fully grown plants 100kg FYM, 1kg N and, 500g K is recommended during July-August. In the initial years protection from stray cattle and scorching heat is essential.

Intercropping: Under protective irrigation, intercropping with coconut, arecanut, cardamom is practised as upper storey and lower storey crop. In rainfed plantation, sweet potato, vegetable crops, flowering annuals and stylo can be taken up in the first 10-12 years as companion crop.

Removal of male plants: In the early flowering stage (7-8 yrs), it is advisable to remove excess male plants, keeping only 10 % of male plants for adequate pollination. Rest of male plants can be converted to female trees by side grafting in the month of Aug-Sept.

Plant Protection:

(A) Insects:

1. Leaf miner is important pest which can be effectively controlled by spraying of Phosphomidon or dimethoate @ 0.03%.

Flowering and fruiting: Flowering starts from Oct-Nov and continue upto Feb and harvesting of fruits commences from Mar to June.

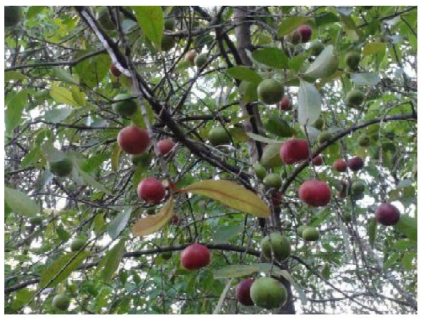
Yield: Varies from 30-173 Kg tree^{-1} year^{-1}.

Source of planting material

Important Research Institutions working on kokum:

Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, www.dbskkv.org

National Bureau of Plant Genetic Resources, Regional Station, Thrissur www.nbpgr.ernet.in/Regional_Stations/Thrissur_Kerala.aspx



Jojoba (*Simmondsia chinensis*)

Jojoba is a potential tree borne oilseed, which can be commercially cultivated in arid and semi-arid areas having low rainfall, extreme cold and hot temperature. It was introduced in India around 1965, but it was given importance only during 80s. It is an ever green slow growing dioecious desert shrub, which can live up to 150 years. It can tolerate extremely high and low temperature. It can grow on wide range of soils but not suitable for water logged, heavy soils and soils prone to flooding. The seed oil is used as lubrication as a substitute for sperm whale oil, in heavy machinery, as it can be used with little or no refining at high temperatures and pressures. It is a good source for biodiesel, also in pharmaceuticals, cosmetics, food related and other chemical industry.

Origin	:	Northen America
Family	:	Simmondsiaceae
Species	:	*Simmondsia chinensis*
Vernacular name	:	Goat nut, Coffeeberry, Quinine nut, Wild hazel, Pig nut

Improved varieties/accessions

Package of Practices

Plantation: Fresh and healthy seeds are soaked in water for 8-10 hrs and then treated with 0.2% solution of bavistin for 3-5 min and then used for sowing in polybags after air drying. 5-6 month old seedlings are planted in the prepared field at the spacing of 4m x 2m (1250 plants ha^{-1}) or 2m x 2m (2500 plants ha^{-1}) in the pits of size 30cm x 30cm x 30cm. The best ratio for effective pollination and maximum fruit set is 1 male: 10 female plants. Application of 75kg N, 37.5kgP and 75kg K per ha in the first year and an increase of 15kg ha^{-1} yr^{-1} N & 7.5kg ha^{-1} yr^{-1} P is recommended.

Intercropping: The low height leguminous crops having no competition for water and nutrient requirement and suitable for desert areas are selected like moong, moth, gram, groundnut, tamarind, vegetables of cucurbitaceous family *etc.* in the initial years.

Irrigation: Being xerophytic, Jojoba plant can survive for longer time without water. However, light irrigation in the early stage of plantation (upto two years) in order to establish the plants is advisable.

Plant protection:

(A) Disease:

1. Seedling rot is controlled by drenching with 1g Bavistin+1g Streptocycline + 2g copper oxychloride dissolved in 10 lt of water @ 100ml $plant^{-1}$.

2. Verticillium/Fusarium wilt, Pythium and Phytopthora, Alternatia are some of the other disease seen in Jojoba. This can be controlled by seed treatment with Bavistin/ Vetavax/Thiram @ 2g kg^{-1} or foliar spray of 1g bavisting + 1g streptocycline and 2g copper oxychloride in 10 lt water.

Flowering and fruiting: Flowering starts from 4th year and continue upto 150 years. Female flowers generally bloom in Dec-Jan and seeds are harvested in June.

Yield: 1.1.5t ha^{-1}.

Source of planting material

Important Research Institutions working on Jojoba:

Association of Rajasthan Jojoba plantation and Research Project, Jaipur;
Central Arid Zone Research Institute, Jodhpur, www.cazri.res.in
Central Salt and Marine Chemicals Research Institute, Bhavnagar, www.csmcri.org
Indian Institute of Petroleum, Dehradun; www.iip.res.in/
Osmania University, Hyderabad; www.osmania.ac.in



Neem (*Azadirachta indica*)

Neem is one of the most valuable tree species found in India. It can grow on wide range of soils upto pH 10, which makes it suitable for every agro-climatic zones except in high and cold regions. It has deeper root system, thus does not compete with annual crops for soil moisture. It is a multipurpose tree which provides all the requirements of rural areas *viz.*, timber, fuelwood, fodder, oil, fertilizers, pest repellant, *etc.* Neem is known for its Azadirichtin content and it has been commercially exploited in many products like medicine, manure, pesticide, insecticide, *etc.*Neem is regarded for its environmental value.

Origin	:	India
Family	:	Meliaceae
Species	:	*Azadirachta indica*
Vernacular name	:	Neem, Bevu,Tamaka, Tamabin, Margosa Tree, Veppu, Nimba, Vepu

Improved varieties/accessions: Grown almost in all the agroclimatic zones of India




Package of practices:

Plantation : Propagated both by seeds or vegetative propagation (cuttings/air-layering/ grafting or tissue culture). 5-6 months old seedlings can be transplanted in a pit size of 30cm x 30cm x 30cm at a spacing of 5m x 5m during monsoon season. About 5-6 kg green manure, 20-25 gm endosulphan dust, 10 g urea, 20 g single super phosphate, 20 g MOP and 1-2 kg neem cake plant^{-1} is recommended during transplanting.

Intercropping: In the gestation period of 5 years, groundnut, mustard, chickpea, cowpea, horsegram, soybean etc can be successfully grown.

Yield: 2-4 t ha^{-1}.

Source of planting material

Important Research Institutions working on Neem:

Arid Forest Research Institute, Jodhpur, afri.res.in

Biofuel Park, Madenur, Hassan, Karnataka, http://biofuelkarnataka.in/jaivika-indana-udyana

Chaudhary Charan Singh Haryana Agricultural University, Hisar; www.hau.ernet.in

ICAR-Central Agroforestry Research Institute, Jhansi; www.nrcaf.res.in

ICAR-Central Arid Zone Research Institute, Jodhpur, www.cazri.res.in

Mahatma Phule Krishi Vidyapeeth, Rahuri; www.mpkv.ac.in

Professor Jayashankar Telangana State Agricultural University; Telangana; www.pjtsau.ac.in,

Sardarkrushinagar Dantiwada Agricultural University, SK Nagar, Dantiwada, www.sdau.edu.in

Tropical Forest Research Institute, Jabalpur; tfri.icfre.gov.in

UAS GKVK, Bengaluru, www.uasbangalore.edu.in

Tung (*Aleurites fordii*)

The tung trees are cultivated for their seeds, the endosperm of which provides a superior quick drying oil, utilized in the manufacture of lacquers, varnishes, paints, linoleum, oilcloth, resins, artificial leather, *etc*. It is also used to coat containers for food, beverages, medicines, insulating wires and other surfaces as in radios, radar, telephone and telegraph instruments, in addition to biodiesel production. Tung is a fast growing deciduous tree that reaches a height of about 12 m at maturity with a life span of 30 years. They need exact climate and soil requirements. It needs long hot summers with abundant moisture, hence most suitable for sub-tropical areas like North Eastren states, Himachal Pradesh and Uttarakhand.

Origin	:	Sourthen China
Family	:	Euphorbiaceae
Species	:	*Vernicia fordii*
Vernacular name	:	Tung, Candlenut, Candleberry, China wood tree, Balucanut

Improved varieties/accessions

Agroclimatic zone	Improved varieties/accessions
Eastern Himalayan Region	La crosser, Lampton, Isabel, Cahl, Folsum

Package of practice

Plantation: Propagated by seed or budding. Transplanting of 5-6 months old seedlings with a spacing of 5m x 4 m is advised.

Flowering and fruiting: Gestation period is 3-4 years and the flowering starts in the month of March, seed ripens from Sept-Nov.

Yield: 4.5-5 t ha^{-1}.

Source of planting material:

Important Research Institution working on Tung:

Agriculture Department, Mizoram, agriculturemizoram.nic.in



Olive (*Olea europaea)*

Olive is a commercial plant of the Mediterranean since ages and in India it was imported for use in salads and other culinary preparations. In 2007, with an Indo-Israel collaboration, its cultivation was tried in Rajasthan and first fruits were harvested in 2011-12. The oil content of the seeds from Indian cultivation ranged from 9-14 % in comparison to 12-16 % of the other olive growing countries. At present, olives are grown in an area of 182 ha in several parts of Rajasthan with 14000 MT. It has global demand for culinary preparation, edible oil and also for biodiesel.

Origin	:	Africa
Family	:	Oleaceae
Species	:	*Olea europaea*
Vernacular name	:	Olive, Olea europa

Improved varieties/accessions

Agroclimatic zone	Improved varieties/accessions
Arid –zone	Arbequina Olive; Barnea Olive; Coratina Olive; Frantoio Olive; Koroneiki Olive; Picholine Olive and Picual Olive

Package of Practice:

Plantation: Planting during November-December or February-March in holes that can be dug manually or mechanically, in dimensions of about 60 cm x 40 cm (manual digging) or 20 cm x 30 cm (mechanical digging). Planting depth should be same as in the nursery. In dry areas, planting holes must be 5-10 cm deeper. After planting, the surrounding earth should be covered with straw to minimize water loss from the soil. Fertilizers @ of 1000-1500 kg ha^{-1} P and 500-800 kg ha^{-1} K at the time of planting and 3-4 fertilizations with ammonium nitrate (20-30 g $tree^{-1}$) every year followed by irrigation.

Intercropping: In the initial year's cotton, tomato, potato, pumpkins, etc can be grown as per the region and it should be restricted among the rows of the olive trees to minimize competition among the plants.

Irrigation: Young trees should be irrigated regularly during the first 2-3 years. Irrigation frequency depends on water availability so as to ensure sufficient soil moisture at the critical stages of the crop

Pruning: Pruning is necessary to adjust the trees to the climatic conditions of the area and increase plantation's productivity, accordingly three type of prunning done as per the need. (1) Regulated pruning to develop the tree's frame in the initial years (2) Pruning for fruiting

to induce productive branches to form fruits leaving the structural branches unaffected (3) Renovating pruning to stimulate sprouting in order to rejuvenate senescent trees. Pruning can be performed from autumn to the first months of spring, but it should be delayed in areas with high risk of frosts.

Flowering and fruiting: First bearing starts at 5-10 years, with flowering in Mar-April and fruit harvesting begins from October.

Source of planting material:

A centre of excellence on Olive cultivation has been established at Bassi near Jaipur, Rajasthan under the State Government with facilities for large scale production of quality planting material of Olive. The centre has developed complete package of Practice for the cultivation of Olive.

Important Research Institutions working on Olive:

Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Solan, www.yspuniversity.ac.in

ICAR-Central Arid Zone Research Institute, Jodhpur, www.cazri.res.in

Sardarkrushinagar Dantiwada Agricultural University, SK Nagar, Dantiwada www.sdau.edu.in

State Institute of Agriculture Management Campus Agriculture Research Station, Durgapura, Jaipur – 302018. www.rajolive.com.



Processing of Tree Borne Oilseeds

Among the tree borne oil seeds, which are of importance to biofuels, some of them have economic value for its flowers and fruits, like Mahua, Kokum, Olive, Wild apricot, *etc.* In those cases, the fruit pulp is removed for commercial purpose and processed separately before processing the stone or seed. In all other cases, fruit or the berry are collected when they are mature, usually this is spread over months because of non-synchronous flowering and fruiting, and are dried under sun or in mechanical driers to reduce the moisture content. In Simarouba, Neem, *etc.*, the collected fruits are depulped, washed at the earliest before sun drying to procure clean nuts. The kernels are separated from the shell manually or mechanical decorticators.

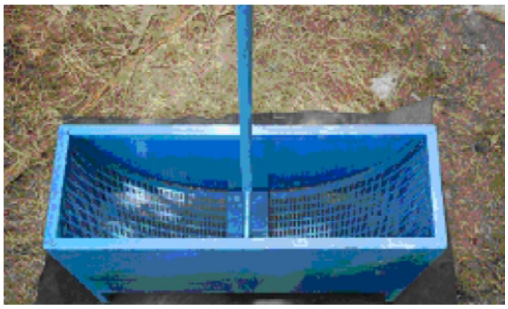
Depulping: The freshly collected fruits (depending on the TBOs) are dipped in water in a tank or in a pond after packing in a gunny bags. The pulp and mucilaginous substances are scraped away by rubbing with gunny bags or sand. Mechanical de-pulpper can also be used.

Drying: The depulped seed is dried under sunlight or hand operated dryer/mechanical direr.

Decortication: The dried fruits are decorticated to obtain seed kernels by two methods, *i.e.,* traditional and modern mechanized method

Traditional method: The fruit shells are washed in water or heated in water filled big container and continuously stirred with a stick. The fruit shells are kept on the floor and pressed to separate the kernels. The separated kernels are dried in the sun. In some cases as in Simarouba, cooking is applied to decorticate seeds prior to pressing, to coagulate the proteins in the walls of the fat containing cells

Modern Method: In the mechanical method, seeds are placed into a cylindrical shaped metallic machine having screws. The machine can be handled manually and by power operation. The kernels come out from the machine with the movement of shafts get separated into four pieces and kept for dry in the sun.

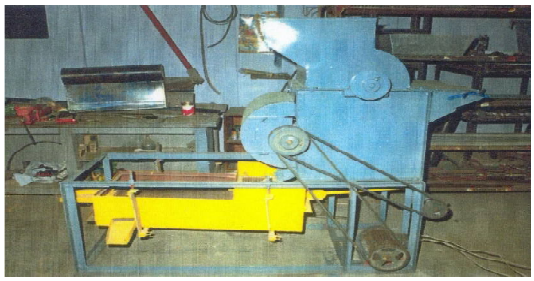


Manual Decorticator for Jatropha Seeds

Hand Operated Dehuller for Jatropha

Karanja Decorticator

Jatropha Decorticator



Mechanized Decorticator for Jatropha / Neem Seeds

Seed Processing: After decortication oil is extracted from the kernals by conventional oil expellers with some modification in compression chamber and steam heating/ cooker arrangement. An efficient oil expeller may extract about 90 % of available fat. Either whole seed or kernel is used for extracting oil while using the modern oil extractors The Oil extractors/expellers are available in the market in different models depending on the capacity.

Oil Expeller and Filter Units

Trans-esterification: The seed/kernel oil thus obtained is further processed to obtain biodiesel. Bio-diesel is a methyl ester formed by a process called Transesterification. The oil is reacted with methanol in the presence of a catalyst to yield methyl esters and glycerol. Sodium hydroxide and Potassium hydroxide are commonly used catalyst. The oil is heated to 65°C and the solution of sodium hydroxide and methanol are added. The quantity of NaOH/KOH and methanol should be 2 and 25-30% respectively, of the total quantity of oil. After mixing this solution into hot oil, the solution should be stirred for 5 to 7 minutes and the solution is incubated for 4 hrs undisturbed. Glycerol being heavy will slowly settle down at the bottom and bio-diesel can be easily separated from the top. To strain the impurities like Sodium, the oil should be washed 2-3 times with water and then finally the water is evaporated and bio-diesel, thus obtained is ready to use.

Biodiesel producing transesterification unit

Salient information on the prioritized Tree Borne Oilseeds (TBOs)

TBOs	Simarouba	Karanj	Kokum	Wild Apricot	Jojoba	Cheura
Scientific name	*Simarouba glauca*	*Pongamia pinnata*	*Garcinia indica*	*Armeniaca vulgaris*	*Simmondsia chinensis*	*Diploknema butyracea*
Habit	Medium sized tree	Medium sized tree	Tree	Medium sized tree	Shrub	Tree
Flowering season	Dec.-Feb.	March-May	Oct-Feb	March	Dec-Jan	Oct-Nov
Harvest season	Feb-April	Jan-March	Mar to June	May-June	June.	June-July
Uses	Biodiesel, medicine, cake as manure, insecticide, biogas production Edible oil	Biodiesel, cake as manure, green manure, soap production, leather industry, biogas production	Seed oil as biofuel, fruits in culinary purpose confectionery, medicines and cosmetics	wood for agricultural implements, thatching mud houses and as fuel & as biofuel, fruits for edible, processing & alcoholic drink, oil for cooking	Biodiesel, lubrication, cosmetics,pharmace-utical, food related uses seed cake as animal feed, fertilizer	pulp; wood as fuel; resin used in glue; seeds-ghee or butter, extracted for edible purpose and biofuel, fruit sweet and edible
Yield starts at (years)	4	5	7-8	5-6	4	8-10
Seed yield (kg)	10-25	15-40	30-173	47	**3-5**	2-12
Oil (%)	60-70	27-39	22-25	30	50	42-47
TBOs	**Neem**	**Mahua**	**Jatropha**	**Olive**	**Tung**	
Scientific name	*Azadirachta indica*	*Madhuca longifolia*	*Jatropha curcas*	*Olea europaea*	*Vernicia fordii*	
Habit	Tree	Tree	Large shrub	Small tree	Tree	
Flowering season	March-May	March-April	May-August	March-April	March	
Harvest season	June-Nov.	Jun-August	Aug.-October	Oct	Sept-Nov	
Uses	Biodiesel, medicine, cake as manure, agricultural equipments, insecticide, soap industry, biogas production	Biodiesel, medicine, cake as manure, agricultural equipments, soap industry, biogas production	Biodiesel, cake as manure, medicine, insecticide, biogas production	Biodiesel, Culinary purpose	Biodiesel, Paint and wax industry	
Yield starts at (years)	8	8-10	3	5-10	3-4	
Seed yield (kg)	20-40	10-40	01-02	2.5-4.0	01-02	
Oil (%)	30	33-43	30-40	60-70	30-40	

Oil properties of different TBOs

S. No.	Oil content in seed (%)	Specific gravity	Refractive index	Acid value	Saponification value	Iodine value
Jatropha	30-40	0.918-0.923	1.462-1.465	19.00	188-196	93-107
Karanj	27-39	0.925-0.940	1.434-1.479	1.3-16.8	185-195	80-96
Wild apricot	46	0.914	1.470	2.27-2.78	189-191	100
Cheura	42-47	0.856-0.862	1.0455-1.465	-	191-200	90-101
Simarouba	60-70	-	1.455	0-06	191	50-54
Mahua	33-43	-	1.452-1.462	-	187-197	55-70
kokum	33-43	0.895		7.2	299.5	37.4
Jojoba	50	0.83		0.43	97	84
Neem	30-50	0.915-0.920			189-193	125-135
Tung	30-40	0.930		36-37	189-195	160-175
Olive	45-70	0.909-0.919			187-196	

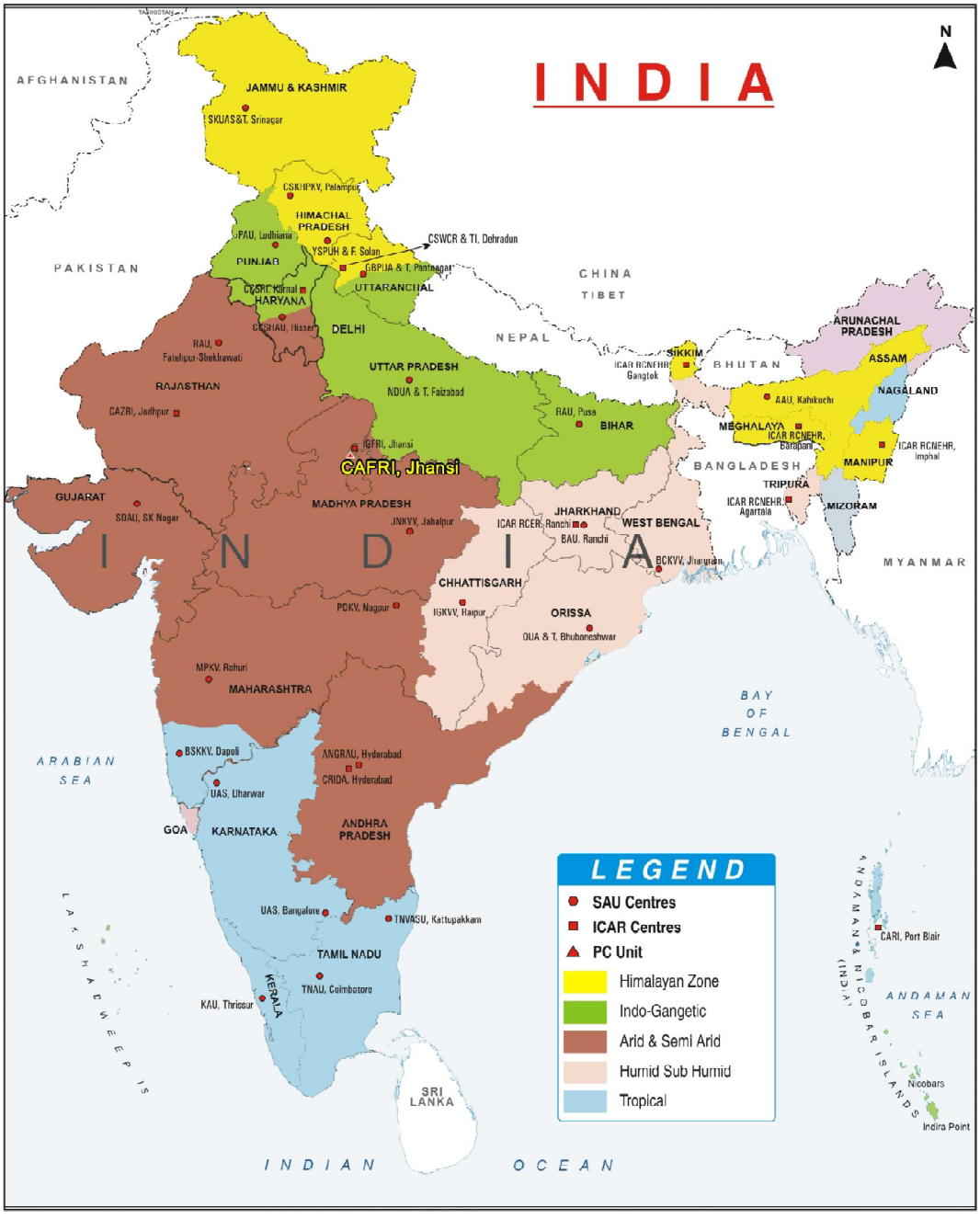
List of TBO processing equipments developed under NOVOD Board

Sl.No.	Equipments	Capacity (Kg/hr)	Approx. cost (₹)
1	Neem Depulper (Manual)	20	40,000.00
2	Karanja Decorticator	50	1,00,000.00
3	Tung Decorticator	40	1,00,000.00
4	Jatropha Decorticator (Manual)	40	50,000.00
5	Neem Decorticator (Mechanical with 2 H.P. Motor)	100	80,000.00
6	Jojoba Seed Dehuller	60	50,000.00
7	Mahua Seed Decorticator	50	50,000.00
8	Wild Apricot Decorticator	45	50,000.00
9	Depulper (for Simarouba, Cheura, Kokum, Olive)	20	40,000.00
10	Decorticator (for Simarouba, Cheura, Kokum, Olive)	40	50,000.00
11	Dehuller (for Simarouba, Cheura, Kokum, Olive)	50	50,000.00
12	Drier (for Simarouba, Cheura, Kokum, Olive)	40	50,000.00
13	Cleaner/grader (for Simarouba, Cheura, Kokum, Olive)	100	30,000.00
14	Oil Expeller for TBOs	1 t day^{-1} (TPD)	2,00,000.00

Cost of cultivation of some important TBOs

Name of the TBO plant	No. of plants ha^{-1}	Approx. cost of Cultivation in Ist year (Rs. ha^{-1})	Ave. Income in 10-12 (Rs. ha^{-1} $year^{-1}$)
Jatropha	2500	41000.00	116268.00
Karanj	500	20000.00	13984.00
Wild apricot	400	16000.00	50000.00
Cheura	250	14000.00	70000.00 - 120000.00
Simarouba	500	24000.00	19076.00
Mahua	200	8756.00	12700.00
kokum	500	15000.00	18812.00
Jojoba	2500	35000.00	104100.00
Neem	400	10000.00	17000.00
Tung	500	13000.00	34000.00
Olive	200	48000.00	

The cost-economics may vary depending upon various agroclimatic conditions, wage rate, input cost etc.



Map showing locations of AICRP on AF Coordinating Centres and PC Unit.

Addresses of Institutions

S. No.	Name of Centre and Place	Address
1	Dr. YSPUHF, Solan (H.P.)	Dept. of SAF Dr. Y.S. Parmar University of Horticulture & Forestry, Solan, HP 173 230
2	SKUA&T, Srinagar (J&K)	Faculty of Forestry, SKUAST-K Benhama, Watlar, Ganderbal 191 201, , Srinagar (J&K)
3	AAU, Jorhat, Mondira (Assam)	AAU, Kahikuchi, Near Guwahati Airport, Guwahati-781 017
4	PAU, Ludhiana (Punjab)	Dept. of Forestry & NR Punjab Agricultural University, Ludhiana-141 004
5	GBPUA&T, Pantnagar (Uttrakhand)	G.B.Pant University of Agriculture &Technology, Pantnagar,U.K- 263 145
6	RAU, Pusa (Bihar)	Rajendra Agriculture University, Pusa, Samastipur-848 125
7	NDUA&T, Faizabad (UP)	N.D.University of Agriculture & Technology, Kumarganj, Faizabad, UP 224 229
8	BCKVV, Kalyani, Jhargram (W.Bengal)	BCKV RRS, Jhargram Paschim Medinipur-721 507
9	OUA&T, Bhubaneshwar (Odisha)	College of Forestry OUAT, Bhubaneswar- 221 003
10	BAU, Ranchi (Jharkhand)	Faculty of Forestry, Birsa Agriculture University, Kanke, Ranchi- 834 006 (Jharkhand)
11	SDAU, SK Nagar (Gujrat)	D.F.R.S (ARID)SDAU, Sardar Krushinagar Dist. Banaskhantha-385 506
12	SKNAU, Fatehpur-Shekhawati (Rajasthan)	Agriculture Research Station, SK NAU, Jobner Jaipur ,Rajasthan-303329
13	CCSHAU, Hissar (Haryana)	Dept. of Forestry Chaudary Charan Singh Haryana Agriculture University Hisar, Haryana 125 004
14	MPKV, Rahuri (Maharashtra)	Mahatma Phule Krishi Vishvidhyala, Rahuri, Ahmednagar Maharastra 413 722

S. No.	Name of Centre and Place	Address
15	PDKV, Nagpur (Maharashtra)	College of Agriculture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Nagpur- 440 001
16	ANGRAU, Hyderabad (AP)	ANGR AU, Rajendranagar, Hyderabad- 500 030 AP
17	JNKVV, Jabalpur (MP)	Jawaharlal Nehru Krishi Vishwavidyalaya, Jabalpur-482 004 MP
18	UAS, Dharwad (Karnataka)	Krishinagar, UAS, Dharwad- 580 005 Karnataka
19	TNAU, Coimbatore (TN)	Forest College and Research Institute, Mettupulayam-641 301
20	KAU, Thrissur (Kerala)	College of Forestry, Kerala Agricultural University Thrisuure Kerala-680 654
21	BSKKV, Dapoli (Maharashtra)	Dr. B.S.Konkan Krishi Vidyapeeth, Dapoli Dist. Ratnagiri – 415 712..
22	TNVASU, Kattaupakkam (TN)	Institute of Animal Nutrition, Kattupakkam Kancheepuram District - 603 203
23	CSKHPKV, Palampur (HP)	CSKHPKV, Palampur, HP - 176 062
24	UAS, Bangalore (Karnataka)	UAS, Bangalore Karnataka , 560 024

Flowering and fruiting in seed grown *Pongamia pinnata* at the age of two and a half years

भाकृअनुप
ICAR

हर कदम, हर डगर
किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद

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