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Tree Borne Oilseed (TBOs): Competitive Source for Biodiesel in Rural India

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Abstract

Non-edible oils (TBOs) obtained from seeds of tree species can be used as potential biodiesel source in rural areas and contribute towards attaining self-sufficiency. TBOs are grown in the country under different agro-climatic conditions in a scattered form in forests, non-forest areas, waste land, deserts and hilly areas. The country has enormous potential of oilseeds of tree origin like mahua (*Madhuca indica*), simarouba (*Simarouba glauca*), wild apricot (*Prunus armeniaca*) etc. in varied agro-climatic conditions. Participation of community in growing selected trees in agroforestry system as a component and processing of seeds for oil extraction requires concerted R&D works on bio-fuel species. Oil obtained from wild apricot can be used locally for diverse pharmaceutical, cosmetic, food and allied industries besides generating revenue for local communities. Standardisation of cultivation practices, development of quality planting material, and establishment of demonstration plantations need to be focused upon for mainstreaming TBOs. In this direction, genotypes of wild apricot have been selected from limited area for the identification of plants having high seed yield and oil content.

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Introduction

Energy is vital for social and economic development. High energy prices, increasing energy imports and to recent petroleum crisis (Venkataraman, 2004) and the demand for petroleum diesel is increasing day by day hence there is a need to find out an appropriate solution. As the energy demand increases worldwide, governments are beginning to explore renewable energy options. 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 raise by 1.68% from 75 million barrels (MB)/day in the year 2002 to 120 MB/day in 2030 *i.e.* a tenfold increase. Energy input in agriculture is also increasing. Part of this energy should come from renewable source for continuity for efficient

and effective and it can be fulfilled by biofuels.

Biofuels are being given serious consideration as potential sources of energy in the future, particularly in developing countries like India. Biofuels are a sub-category of bioenergy, which refers to any energy sourced from non-fossil biomass used for heat, electrical power, or transport. Bioenergy currently accounts for roughly 10% of total primary energy supply globally but most of this energy is consumed as wood for cooking in developing countries. Biofuels make up only a small fraction of current bioenergy use.

It is increasingly acknowledged that the biofuels hold the potential to offer a sustainable energy future which would create opportunities for achieving environmental and socio-economic goals of the sustainable development (US Department of Energy 1998; Kartha and Larson 2000, Hardy 2002). All fuels can be broadly divided into modern and traditional biofuels (Rajagopal and Zilberman 2007; Goldemberg and Coelho 2005). Modern biofuels typically include liquid fuels (ethanol and biodiesel) and biogas. The details on biofuel production is given in Table 1. Ethanol and biodiesel are the two most common forms of biofuels that are widely used in the energy sector.

Biodiesel is a clean burning alternate fuel, both edible and non-edible. It can be used in compression-ignition (diesel) engines with little or no modifications .Bio diesel is simple to use, biodegradable, nontoxic, and essentially free of sulfur and aromatics. It can be stored just like petroleum diesel fuel and hence does not require a separate infrastructure. The use of biodiesel in conventional diesel engines results in substantial reduction of unburned hydrocarbons, carbon monoxide and particulate matters. Its higher cetane number improves the ignition quality even when blended in petroleum diesel. The use of edible oil to produce biodiesel in India is not feasible in view of big gap in demand and supply of such oil (Padhi and Singh, 2011).The major source of bio-diesel in India is non-edible oil seeds (TBOs) and the technology for its production is indigenously available. 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),* Jojoba (*Simmondsia chinensis),* chullu *(Prunus armeniaca),* Cheura (*Diploknema butyracea*) ,wild walnut (*Aleurites molucana*) and Tung (*Vernicia fordii*). The oil content varies between 21 to 73% in these species. There are at least four ways in which oils and fats can be converted into biodiesel, namely, transesterification, blending, micro-emulsions and pyrolysis—transesterification being the most commonly used method (Ramdhas *et al.*. 2005, Ma and Hanna, 1999). Transesterification refers to a catalyzed (KOH/NaOH) chemical reaction involving oil/fat (triglyceride) and an alcohol (methanol/ethanol) to yield fatty acid alkyl esters (i.e., biodiesel) and glycerol. The main factors affecting transesterification are the amount of alcohol and catalyst; reaction temperature, pressure and time; the contents

of free fatty acid (FFAs) and water in oils. Conversion is complicated if oil contains large amount of FFA (41% w/w) that will form soap with alkaline catalyst. The soap can prevent separation of the biodiesel from the glycerin fraction (Srivastav and Prasad, 2000).

Biofuel	Feedstock	Processes
Ethanol	Agricultural crops containing starch; sugar; lignocellulosic biomass	Fermentation: sugars are converted into ethanol using micro-organisms under anaerobic conditions. Hydrolysis: the long chains of polymers of starch molecules are first broken down to simple molecules of glucose and then glucose is fermented to produce ethanol. Pretreatment and acid hydrolysis cellulose and hemicellulose in the lignocellulosic biomass are broken down to simple individual sugars and sugars are fermented to produce ethanol.
Biodiesel	Oilseed crops such as soybean, canola, sunflower, palm oil	Transesterification: fat or oil is mixed with an alcohol to form methyl esters known as biodiesel and glycerol
	Biomass, cow dung, animal carcasses, *etc*.	Hydrolysis: insoluble organic materials (*e.g.* lipids, proteins, fats *etc*.) are transformed to soluble organic materials. Fermentation: where soluble organic materials are fermented to acetic acid. These are converted into a mixture of methane called biogas and carbon dioxide

Table 1: Details on biofuels production by type of biofuels

Tree borne oilseeds are the multipurpose tree species in agriculture system. 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 best characteristic is that it can be grown and established in the wasteland and have varied agro-climatic conditions. They are also of domestic and industrial utility like agriculture, cosmetic, pharmaceutical, diesel and substitute, cocoa-butter substitute, carbon sequestration in wasteland, consumption of oil *etc*. besides generating additional employment for vast rural populations. They are 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. There is favorable environment for large scale cultivation of this plant in the country which will further add not only in the reduction of biodiesel production cost but will also add to the food stock of the country. (ICAR-Central Agroforestry Research Institute report, 2015).

Major Tree Borne Oilseeds (TBOs)

Wild apricot (*Prunus armeniaca syn Armeniaca vulgaris*)

Wild apricot belongs to rosaceae family. It is an endangered plant. Locally called as chullu, 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. Wild apricot is quite hardy and can be grown in most of the soils, which are deep and well drained. The cultivated apricot has its origin in North-Eastern China, whereas, wild apricot appears to be indigenous to India. In India it is found in the dry temperate regions of North-Western Himalayas particularly in the valleys of Jammu & Kashmir (especially Ladakh), Chenab; Kullu and Shimla regions of H.P. and Garhwal hills of Uttarakhand at altitudes up to 3000 m. 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. It comes to full bearing of fruits from 5-6 years onwards. Oil content ranged from 50.05 - 57.97%, while range of stone length, breadth and thickness was from 14.64 - 26.48, 12.26 - 21.49 and 8.63 - 14.65 mm, respectively. Stone and kernel weight varied between 66.60 - 295.10 and 18.20 - 68.18 g. Kernel size (length, breadth and thickness) and weight are most desirable characters which affect oil percentage. 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.

Ullah *et al.*, 2009 calculated the benefit/cost ratio of wild apricot in Pakistan was evaluated for biodiesel produced from wild apricot kernel oil on laboratory scale. They found that the cost of biodiesel produced from wild apricot kernel oil was 1.2 U.S $L. This high cost is due to problems associated with collection of kernels from farmers and laborious pressing of kernels for oil extraction. The above estimated price for wild apricot kernel oil biodiesel appears high than existing price of high speed diesel (0.70 U.S $/L) in Pakistan. However, the cost of production can be further reduced by utilizing byproducts of biodiesel such as glycerin for industrial uses (soap, cosmetics etc) and kernel cake as animal feed and preparation of inocula for biofertilizers.

Siamrouba (*Simarouba glauca*)

Simarouba or the paradise tree, belongs to family simroubaceae is an ever green multi utility tree. It is a both source of edible oil and also biofuel. The oil can be used as cocoa butter substitute/ extenders in confectionary and bakery industry. The oil cake is valued organic manure. It could grow under a wide range of agro climatic conditions like warm, humid and tropical regions. Its cultivation depends upon rainfall distribution (around 400 mm), water holding capacity of the soil and sub-soil moisture. It is suited for temperature range 10 – 40 ^{0}C, pH of the soil be 5.5 – 8. It produces bright green leaves 20-50cm length, yellow flowers and oval elongated purple colored fleshy fruits (Yadvika *et al..,* 2004) Its seeds contain about 40 % kernel and kernels content 55-65% oil. The amount of oil would be 1000 – 2000 kg/ha/year for a plant spacing of 5m x5m. It is used for industrial purposes in the manufacture of soaps, detergents and lubricants etc. The oil cake being rich in nitrogen (7.7 to 8.1%), phosphorus (1.07%) and potash (1.24%) could be used as valuable organic manure (Yuan *et al..,* 2008)**.** Simarouba glauca can easily be propagated through seeds provided they are sown as fresh seeds. It is a polygamodioecious tree and seed-raised plantations result in segregation of male, andromonoecius and female plants and in certain instances the frequency of male plants reaches 60-70%. Even in female plants, only a few are generally, heavy bearers.

Cheura (*Diploknema butyracea*)

Cheura belongs to sapotaceae family and popular known as Indian butter tree and mainly found in Uttarakhand state. It is a multipurpose tree. It is a medium size deciduous tree with straight trunk attaining a height of 15-22m and girth of 1.5-1.8 m. The fruit is a berry ,2.0-4.5 cm long , bright green

in colour with three seeds which turns juicy and grey after getting ripen. The exterior of the fruit is thick, soft, and rich with glucose and fragrance. It contains black and sparkling seeds of 1.5 to 2.0 cm in length which has almond shaped white coloured kernels inside itself. Seed coat is thin to thick, woody to crusty.

Cheura may be propagated through seeds and cuttings. It is used as food, fodder and medicines in kumaon hills and kalp-vriksha. Cheura leaves are used as fodder for animals. Leaves are also used for biodegradeable plates for serving food.Useful for preparing medicines, ointment, candles, cream and other user-friendly products. Cake is used as manure and can also has pesticidal properties. Average fruit yield per annum is about 100-250 kg/tree.

Jatropha (*Jatropha curcas*)

Jatropha curcus is a drought-resistant perennial, growing well in marginal/poor soil. Jatropha, the wonder plant produces seeds with an oil content of around 37%. The oil can be combusted as fuel without being refined. It burns with clear smoke-free flame, tested successfully as fuel for simple diesel engine. The by-products are press cake a good organic fertilizer, oil contains also insecticidal properties. Jatropha grows almost anywhere, even on gravelly, sandy and saline soils. It can thrive on the poorest stony soil. Its water requirement is extremely low and it can stand long periods of drought by shedding most of its leaves to reduce transpiration loss. Jatropha is also suitable for preventing soil erosion and shifting of sand dunes. The seed productivity of Jatropha under block plantation varies from as low as 1.5 kg /plant to 5 kg/ plant at 2 m x 2 m spacing. The plant comes into seed bearing from the second year onwards and stabilizes by the 4th or 5th year. Normally, the seed yield from one-acre plantation is in the range of 800 – 1000 kg depending on the local climatic and hydro-geological conditions (ICAR, 2006 and Rao *et al*., 2006).

Recovery of oil from seed of 28 percent, it would take 3,571 kilograms (kg) of seed to produce one ton of oil. Assuming a cost of US$0.11/kg for seed and processing costs of approximately US$19.60/ton, the overall cost of production would be approximately US$407.80/ton, which translates to US$0.53/liter of biodiesel. The sale of the glycerin and seedcake byproducts could optimistically reduce the net cost to approximately S$0.40/liter. Annual production of non-edible oil seeds in India is given in Table 2.

Current scenario of Tree Borne Oilseeds (TBOs)

At present, the tree borne oilseeds (TBO's) contribute an insignificant portion of vegetable oil production in the country mainly due to lack of improved varieties, elite planting material and agronomic practices. A National Biodiesel Mission, 2009 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. Government of India 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.

Type	Production (MT)	Oil%
Neem	500	30
Karanja	200	27-39
Pilu	50	33
Ratanjot	-	30-40
Jojoba	-	50
Bhikal	-	37
Wild walnut	-	60-70
Undi	04	50-73
Thumba	100	21
Kusum	80	34

Table 2: Annual Production of Non-edible Oil Seeds in India (Interim Report of "Auto Fuel Policy").

01.01.2006 @ 25 / 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). Moreover, 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.

Problems and priorities of Tree Borne Oilseeds (TBOs)

Under the existing situation of tree borne oilseeds being of forest origin, the problems encountered are: collection from scattered locations, high dormancy and problems in picking and harvesting in avenue and forest plantations, non-availability of quality planting material or seed, limited period of availability, unreliable and improper marketing channels, lack of post-harvest technologies and their processing, non-remunerative prices, wide gap between potential and actual production, absence of state incentives promoting bio-diesel as fuel, and economics and cost-benefit ratio. At present, the tree borne oilseeds (TBO's) contribute an insignificant portion of vegetable oil production in the Research and development on germplasm resources, identification of elite planting material, propagation techniques, production technology for management of large scale block plantations of single or few species, performance of progenies under different agroclimatic situations, the resultant pest and diseases situation, quality parameters etc. need to be undertaken as a priority. Promoting TBOs has many benefits to the country and the environment in terms of additional supplies of vegetable oils, employment to needy population, eco-friendly system, foreign exchange earnings, diesel substitution and pollution reduction is required. Table no. 3 explains the integrated R&D programs for biofuel feedstocks.

Conclusion

Producing biodiesel from tree-borne oilseeds (TBOs) is seen by many as a win-win opportunity to solve India's most pressing problems. It will stimulate rural development and will bring rural infrastructure. Better management of marginal and wasteland can be helpful with extensive cultivation using

Modeling Studies	Process Technology	Agronomy Basic	R&D
Life cycle analysis and Industrial ecology Aspects	Optimization of oilseed processing and extraction	Crop yield analysis testing of local varieties and hybrids	Fatty acid profiling Identification and isolation of potential high value products
Net energy and CO_2 emissions estimation	Development of jatropha oil purification/refining and other feed stocks for processing	Testing of various farming practices (*e.g.* optimal crop spacing)	Toxicological studies
Ecological risk assessment	Optimization of transesterification	Development of organic fertilization schemes	Germplasm bank
Socioeconomic Impact assessment	Construction of integrated pilot plant	Identification of potential pests and diseases. Start up of a pilot farm to be integrated with the pilot plant	Engine performance and emissions testing

Table 3: Integrated R&D programs for biofuel feed stocks

improved, standard and certified planting material for the sustainable biofuel business. This will bring boost to processing industries and plantation, pharmaceutical and other subsidiary industries. With Clean Development Mechanism (CDM) companies in industrialised countries can buy "carbon credits" from project developers in developing countries in order to achieve their own green house gas reduction targets. Biodiesel could bring agricultural development and create employment and income for many of the poor people. At the same time, it may satisfy a significant part of the country's fuel demand, increasing India's energy security and saving foreign exchange. Shifting to biodiesel could also reduce greenhouse gas emissions and urban air pollution.

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