

Status of *Jatropha Curcas* for Biodiesel Production

I. INTRODUCTION

Biodiesel: fuel of the future?

Biodiesel resources can provide energy security WITH THE upsurge in economic activities, India is consuming over a whopping 127 million tonnes of crude oil a year and is forced to import about 70 per cent of its needs. The current yearly consumption of diesel alone is approximately 40 million tonnes in India constituting about 40 per cent of all petro-products. In the current scenario, exploring energy alternatives in the form of bio-fuels, namely, ethanol and biodiesel assumes top priority. Biodiesel, derived from the plants (bearing oils) like sunflower, rapeseed, canola or *Jatropha Curcas*, can be used as a substitute or an additive to diesel. Biodiesel can provide power similar to conventional diesel and thus can be used in diesel engines. Biodiesel is non-toxic and environment friendly as it produces substantially less carbon monoxide and the combustion gases contain no sulphur dioxide and unburnt hydrocarbons.

What is Bio-diesel?

Bio-diesel is the name of a clean burning alternative fuel, produced from domestic, renewable resources. Bio-diesel contains no petroleum, but it

Status of Jatropha Curcas for Biodiesel Production

can be blended at any level with petroleum diesel to create a Bio-diesel blend. 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. Potential Varieties of Bio Diesel oil seeds:

- ◆ Jatropha Curcas
- ◆ Karanja (Pungam)
- ◆ Jojoba
- ◆ Kusum
- ◆ Mahua
- ◆ Neem
- ◆ Sal
- ◆ Simarouba

Nearly 80 species are known to produce oil from seeds. Even though there are plenty of varieties of tree borne oil seeds, Jatropha Curcas shrubs are found to be an ultimate potential variety, and the pungam comes in the next.

Jatropha Bio-diesel

Jatropha Curcas has the advantage that not only is it capable of growing on marginal land, but it can also help to reclaim problematic lands and restore eroded areas. As it is not a food or forage crop, it plays an important role in deterring cattle, and thereby protects other valuable food or cash crops. Jatropha seeds can be pressed into bio-oil that can be used to run diesel engines,

Status of *Jatropha Curcas* for Biodiesel Production



F-A: *Intercropping of Jatropha with maize.*

F B: The various stages of fruit development can be seen, and an open fruit shows the (black) seeds inside.

Status of Jatropha Curcas for Biodiesel Production

used to run diesel engines, which in turn can drive pumps, food processing machinery, or electricity generators. The bio-oil can also be the basis for soap making. The pressed residue of the seeds is a good fertilizer and can also be used for biogas production.

- Many alternative Bio-diesel fuels have been shown to have better exhaust emissions than traditional Diesel fuel. Jatropha Bio-diesel holds promise as fuel alternatives for diesel engine.
- Reduction of the usage of Primary Fuels.
- Bio-diesel are produced with an agricultural orientation.
- Numerous researches have shown that Jatropha Bio-diesel has fuel properties and provides engine performance that is very similar to diesel fuel.
- Bio-diesel are non toxic, bio degradable and renewable fuel.
- The severe emission regulations in the world have placed design limitations on heavy duty diesel engines. The trend towards cleaner burning fuel is growing worldwide and it is possible through Jatropha Bio-diesel.
- Bio-diesel includes a high cetane number, low sulphur , low volatility and the presence of Oxygen atoms in the fuel molecule.
- Expected efficiency is achieved through Bio-diesel.
- Bio-diesel performs better than the Petroleum diesel.

Status of *Jatropha Curcas* for Biodiesel Production

- *Jatropha* Bio-diesel readily mixes with diesel fuel and it runs in any diesel engine without modification.
- Reduces serious air pollutants such as particulates, carbon monoxides, hydrocarbons and air toxic.
- Mutagenicity studies shows that bio diesel dramatically reduces potential risks of cancer and birth defects.

Economical Benefits

- ❖ National security: Bio-diesel can be made domestically, so it reduces our dependency on foreign oil.
- ❖ National economy: Using Bio-diesel keeps our fuel buying money at home instead of sending it to foreign countries. This reduces countries' trade deficit and creates jobs.

Biodiesel is an alternative to petroleum-based diesel fuel made from renewable resources such as vegetable oils or animal fats. Chemically, it comprises a mix of mono-alkyl esters of long chain fatty acids. A lipid transesterification production process is used to convert the base oil to the desired esters and remove free fatty acids. After this processing, unlike straight vegetable oil, biodiesel has combustion properties very similar to those of petroleum diesel, and can replace it in most current uses. However, it is at present most often used as an additive to petroleum diesel, improving the otherwise low lubricity of pure ultra low sulfur petrodiesel fuel. It is one of the possible candidates to replace fossil fuels as the world's primary transport energy source, because it is a

Status of Jatropha Curcas for Biodiesel Production

renewable fuel that can replace petrodiesel in current engines and can be transported and sold using today's infrastructure. Biodiesel use and production is increasing rapidly, especially in Europe, the United States, and Asia, though in all markets it still makes up a small percentage of fuel sold. A growing number of fuel stations are making biodiesel available to consumers, and a growing number of large transport fleets use some proportion of biodiesel in their fuel. Biodiesel, with a flash point of 150 °C, is not as readily ignited as petroleum diesel (64 °C) and far less so than the explosively combustible gasoline (-45 °C). Indeed, it is classified as a non-flammable liquid by the OSHA, although it will of course burn if heated to a high enough temperature. This property makes a vehicle fueled by pure biodiesel far safer in an accident. Biodiesel gels at higher temperatures (around 0 °C) than petroleum diesel, which limits its use in pure form in cold climates. Unlike petrodiesel, biodiesel is biodegradable and non-toxic, and it significantly reduces toxic and other emissions when burned as a fuel. The most common form uses methanol to produce methyl esters, though ethanol can be used to produce an ethyl ester biodiesel. A byproduct of the transesterification process is the production of glycerol.

Cancer risk reduced

Because of these properties cancer risks and neonatal defects are reduced. Biodiesel mixed (5-20 per cent) with conventional diesel can extend engine life. It has good potential for rural employment generation.

Status of Jatropha Curcas for Biodiesel Production

Considering all the options in India, Jatropha Curcas has been identified as the most suitable source due to its lower gestation period. While the seeds are used for oil extraction, other parts of the plant, that is, leaves, bark and the like, can be used for organic dyes, medicines, biogas and the like. Originating in the Caribbean islands, jatropha has spread as a valuable hedge plant to Africa, Asia and India. It grows in a variety of agro-climatic conditions. Thus it ensures a reasonable production of Seeds with little inputs.

Intercropping

Intercropping of jatropha with lemon grass, turmeric, ashwagandha and the like has been found to be an economically viable option when compared with monocropping. Since jatropha is not suitable for forage, fence farming is also an attractive option. Plantation of saplings from the seeds rather than vegetative propagation is a better option for the dry areas. The plantation of saplings (4 months old) should be carried out before the rains. As the growth and canopy coverage are more in fertile soil, the plants occupy more area when compared with dry land cultivation.

While the plantation pitch for jatropha could be 1.5 x 1.5m in lighter/dry lands, a spacing of 2.0 x 2.0m would be required in fertile soil resulting In 2,500 plants/hectare. For intercropping, a spacing of 3m should be maintained between the rows for inter-cultivation and ploughing

Status of Jatropha Curcas for Biodiesel Production

required for vegetables and flowers. For better growth, the plants require irrigation for the first two years. The plants require pruning after they grow over 1.0 m in height.

Effective yield

The jatropha plant bears fruits from the 2nd year after its plantation and the economic yield stabilises from the 4th or 5th year onwards. The plant may live for more than 50 years with an average effective yielding time of 50 years. The economic yield can be considered as 0.75-2.00kg/plant and 4.00-6.00 tonnes per hectare per year depending on the agro-climatic zone and agricultural practices. The cost of plantation has been estimated as Rs.20,000 a hectare, inclusive of plant material, maintenance for one year, training, overheads and the like. A selling price of jatropha seeds at Rs.12 a kg would be an economically attractive proposition for farmers. Oil from jatropha seeds (oil content: 35 per cent on average) can be extracted by using a screw press for further processing into biodiesel by the transesterification route. Transesterification is the process of converting the raw vegetable oil into biodiesel. The process involves displacement of alcohol from an ester by another alcohol (methanol is used commonly).

Return on Investment

For an optimal capacity of 10,000 TPA of biodiesel, the capital cost for oil extraction and transesterification would be Rs.20,000/tonne capacity.

Status of Jatropha Curcas for Biodiesel Production

The return on investment (ROI) has been arrived at 15 per cent pre tax on the capital cost. The efficient storage of biodiesel resources can provide energy security to the country. Biodiesel can safely be stored for up to 6 months. The existing storage facilities and infrastructure for petrol and diesel can be used for the biodiesel with minor alterations

12 million jobs

India has vast stretches of degraded land, mostly in areas with adverse agro-climatic conditions, where species of jatropha can be grown easily. Considering 10 million plantation on both sides along the railway tracks, 1,26,000 hectares can be cultivated with jatropha. Use of 11 million hectares of wasteland for jatropha cultivation can lead to generation of a minimum of 12 million jobs. Production of bio-fuel from plant materials is a major step toward harnessing one of the world's most-prevalent, yet least-utilised renewable energy resources. India, with its huge waste/non-fertile lands, has taken a well-noted lead in jatropha cultivation and commercial production is what the industries have to focus on for sustainable development.

II. Status of *Jatropha Curcas* for Biodiesel Production

Energy challenge for the developing countries like India is daunting today. Oil prices have remained above US \$60 per barrel for some time now. Oil and gas imports cost the country is more than Rs 150,000 crore (Rs 1,500 billion) annually. India imports about 73 % of total consumption of 124 million tonnes (MT) of crude and petroleum products. Given that our consumption of energy will only increase and that India has only about 700 million tonnes of economic reserves of crude left (enough oil for 22 years of production at the current level and six years of current consumption



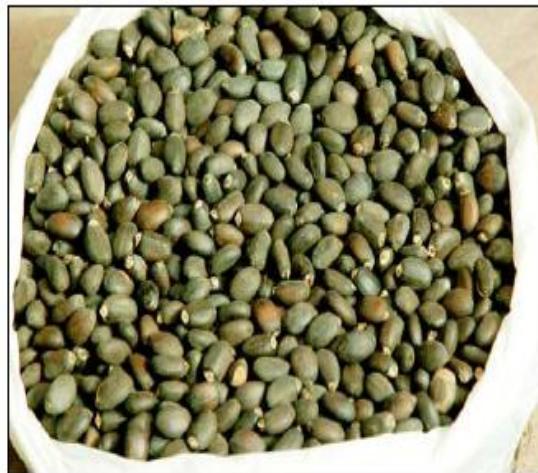
Diesel Oil provides energy for 95% of transport and the demand of transport fuel continues to rise. As per Planning Commission estimates, the requirement of petrol is expected to grow from approximately 7

Status of Jatropha Curcas for Biodiesel Production

million tonnes in 2001-2012 to more than 10 million tonnes in 2006-07 and 12.5 million tonnes in 2011-2012. Similarly, the demand for diesel is likely to touch the level of about 52 million tonnes in 2006-07 and 66 million tonnes in 2011-2012. Contrary to the demand situation, the domestic supply is in position to cater to only about 22% of the total demand.



Fruiting Plant



Seed

Therefore, attempt needs to be made to reduce dependence on imports and seek better alternatives. Biofuels are the best alternatives and the country has a ray of hope for the same. Biofuels are renewable and coming from biological raw material. Biofuels –ethanol and Biodiesel both are gaining worldwide acceptance as a solution to energy crises.

High Speed Diesel (HSD) is the main transport fuel in India, hence introduction of biodiesel both as a diesel substitute and for blending with petroleum diesel is an imperative need. Mainly, biodiesel is being produced by the crops like sunflower, Soybean and mustard oil etc. in

Status of *Jatropha Curcas* for Biodiesel Production

many parts of the world. As the nation is facing a shortage of edible oils, it would not be feasible to produce Biodiesel by edible oils.

However, the country has enormous potential to produce tree borne oilseeds for Biodiesel production to cope with the demand of about 40% diesel requirement from total crude oil. *Jatropha* among the potential tree borne oilseeds is one of the alternatives. The country has a vast area of wasteland spread over Approximately 40.00 million hectares of land spread out in 23 states and Union Territories, which have been identified as potential areas for *Jatropha curcas* plantation. According to climatic conditions and potentiality for plantations, 23 states have been selected covering about 40 million hectares for *Jatropha* plantation.

Why Bio-diesel?

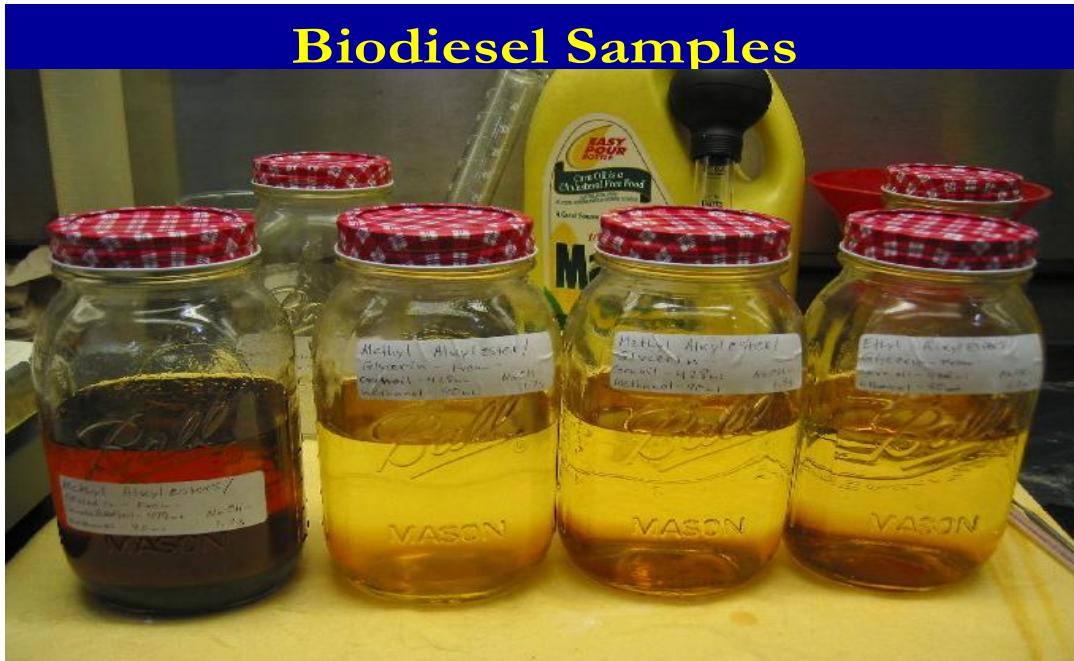
Bio-diesel is the name of a clean burning alternative fuel, produced from domestic, renewable resources. Bio-diesel contains no petroleum, but it can be blended at any level with petroleum diesel to create a Bio-diesel blend. It can be used in compression-ignition (diesel) engines with little or no modifications. Bio-diesel is simple to use, biodegradable, nontoxic, and essentially free of sulfur and aromatics. Many alternative Bio-diesel fuels have been shown to have better exhaust emissions than traditional Diesel fuel. *Jatropha* Bio-diesel holds promise as fuel alternatives for diesel engine. It reduces of the usage of Primary Fuels. Biodiesel is an alternative to petroleum-based diesel fuel made from renewable resources such as vegetable oils or animal fats. Chemically, it comprises

Status of Jatropha Curcas for Biodiesel Production

a mix of mono-alkyl esters of long chain fatty acids. A lipid transesterification production process is used to convert the base oil to the desired esters and remove free fatty acids. After this processing, unlike straight vegetable oil, biodiesel has combustion properties very similar to those of petroleum diesel, and can replace it in most current uses. However, it is at present most often used as an additive to petroleum diesel, improving the otherwise low lubricity of pure ultra low sulfur petrodiesel fuel. It is one of the possible candidates to replace fossil fuels as the world's primary transport energy source, because it is a renewable fuel that can replace petrodiesel in current engines and can be transported and sold using today's infrastructure. Biodiesel use and production is increasing rapidly, especially in Europe, the United States, and Asia, though in all markets it still makes up a small percentage of fuel sold. A growing number of fuel stations are making biodiesel available to consumers, and a growing number of large transport fleets use some proportion of biodiesel in their fuel. Biodiesel, with a flash point of 150 °C, is not as readily ignited as petroleum diesel (64 °C) and far less so than the explosively combustible gasoline (-45 °C). Indeed, it is classified as a non-flammable liquid by the OSHA, although it will of course burn if heated to a high enough temperature. This property makes a vehicle fueled by pure biodiesel far safer in an accident. Biodiesel gels at higher temperatures (around 0 °C) than petroleum diesel, which limits its use in pure form in cold climates. Unlike petrodiesel, biodiesel is biodegradable and non-toxic, and it significantly reduces toxic and other emissions when burned as a fuel. The most common form uses methanol

Status of Jatropha Curcas for Biodiesel Production

to produce methyl esters, though ethanol can be used to produce an ethyl ester biodiesel. A byproduct of the transesterification process is the production of glycerol.



Bio-diesel are produced with an agricultural orientation. Numerous researches have shown that Jatropha Bio-diesel has fuel properties and provides engine performance that is very similar to diesel fuel. Bio-diesel are non toxic, bio degradable and renewable fuel. The severe emission regulations in the world have placed design limitations on heavy duty diesel engines. The trend towards cleaner burning fuel is growing worldwide and it is possible through Jatropha Bio-diesel.

Status of Jatropha Curcas for Biodiesel Production

Bio-diesel includes a high cetane number, low sulphur , low volatility and the presence of Oxygen atoms in the fuel molecule. Expected engine efficiency of is achieved through Bio-diesel. It performs better than the Petroleum diesel. Jatropha Bio-diesel readily mixes with diesel fuel and it runs in any diesel engine without modification and reduces serious air pollutants such as particulates, carbon monoxides, hydrocarbons and air toxic. Mutagencity studies shows that bio diesel dramatically reduces potential risks of cancer and birth defects.

Kinds of Wasteland

The *Jatropha* crops have been recommended for cultivation in the wasteland so that the cultivated lands may not be diverted for *Jatropha* crop. *Jatropha* being the drought tolerant and hardy crop, it can be grown under various kinds of wasteland, however, being the oil yielding plant, it also needs the fertile soil for its cultivation and regular bearing of fruits with desired oil content. Though, the plant can survive in the stress condition, however, it will not give economical yield. The initial findings reveals that the soil should have at least 1.5 to 2 ft. depth and the minimum annual rainfall should be 600 mm.

Though, the various kind of wasteland are available in the country, however, some wastelands such as gullied and ravenous, up-land with or without scrub, degraded land under plantation, pastures, grazing, mining industrial wasteland, hill slopes, fallow land, railway tracks, canal, field boundary and community land etc. are found suitable for *Jatropha*

Status of *Jatropha Curcas* for Biodiesel Production

info@biodieseltechnologiesindia.com



State-wise distribution of Wasteland suitable for

Status of *Jatropha Curcas* for Biodiesel Production

Jatropha Cultivation

Sr. No.	States	Potential Area for <i>Jatropha</i> cultivation (Lakh ha.)
1.	Andhra Pradesh	43.96
2.	Arunachal Pradesh	9.97
3.	Assam	14.56
4.	Bihar/Jharkhand	18.60
5.	Goa	0.40
6.	Gujarat	28.71
7.	Haryana	2.62
8.	Karnataka	17.89
9.	Kerala	1.00
10.	Madhya Pradesh/Chhattisgarh	66.20
11.	Maharashtra	48.55
12.	Manipur	12.62
13.	Meghalaya	9.37
14.	Mizoram	4.07
15.	Nagaland	8.40
16.	Orissa	18.88
17.	Punjab	1.06
18.	Rajasthan	56.88
19.	Sikkim	2.13
20.	Tamil Nadu	17.95
21.	Tripura	1.28
22.	Uttar Pradesh/Uttranchal	12.14
23.	West Bengal	2.58
Grand Total		400.37

Status of Jatropha Curcas for Biodiesel Production

Merits of biodiesel production

The Tree Borne Oilseeds namely *Jatropha (Jatropha curcas)*, *Karanja (Pongamia pinnata)*, *Jojoba (Simmondsia chinensis)*, *Neem (Azadirachta indica)* etc. have potential to grow in categorized wasteland. These TBOs posses 20-60% oil content in seeds, which are non-edible and can be utilized as source of Biodiesel production. *Jatropha* is one of the best alternative of energy plantation due to its following characteristics:

- It can be grown in areas of low rainfall (600 mm per year) and in problematic soils. In high rainfall and irrigated areas too it can be grown with much higher yields.
- *Jatropha* is easy to establish, grows relatively quickly and is hardy.
- *Jatropha* lends itself to plantation with advantage on lands developed on watershed basis and on low fertility marginal, degraded, fallow, waste and other lands such as along the canals, roads, railway tracks, on borders of farmers' fields as a boundary fence or live hedge in the arid/semi-arid areas and even on alkaline soils. As such it can be used to reclaim waste lands in the forests and outside.
- *Jatropha* is not browsed by animals.
- Being rich in nitrogen, the seed cake is an excellent source of organic manure.
- One hectare of *Jatropha* plantation will produce 3 to 4 MT seed.

Status of *Jatropha Curcas* for Biodiesel Production

- Gestation period is two years
- Various parts of the plant have medicinal value, its bark contains tannin, the flowers attract bees and thus the plant has honey production potential.
- Like all trees, *Jatropha* removes carbon from the atmosphere, stores it in the woody tissues and assists in the build up of soil carbon. It is thus environment friendly.
- *Jatropha* can be established from seed, seedlings and vegetatively from cuttings. Use of branch cutting for propagation is easy and results in rapid growth;
- The bush can be expected to start bearing fruit within two years and in some cases after one year of planting.
- The plant is undemanding in soil type and does not require tillage.
- It can meet a number of objectives such as meeting domestic needs of energy services including cooking and lighting; as an additional source of household income and employment through markets for fuel, fertilizer, animal feed, medicine, and industrial raw material for soap, cosmetics, etc. in creating environmental benefits – protection of crops or pasture lands, or as a hedge for erosion control, or as a windbreak and a source of organic manure.

Although ability to control land degradation and oil production are the most important environmental uses of *Jatropha*, its products provide

Status of Jatropha Curcas for Biodiesel Production

numerous other benefits that would additionally improve the living conditions of the rural people and offer greater income opportunities through enhanced rural employment. For instance, the *Jatropha* oil can be used for soap production and cosmetics production in rural areas and all parts of the plant have traditional medicinal uses (both human and veterinary purposes) that are being scientifically investigated.

The oil is a strong purgative, widely used as an antiseptic for cough, skin diseases, and as a pain reliever from rheumatism. *Jatropha* latex can heal wounds and also has anti-microbial properties. *Jatropha* oil has been used commercially as a raw

material for soap manufacture for decades, both by large and small industrial producers. The oil cake cannot be directly used as animal feed because of the presence of toxic compounds, but it is valuable as organic manure having nitrogen content comparable to chicken manure and castor seed cake. *Jatropha* oil cake is rich in nitrogen (3.2%), phosphorous (1.4%) and potassium (1.2%).

Jatropha Oil as an Alternative to Diesel

In the present scenario, the appropriate answer to the current oil crisis is to explore the possibility of substitution of diesel with an alternative fuel, which can be produced on a massive scale for commercial utilization. The non-edible oil of *Jatropha* has requisite potential of

Status of Jatropha Curcas for Biodiesel Production

providing a promising and commercially viable alternative to diesel as it has the desired physio-chemical and performance characteristic comparable to petro-diesel. *Jatropha* oil has higher cetone number (51) compared to other oils, which is comparable to diesel (46 to 50) and makes it an ideal alternative fuel and requires no modification in the engine. The initial flash point of *Jatropha* oil is 1000C as compared to 500C in case of diesel. In view of higher flashpoint, it has advantage over petrodiesel such as more safety during storage, handling and transport. However, higher flash point may create initial starting problem in the engine. Similarly, higher viscosity of *Jatropha* oil could pose the problem of smooth flow of oil in fuel supply pipe and nozzle. These problems/difficulties can easily be overcome by esterification of *Jatropha* oil, which is a very effective way of overcoming high viscosity and smoke emissions of vegetable oil by forming their ethyl/methyl esters.

Status of Jatropha cultivation

The country has enormous potential of oilseeds of tree origin like oil palm, 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. Most of these TBOs are scattered in forest and non-forest areas and

Status of *Jatropha Curcas* for Biodiesel Production

hardly 20% of the existing potential is being crushed and utilized that too of poor quality due to lack of awareness of their uses, collection and marketing etc.

Among the various Tree Borne Oilseeds, *Jatropha curcas* has been found more suitable for biodiesel production on the basis of various characters. The cultivation of *Jatropha* is possible under stress condition and the oil of these species having various characters is more suitable for biodiesel production. To explore the potential of Tree Borne Oilseeds species including *Jatropha curcas*. Board has initiated a Central Sector Scheme with following objectives:

Objectives

The Board has been entrusted with the nodal responsibility for integrated development of tree borne oilseeds with focus on generation of rural employment through exploitation of existing potential and augmenting the future potential. The brief objectives of the scheme for the implementation during 10th plan are given below :

- ◆ Improve the quality of seeds of TBO collected by unemployed women and tribal by augmenting handling through creation of appropriate infrastructure.
- ◆ Promote the plantation of potential TBOs in wasteland through augmentation of superior planting material, production technologies and handling system.

Status of Jatropha Curcas for Biodiesel Production

- ◆ Develop and refine the technologies for improved productivity, quality, value addition etc by assisting capable institutions to take such programmes.
- ◆ Create awareness through training, seminar, workshop, publication and publicity etc. among farmers and primary processing industries for improved agronomic practices and new technologies.
- ◆ Generate income and employment opportunities for small and marginal farmers and other weaker sections of society, particularly those living below poverty line and women folk etc. To achieve the above objectives, the Central Sector Scheme ‘Integrated Development of Tree Borne Oilseeds’ includes following programmes:-

Programmes

- Research and development programmes
- Establishment of TBOs gardens
- Back-ended credit linked subsidy programme
- Back-ended direct subsidy programme
- Model plantation with superior planting material
- Creation of pre-processing and processing facilities
- Establishment of seed procurement and oil expelling centre
- Development of pilot trans-esterification unit
- Transfer of technology

R&D Programmes

Status of *Jatropha Curcas* for Biodiesel Production

It has been observed that the productivity of *Jatropha curcas* is not much economically beneficial to the farmers due to lesser productivity and non-availability of package of practices. It becomes necessary to make countrywide efforts to enhance the productivity and development of location specific package of practices. To address the various researchable issues, a National network on *Jatropha* has been initiated by the Board during 2003-04 with following major objectives:-

- ❖ Selection of superior planting material
- ❖ Standardization of propagation techniques – Micro and Macro propagation
- ❖ Standardizing agro-techniques
- ❖ Establishment of model plantations
- ❖ Tree improvement
- ❖ Detoxification of seed meal
- ❖ Development of pre-processing and processing equipments
- ❖ Imparting training to the farmers

The above researchable issues were identified by a team of Scientists from various institutions like ICAR, CSIR, ICFRE, State Agricultural Universities, Ministry of Agriculture, NOVOD Board, IIT etc. The project was launched during 2004-05 in 35 institutions covering 23 states of the country. The consolidated summary of research findings are as hereunder:-

Status of *Jatropha Curcas* for Biodiesel Production

Sl. No.	Name of Research Institute	No. of CPTs/Seed source identified (2004-05)	No. of CPTs/Seed source identified (2005-06)
1.	CSFER, Allahabad	7	22
2.	MPKV, Rahuri	23	53
3.	UAS, Dharwad*	-	64
4.	ICAR,R.C.NEH, Nagaland	-	11
5.	ICAR,R.C.NEH, Tripura	-	8
6.	SFRI, Jabalpur	382	50
7.	TFRI, Jabalpur	150	25
8.	PDKV, Akola	22	29
9.	SDAU, S.K. Nagar, Gujarat	21	50
10.	NRCAF, Jhansi	77	88
11.	PAU, Ludhiana	40	40
12.	MPUAandT, Udaipur	-	50
13.	CSAUAAandT, Kanpur	9	9
14.	CCS, HAU, Bawal	24	50
15.	CSK, H.P.K.V, Palampur (2005)	-	54
16.	BCKV, Nadia, W.B.(2005)	-	25
17.	GBPUAandT, Pantnagar	24	64
18.	SKUAandT, Jammu	23	34
19.	CRIDA, Hyderabad	57	55
20.	IGKV, Raipur	31	40
21.	FCRI, TNAU, Mettupalayam	22	-
	Total	912	821

Development of elite planting material and model plantation

Status of Jatropha Curcas for Biodiesel Production

The *Jatropha curcas* are available in almost all the states but in scattered manner that too with traditional plantation with low productivity and less

Sl.No.	Name of State	<i>Jatropha</i> plantation (ha.)
1.	A.P.	260
2.	Bihar	110
3.	Chhattisgarh	650
4.	Delhi	665
5.	Gujarat	1140
6.	Goa	10
7.	Haryana	520
8.	Jharkhand	200
9.	Karnataka	120
10.	Kerala	50
11.	Manipur	200
12.	Mizoram	300
13.	Meghalaya	200
14.	Maharashtra	1310
15.	M.P.	845
16.	Nagaland	240
17.	Rajasthan	715
18.	Tamilnadu	960
19.	U.P.	633
20.	Uttranchal	650
21.	West Bengal	100
	Total	9878

oil content in the seed. The countrywide efforts have been made and Superior trees having more yield and high oil content have been identified in the country. The seed material of such plants have been

Status of *Jatropha Curcas* for Biodiesel Production

collected and are being provided to various Agricultural Universities and institutions for developing model plantation. Such plantation has been undertaken in more than 10,000 ha in 21 states. The efforts for creating model plantation is being made to meet the requirement of quality planting material for undertaking large scale *Jatropha* plantation in the country. These model plantations have been undertaken by using elite planting material during 2004-05 and 2005- 06 in the Central and State Agricultural Universities, ICAR, CSIR, ICFRE institutions and State Govt Seeds Farms. These model plantation in 10,000 ha. In 21 states will be sufficient to provide quality planting material for plantation in 25 lakh ha. Area. The planting material will be made available from 2006-07. The state-wise summary of model plantation undertaken by NOVOD Board may be perused as hereunder:-

Establishment of TBOs gardens

The programme has been initiated to create the awareness about Tree Borne Oilseeds, its potential and uses in the urban, sub-urban and metropolitan cities. Minimum three Tree Borne Oilseeds like Neem, *Jatropha*, Karanja, Mahua, Jojoba, Wild apricot, Cheura, Kokum etc. depending upon the climatic condition are to be planted in 2 ha to 40 ha. Block.

Status of Jatropha Curcas for Biodiesel Production



TBOs garden have been established in 11 states covering 126 ha. Area as detailed hereunder:-

Sr. No.	Name of State	Implementing Agencies	Target (in ha.)
1	Chhattisgarh	Chhattisgarh Council of Sci. and Tech., Raipur	3
		Department of Agriculture, Raipur	4
2	Haryana	CCS Haryana Agri.Univ., Hisar	10
3	Jharkhand	Chief Conservator of Forest, Ranchi	2
4.	JandK	SK Univ. of Agri. Sci. and Tech. Srinagar	5
5.	Karnataka	Univ. of Agril. Sciences, Bangalore	10
		State Department of Horticulture, Bangalore	13
		UAS, Dhardwad	12
		UAS, Raichur	2

Status of Jatropha Curcas for Biodiesel Production

6.	M.P.	M.P. Council of Science and Technology, Bhopal	3
		Jawahar Lal Nehru Krishi Vishwavidhalaya, Jabalpur	9
		Department of Horticulture, Bhopal	20
7.	Mizoram	Department of Horticulture, Aizawl	4
8.	Meghalaya	SDA, Meghalaya, Shillong	9
9.	Maharashtra	Social Forestry, Solapur	5
		State Deptt. of Agriculture	8
10.	Nagaland	Department of Agriculture, Kohima	2
11.	Uttranchal	G.B.Pant University, Pantnagar	5
	Total		126

BACK-ENDED SUBSIDY PROGRAMME

Credit-linked subsidy programme

The programme is being implemented in partnership mode with entrepreneur and farmers by providing 30% back ended credit linked subsidy which would be linked with credit 50% from financial institutions and 20% beneficiary share to be formation in the form of land, labour, irrigation facilities etc.

Status of *Jatropha Curcas* for Biodiesel Production

Back-ended direct subsidy programme

Under this programme, 30% subsidy will also be provided directly to the beneficiary, who are willing to use 50% funds from their own resources.

Transfer of technology

To generate mass awareness about the utility of Tree Borne Oilseeds in various industries as well as for Biodiesel production in the country, the programmes like farmers training, trainers training, seminar/workshop etc. are being organized under Transfer of Technology programme.

Establishment of seed procurement and oil expelling centre

In order to increase the procurement of quality seeds of various TBOs, it is important to create infrastructure facilities for handling and storage of TBOs, which will be equipped with pre-processing facilities like seed driers, depulper, decorticator, cleaner, grader, digital moisture meter, digital weighing machine, seed storage, drying floor godown, expellers etc. Besides, it will maintain the quality of collected seeds by avoiding deterioration of seeds due to prolonged storage at unequipped centres and to provide remunerative prices to seed collectors. The procurement centre are being established with five sub-centres in surrounding areas.

Procurement/Purchase Policy

The Minimum Support Price(MSP) for *Jatropha* seed is under process with the Ministry of Agriculture. However, the Minimum Procurement Price of biodiesel has been declared by Ministry of Petroleum and Natural Gas. The price of biodiesel Rs. 25/- per litre w.e.f. 1.1.2006 is in

Status of *Jatropha Curcas* for Biodiesel Production

operation. To procure the biodiesel, Ministry of Petroleum has identified 20 centres in 12 states as hereunder:-

Sr.No.	States	Location
1.	A.P.	Ghatkesar (HPC)
2.	Chhattisgarh	Mandirhasaud (HPC)
3.	Delhi	Bijwasan (IOC)

4.	Gujarat	Kandla (BPC)
5.	Haryana	Rewari (IOC)
6.	Karnataka	Devanagunthi (Bangalore) Mangalore (IOC)
7.	M.P.	Indore
8.	Maharashtra	Manmad (BPC), Nagpur (BPC), Loni (HPC), Vashi (HPC)
9.	Punjab	Bhatinda (IOC)
10.	Rajasthan	Jaipur (BPC), Salawas (HPC)
11.	T.N.	Chennari (IOC), Narimanam (IBP), Karur (BPC)
12.	U.P.	Panki (IOC), Lucknow (IBP)

Estimated plantation of *Jatropha*

The efforts being made by Central Govt/Ministries and various State Governments for undertaking plantation of *Jatropha* in the country. It is expected that 31.17 lakh hectare plantation would be completed by the end of 2008-09. The state-wise estimated plantation during three years may be as hereunder:

Status of *Jatropha Curcas* for Biodiesel Production

Sr. No.	Name of State	Plantation upto 2005-06 (in ha.)	Plantation upto 2006-07 (in ha.)	Plantation upto 2008-09 (in ha.)
1.	A.P.	17500	35000	200000
2.	Chhattisgarh	47000	80000	500000
3.	Gujarat	8000	50000	400000
4.	Karnataka	2000	10000	50000
5.	M.P.	1700	50000	100000
6.	Maharashtra	5000	25000	500000
7.	Mizoram	2000	25000	100000
8.	T.N.	5000	25000	500000
9.	Uttranchal	9220	50000	200000
10.	M.O.E. & Forest	-	40000	160000
11.	Railways	3000	25000	47000
12.	Other ministries	10000	50000	200000
	Total	127420	560000	3117000

Conclusion

- ❖ 5.60 lakh ha. Area will produce 6.00 lakh larma of Biodiesel, which will be sufficient to replace more than 1% of diesel requirement of entire country or it can replace 5% of selected states during initial stage from next year onwards.
- ❖ 31.17 lakh ha. Area will be covered by 2008-09, which will replace 5% diesel requirement for entire country or 10% of selected states.

There is a growing interest in *Jatropha curcas* as a biodiesel “miracle tree” to help alleviate the energy crisis and generate income in rural

Status of Jatropha Curcas for Biodiesel Production

areas of developing countries. Jatropha is becoming a poster child among some proponents of renewable energy and appropriate technology, especially as an oil-bearing, “drought resistant” tree for marginal lands for small farmers.



Forgotten perhaps is that a great share of the farmers in developing countries only have access through some form of limited tenure to a very small plot of land needed to grow food crops. Not to be forgotten, marginal yields are obtained from plants grown on marginal lands. To be economical as a biodiesel fuel, Jatropha must be produced in volume, and those who stand to profit the most are the processors, retailers and the “middle- men;” the latter have a history of exploiting vulnerable

Status of *Jatropha Curcas* for Biodiesel Production

small producers by paying only a fraction of the actual value of their product.

There may seem to be a great amount of marginal land in developing countries that is not being used and where *Jatropha* could be grown; however, most often these lands are for communal use to graze/browse livestock. *Jatropha* is toxic to livestock, weedy, and not a good species to use in agroforestry systems except as living fences to protect food crops from livestock; and *Jatropha* wood is of little value for fuelwood and charcoal. Closely spaced, *Jatropha* would eliminate grasses and shrubs on which livestock feed; livestock that are especially important for women and children, for they are either eaten or sold to purchase nutritious food to supplement their meager diets. Also without some form of tenure recognized by the community, it is almost impossible for individual farmers to plant, protect and manage trees on these lands and benefit from their labor – thus these lands remain “the tragedy of the commons.” **Haiti is a classic example of this conundrum, where these lands are under the jurisdiction of the Tax Bureau.**

There is a growing interest in *Jatropha curcas* as a biodiesel “miracle tree” to help alleviate the energy crisis and generate income in rural areas of developing countries. *Jatropha* is becoming a poster child among some proponents of renewable energy and appropriate technology, especially as an oil-bearing, “drought resistant” tree for marginal lands for small farmers. Forgotten perhaps is that a great share of the farmers in developing countries only

Status of *Jatropha Curcas* for Biodiesel Production

have access through some form of tenure to a very limited area of land needed to grow food crops. Not to be forgotten, marginal yields are obtained from plants and trees when grown on marginal lands. In the quest for a magical silver bullet, yet another “miracle tree”, people working on developing country issues often forget that trees are no different than any other agricultural crop, and obtaining optimal yields is dependent upon a variety of things including: a) the use of improved germplasm, selected for optimal yield of nuts with an optimal amount of oil, and b) matching this germplasm to sites with fertile soils and adequate moisture that will allow it to express its genetic potential to produce optimal yields. Most often, marginal lands lack either adequate nutrients or moisture or both; that’s why they are marginal, and as the old saying goes, “There is no free lunch.” Trees, as do other plants, mine nutrients from the soil, and for optimal and sustained production, these nutrients must be replenished.

Although *Jatropha* may look promising as a tree/shrub for marginal lands, without added nutrients, moisture and improved germplasm, marginal yields can be expected. Well intended development efforts often fail when project subsidies are no longer there and funding runs out. The successful processing of oil nuts and the use of these oils in India is often used as an example to justify the development of oil nut projects in other countries. Often forgotten is that these enterprises are based on the processing of an adequate year-around supply of a variety of oil nuts that allows entrepreneurs to amortize the relative expensive

Status of *Jatropha Curcas* for Biodiesel Production

machinery over a period of time, pay their help, and to make a decent profit. Also in India, an established traditional market for these oils already exists. Projects based on a single source of oil, such as that from Jatropha, which produces an unsure yield of nuts only during a short period of time (once or twice a year) and may not produce optimal yields for several years, may prove to be problematic and unsustainable. To optimize oil extraction from Jatropha seeds and to produce a quality of oil that will maximize profits (e.g., a diesel oil substitute) requires: equipment, some quite expensive; chemicals, such as methanol and caustic soda, that are highly flammable, toxic and dangerous to use and are somewhat costly and not readily available; and infrastructure and trained personnel that must be in place in a timely manner. Nevertheless, it is a forgone conclusion the use of refined Jatropha oil as a substitute for diesel fuel and for soap production may have the potential to improve the livelihood of the people in rural areas by providing additional income; but only if the right conditions exist.

The jury is still out on the economics of Jatropha oil as a substitute for diesel; however, if one is to look at its potential for alleviating rural poverty, one must examine the potential of Jatropha in its entirety as part of a system. **Nevertheless, the IPGRI report quotes the comments of one astute observer, Jatropha “oil is competitive with imported diesel, especially in remote areas where fuel is often not available.”** Perhaps we may learn from Lewis Carroll who wrote in his classic *Through the Looking Glass* (Alice in Wonderland): “Cheshire –

Status of *Jatropha Curcas* for Biodiesel Production

Puss,” she began rather timidly “...would you tell me please, which way I ought to go from here?” “That depends a good deal on where you want to get to.” Said the cat.

Note: Some of the biggest advocates for Jatropha are those who are selling seeds (of unknown genetic potential), who stand to make the profits in the near term. Often, in many calculations of projected profitability, one or more of the costs of establishment, harvesting, transport, processing and marketability may not be included, while the over-valued speculation of selling carbon credits is; therefore, a somewhat distorted view of bottom-line economics is presented.

Some common names

Common names include: Jatropha, physic nut, Barbados nut, purging nut, pig nut, fig nut, and it is sometimes referred to as the biodiesel or diesel tree (not to be confused with *Copaifera langsdorfii* Desf., which grows only in moist tropical forests).

Description

Jatropha curcas L belongs to the euphorbia family and is a drought-resistant bush or small tree with spreading branches and stubby twigs that grows to 20 feet high under favorable conditions. When propagated from seed five roots are formed – one tap root and 4 lateral roots. Plants propagated from cuttings normally develop only lateral roots with one perhaps developing into a pseudo-tap root that may reach only $\frac{1}{2}$ to $\frac{2}{3}$

Status of Jatropha Curcas for Biodiesel Production

the length of a normal tap root. Jatropha has both male and female plants, which may produce different yields of nuts. Dormancy is induced by fluctuations in rainfall and temperature/light; nevertheless, not all trees respond simultaneously. In a hedge you may have branches without leaves beside ones full of green leaves. The life-span of Jatropha may be more than 50 years; however, termites are reported to attack older trees.

Toxicity

The leaves and nuts of Jatropha are toxic (containing Phorbol esters and curcin, a highly toxic protein similar to ricin in Castor), and although purgative, the nuts are sometimes roasted and dangerously eaten. However, a non-toxic variety is reported to exist in Mexico and Central America that is used for human consumption after roasting, and does not contain Phorbol esters; but, the curcin content was not mentioned. (Also see section on ***Constraints and Limitations.***)

Distribution

Jatropha is thought to be native to Central America and Mexico where it occurs naturally in the forests of coastal regions, since it is not found in these forms of vegetation in Africa and Asia, where it is found only in the cultivated form. However, Jatropha is almost pantropical now, and although toxic, it is widely planted as a medicinal plant. A non-toxic variety is reported to exist in Mexico and Central America. A species said to be endemic to Madagascar (Madagascars), *J. mahafalensis*, is reported to have equal energetic promise. In many parts of Africa and

Status of Jatropha Curcas for Biodiesel Production

elsewhere, Jatropha is widely planted as a hedge or living fence to protect field crops since the foliage is toxic to animals. **It is listed as a weed in Australia, India, Brazil, Fiji, Honduras, Panama, El Salvador, Jamaica, Puerto Rico, and other parts of the Caribbean.**

Ecology

Jatropha sheds its leaves during the dry season. The current distribution shows that introduction has been most successful in drier regions of the tropics with an average annual rainfall between 300 and 1000mm, **and occurs mainly at lower altitudes (0-500m)**. It is not sensitive to day length. It grows best on well-drained soils with good aeration but is well adapted to marginal soils with low nutrient content; although in heavy soils, root formation is reduced.

Ranging from Tropical Very Dry to Moist through Subtropical Thorn to Wet Forest Life Zones, Jatropha grows well with more than 600 mm of rainfall per year, and it withstands long drought periods. With less than 600 mm it cannot grow except in special conditions like on Cape Verde Islands, where the rainfall is only 250 mm, but the humidity of the air is very high (rain harvesting). Jatropha can withstand only a very light frost that causes it to lose all of its leaves, and the seed yield will probably sharply decline.

Propagation and Cultivation

Jatropha grows readily from seeds or cuttings; however, trees propagated by cuttings show a lower longevity and possess a lower drought and

Status of Jatropha Curcas for Biodiesel Production

disease resistance than those propagated by seeds. Trees produced from cuttings do not produce true taproots (hence less drought tolerant), rather they produce pseudo-taproots that may penetrate only $\frac{1}{2}$ to 2/3rds the depth of the soil as taproots produced on trees grown seed. Clonal propagation by cuttings or other methods from trees that are known to produce high yields of seeds is the fastest way to develop high yielding varieties; however, this results in cytoplasmic uniformity, making high-density Jatropha plantings more susceptible to insect and disease infestation. Spacing between plants influence yields, and those with wider spacing have the highest seed yields (e.g.; 3m X 3m), likely a result of reduced competition for moisture and nutrients. (IPGRI) Plants inoculated with mycorrhizae will likely survive stressful conditions and give higher yields since this fungi increases drought tolerance of plants by facilitating the transport of moisture to and within the root system. The uptake of other nutrients essential for plant growth is also facilitated by mycorrhizae, and it has the ability to convert unavailable forms of phosphorus to forms available for plant uptake.

Vegetative propagation:

Cuttings strike root so easily that Jatropha can be used to quickly establish living fences or hedges. Thicker (3 cm) and longer (30cm) cuttings develop more roots and have a higher survival rate. Treating cuttings with IBA (indole-butyric acid) hormone did not promote root formation. Rooting of stem cuttings is influenced more by: the age of the plant from which cuttings are taken; the position of the cutting within

Status of Jatropha Curcas for Biodiesel Production

the plant; and good rooting media, aeration and drainage. Hedges planted by cuttings develop more extensive lateral root systems, and compete for moisture and nutrients if they border other crops. Jatropha would not be a good agroforestry species. With good rainfall conditions, nursery produced plants (not clear if these were from cuttings or seed, ed.) are said to bear fruit after the first rainy season, with directly seeded plants bearing fruits for the first time after the second rainy season. With vegetative propagation, the first seed yield is higher than from plants established by direct seeding. Differences in seed fruit yields from plants produced from the different methods of propagation will probably disappear after a few years; however, when stressed from low rainfall, the direct-seeded plants will more than likely produce higher yields since more developed taproots allow plants to access moisture at lower depths. **According to the IPGRI report, plants propagated by cuttings show a lower longevity and possess a lower drought and disease resistance than plants propagated by seed.**

Direct seeding :

Direct seeding gives mixed results on survival, which is heavily influenced by the timing, amount of rainfall and the depth of planting. Jatropha planted by direct seeding are said to live longer than if planted by cuttings and this method is recommended for plantation establishment.

Status of *Jatropha Curcas* for Biodiesel Production

Harvesting

For medicinal purposes, the seeds are harvested as needed. The active medicinal compounds might be extracted from the seed, before or after the oil, leaving the oil cake for biomass or manure. According to the IPGRI report, the best pickers in Nicaragua harvest up to 30kg of fruits (18kg of seeds) per hour. Freitas (cited by IPGRI) reported two harvest times, corresponding to the flowering times.

Observations by other authors showed that the main harvest occurs several months after the end of the rainy season, since flowering is connected to vegetative development. For energy purposes, seeds should be harvested all at once so that processing can be more efficient and profitable.

III. OVERVIEW OF POTENTIAL PRODUCTS AND USES

In India, pounded leaves are applied near horses' eyes to repel flies. Nuts can be strung on grass and burned like candlenuts. The oil has been used for illumination, making candles and soap, adulterating olive oil, and making Turkey red oil. Mexicans grow the shrub as a host for the lac insect that secretes resin used as a dye and to make shellac. Ashes of the burned root are sometimes used as a salt substitute. *Jatropha* has been found to have strong molluscicidal activity and the latex to be strongly inhibitory to watermelon mosaic virus. It is also listed as a homicide, piscicide and raticide. *Jatropha* is considered as a poor quality fuel wood since the soft wood burns too rapidly. In Africa, *Jatropha* is widely planted as a "living fence" and hedgerows to protect food crops from damage by livestock and as a windbreak to prevent soil erosion moisture depletion. In Madagascar, *Jatropha* is used as a support plant for Vanilla. The bark is reported to yield tannin in commercially useable quantities. In a startling 1982 study, several oil- energy species with the potential to grow in Malagasy (Madagascar) were compared, and Oil palm was considered energetically more promising than *Jatropha*; nevertheless, around 10,000 ha have been planted to *Jatropha* (although the citation did not specify whether the plantings were *J. curcas* or *J. mahafalensis*, ed.). Other studies conclude that using the oil to make soap is more

Status of Jatropha Curcas for Biodiesel Production

profitable than using it as biodiesel; however, this was before the recent rise in fuel costs.

Medicinals

Although toxic, Jatropha is known as the physic or purging nut for its use as purgative/laxative, and is widely known as a source of medicinals for treatment of a variety of ailments. A range of healing properties have been ascribed to leaf preparations for both topical application and ingestion. Duke provides a most extensive list of its various uses in folk medicine.

Human consumption

Jatropha can be toxic when consumed; however, a non-toxic variety of Jatropha is reported to exist in Mexico and Central America, said not to contain toxic Phorbol esters. This variety is used for human consumption after roasting the seeds/nuts, and "the young leaves may be safely eaten, steamed or stewed." They are favored for cooking with goat meat, said to counteract the peculiar smell. As such, it is suggested by some that "This non-toxic variety of Jatropha could be a potential source of oil for human consumption, and the seed cake can be a good protein source for humans as well as for livestock." This non-toxic variety has not been studied as well as the toxic varieties; therefore, its properties and yields are relative unknown and "claims" unproven. The IPGRI study reports ...that the seeds are edible, once the embryo has been removed (no indication of which variety, ed.).

Status of Jatropha Curcas for Biodiesel Production

Jatropha Oil

It is unclear how much genetics play in the amount of oil contained in Jatropha seed and kernels; nevertheless, estimates of the oil content in seeds range from 35-40% oil and the kernels 55-60% (www.jartropha.org). However, the amount of actual oil produced from seeds and kernels is contingent upon the method of extraction, with hand presses extruding only about 20% and more sophisticated a much higher quantity. The by-product of oil extraction from the seeds and kernels is called seed cake, and when oil is extracted as a cottage industry the resulting cake is said to still contain approximately 11% oil. The more sophisticated and efficient method of extraction produces seed-cake with much lower oil content.

The clear oil expressed from the seed has been used for illumination and lubricating, and more recently has been suggested for energetic purposes as a substitute for diesel. One source reports that one ton of nuts yield an estimated 70 kg refined petroleum, 40 kg "gasoil leger" (light fuel oil), 40 kg regular fuel oil, 34 kg dry tar/pitch/rosin, 270 kg coke- like char, and 200 kg ammoniacal water, natural gas, creosote, etc.

Oil for lighting and cooking

Jatropha nuts can be strung on grass and burned like candlenuts, and the oil to make candles. Although many researchers have described Jatropha as a potential domestic fuel for cooking and lighting, with properties similar to kerosene, it cannot be used directly in conventional kerosene stoves or lamps. High ignition temperatures and viscosity (75.7 10-6

Status of Jatropha Curcas for Biodiesel Production

m²/s) as compared to kerosene (50-55 C, and 2.2 10-6m²/s respectively) mean that Jatropha oil will not burn as well, and would clog up all the tubes and nozzles in a conventional stove or lamp. Approaches to circumventing these problems are being tried. A low intensity lamp with a wick has been developed. The oil lamp requires a very short wick so that the flame is very close to the oil surface. At Hohenheim University in Germany, a group is developing a special stove to solve the problems, but neither the lamp nor the stove is readily available. So far, models require kerosene both to start the stove and to clean it just before it is turned off.

BIODIESEL

The market that excites the most interest is that for biodiesel. However, there are several points of view that differ considerably regarding Jatropha's suitability as a substitute for petroleum products. Right now these views yield less in actual sales than in prospects. How quickly these prospects will develop depends on the observer's point of view. Jatropha oil has long been seen as a possible substitute for fuel oil for diesel engines. This is the product where interest is highest and most research is being conducted. ***Unrefined Jatropha oil can only be used in certain types of diesel engines, such as Lister-type engines; but even then they require modifications, and are high-maintenance.*** The Lister type engine is commonly used in developing countries to run small-scale flourmills or electric generators. These engines also have to be located in

Status of Jatropha Curcas for Biodiesel Production

warm climates because the viscosity of Jatropha oil is too high at low temperatures. However, any diesel engine, with no modification other than the replacing of natural rubber with synthetic rubber hoses (which late model engines do not have anyway), can run on Jatropha fuel once the oil has gone through a process called trans-esterification.

According to the IPGRI publication, the trans -esterification is process is normally carried out in centralized plants since the small-scale economy of trans -esterification has not been determined. During the process, methanol, a highly flammable and toxic chemical, has to be used, and this requires explosion-proof equipment that might not be available in developing countries. The WSU study contradicts the IPGR statement by claiming that the process is simple to carry out by just mixing the oil with methanol and caustic soda and leaving it to stand; nevertheless, the chemicals are toxic and highly flammable, and the processing dangerous. Regardless, this could be dangerous. Glycerin settles to the bottom of the tank, leaving the methyl ester, or biodiesel, at the top. This warrants further investigation in order to determine which statement is true. Perhaps both statements are true, and the former process is for more commercial-scale operations, and the latter is an “appropriate technology” developed for small-scale, cottage- industry producers.

Biodiesel is reported to be environmentally superior to petroleum diesel, for Jatropha biodiesel emits about two-thirds less in unburned

Status of Jatropha Curcas for Biodiesel Production

hydrocarbons and almost half as much carbon monoxide and particulate matter as conventional diesel. It contains no sulfur and so emits none. From the point of view of global warming, it is neutral in its net addition to greenhouse gasses because the carbon dioxide released in combustion was sequestered when growing the crop (this claim is questionable, since CO₂ released would soon equate the CO₂ sequestered by the plants after a relative short time, ed.). The WSU study optimistically concludes that while many vegetable oils are used to manufacture biodiesel, a given amount of land will produce much more oil from Jatropha than from the common alternatives (soybeans, cotton seed, rapeseed, sunflower, groundnuts).

The glycerin by-product of the **trans-esterification** process can be used to make a high quality soap, or it can be refined and sold at a range of prices, depending on its purity, to be used in an immense range of products, including cosmetics, toothpaste, embalming fluids, pipe joint cement, cough medicine, and tobacco (as a moistening agent).

Soap production

The glycerin that is a by-product of biodiesel can be used to make soap, and soap can be produced from Jatropha oil itself. It will produce a soft, durable soap, and the rather simple soap making process is well adapted to household or small-scale industrial activity. The WSU study reports that in Africa where Jatropha hedgerows are widely planted to protect crops from livestock, Jatropha oil is used mainly in the manufacture of high quality soap. Soap making takes place on a cottage industry scale

Status of *Jatropha Curcas* for Biodiesel Production

and is a boon to the people concerned, offering a chance to earn an income in economic environments where there are few such opportunities. The benefits accrue to the oil pressers and soap makers as well as to the farmers who provide the seed. The fact that the seed has a value is an added encouragement to the use of *Jatropha* shrubs as live hedges that already yield benefits in the form of livestock control and soil erosion reduction. *However in other developing countries, other oils or tallow may be more plentiful and cheaper than Jatropha oil; therefore, planting Jatropha for oil as a raw material and creating cottage industries to make soap may not be economically feasible.*

According to the IPGI report, research carried out by the Tata Oil Mills Co., Ltd. in Bombay, India, has shown that with a mixture of 75% hydrogenated *Jatropha* oil, 15% refined and bleached *Jatropha* oil, and 10% coconut oil, a soap can be produced with lathering values equivalent to regular toilet soap. As can be seen in the table below, pressing of 12 kg of seeds yields 3 liters of oil that is then transformed into soap. The soap making technology is very simple, and is a real village technology with the only investment is a hand-operated press for \$150 US (this figure seems unusually high, ed.). The soap can be made in plastic bowls or buckets, and the pieces cut with ordinary knifes. As the table shows, the processing of 12 kg of seeds gives 28 pieces of soap of 170 g each, which is 4,760 kg. This takes 5 hours of work (estimated). The total input is added to \$3.04 US. The soap can be sold for \$4.20 US, and the resulting 9 kg of presscake is well appreciated as organic

Status of Jatropha Curcas for Biodiesel Production

fertilizer and can be sold for \$0.27 US; a total revenue of \$4.47 US. Reduced by the input of \$3.04 US, the net profit of processing 12 kg of Jatropha seeds is \$1.43 US, which is about \$0.28 US per hour. Even if the estimated time for processing is doubled, the net profit is about \$0.15 US per hour that is more than the average wage for workers.

Skin care and cosmetics

The seed oil can be applied to treat eczema and skin diseases and to soothe rheumatic pain (Heller 1996). The 36% linoleic acid (C18:2) content in Jatropha kernel oil is of possible interest for skincare.

Pesticides

The oil and aqueous extract from oil has potential as an insecticide. For instance, it has been used in the control of insect pests of cotton including cotton bollworm, and on pests of pulses, potato and corn. Methanol extracts of Jatropha seed (which contains biodegradable toxins) are being tested in Germany for control of bilharzia-carrying water snails. And the pesticidal action of the seed oil is also the subject of research of International Crops Research Institute for the Semi-Arid Tropics, (ICRISAT) in India.

Other uses

Jatropha oil is also used to soften leather and lubricate machinery (e.g. chain saws).

Status of *Jatropha Curcas* for Biodiesel Production

Seed-cake

Seed-cake or press-cake is a by-product of oil extraction. *Jatropha* seed-cake contains curcin, a highly toxic protein similar to ricin in Castor, making it unsuitable for animal feed. However, it does have potential as a fertilizer, discussed in the next section below on markets. If available in large quantities, it can also be used as a fuel for steam turbines to generate electricity. When processed as a cottage industry, the seed cake still contains approximately 11% oil, has 58-60 % crude protein (53-55 % true protein content), and the level of essential amino acids except lysine is higher than the FAO reference protein. Nevertheless, without extensive processing, the seed cake is poisonous to animals, and untreated, is only good as a source of organic fertilizer.

The production of oil from *Jatropha* seed inevitably results in a by-product of press-cake with a high percentage of protein -- 58 to 64%. One source suggests that it would be an excellent animal feed; however, it is toxic. Pentagon Chemicals in Zimbabwe succeeded in largely detoxifying the press-cake through a combination of heat treatment and solvent extraction, but apparently it was not an economically viable option for commercial production. There are, after all, other kinds of press-cake derived in processing other tree and plant oils that do not need detoxification. Press-cake derived from the non-toxic varieties of *J. curcas* from Mexico and Central America may not be toxic, but the literature reviewed did not show evidence of this. Non-toxic varieties are not grown in southern Africa.

Status of *Jatropha Curcas* for Biodiesel Production

According to the WSU study, trials with *Jatropha* seed-cake have concluded that its properties compare favorably with those of other organic fertilizers with regard to nitrogen, phosphorus and potassium. However, there are issues needing to be addressed with respect to storage, the formation of organic acids, the slow degradation of lignin (shells) and the possible need for treatment with pesticides that might result from lack of microbial degradation. The improper storage of the seed cake might also result in the production of toxic aflatoxins.

Charcoal

In simple charcoal manufacture, 70 to 80 percent of the wood's energy is wasted and lost with yields of 30 percent in an industrial processes and 15-20 percent in a less sophisticated process in developing countries where charcoal is still one of the few simple fuel options. *Jatropha* wood is a very light wood and is not popular as a fuelwood source because it burns too rapidly. Four samples of *Jatropha curcas* wood were measured at USDA's Forest Products Laboratory and their densities were 0.35, 0.33, 0.37 and 0.22. **The scientist concluded that *Jatropha* wood would not be of much value for either firewood or charcoal.**

Some have suggested converting press cake into charcoal, but press cake is much more valuable to use as a fertilizer to ameliorate the impoverished soils in the developing countries with organic matter and nutrient contained within in order to increase crop production. However if the seed hulls were chopped and pressed, it could be used as a fuel for cottage industry use. The extraction oil from *Jatropha* seeds/nuts is of

Status of Jatropha Curcas for Biodiesel Production

much higher economic value of Jatropha than converting the wood to charcoal. An exception is if a large area of land was colonized by a variety of Jatropha that had very low yields of nuts/oil and there is a desire to clear the area and replant it with a variety that produced much higher yields of nuts that contain more oil.

There has been some thought to converting Jatropha seed shells into charcoal, but one needs to first seriously study what is involved, and if would you end up with an economical product. This would be economically feasible only if you had a large source of seed shells from Jatropha plantations.

Hawaii Natural Energy Institute (HNEI) scientist Dr. Michael Antal has developed a fuel cell using charcoal as its fuel. Dr. Antal's research led to the discovery of a new Flash Carbonization™ process that quickly and efficiently produces biocarbon (i.e., charcoal) from biomass. This process involves the ignition of a flash fire at elevated pressure in a packed bed of biomass. Because of the elevated pressure, the fire quickly spreads through the bed, triggering the transformation of biomass to biocarbon. Fixed-carbon yields can attain the thermochemical equilibrium limit after reaction times of 20 to 30 minutes. Feedstocks have included woods and agricultural byproducts such as macadamia nut shells (somewhat similar to Jatropha seed shells) and corncobs. In the case of corncobs, the fixedcarbon yield attained the theoretical limit, and the reaction was complete after 20 minutes. The result is a very high-quality charcoal that has the potential to be used in high- value markets and sold as barbecue fuel, a soil amendment, a digestive health aid, for

Status of Jatropha Curcas for Biodiesel Production

steel or metal production and to manufacture activated carbons used to purify water.

Oil expellers

More efficient oil expellers will extract a higher percent of oil from the seeds, which in turn should produce higher profits in a Jatropha system, since oil sells for more than the residual seed-cake. More efficient expellers cost more; therefore, one must have a very large amount of seed for processing and a ready market at competitive prices for the oil to make the expellers affordable. When using inefficient expellers, the seed-cake still contains at least 10% of the oil and if the seed contains 40% oil, that means 1/4th of the oil is wasted; a huge economic loss for any business enterprise. In 1995 a GTZ-expert in economy analysed the economic feasibility of the Jatropha approach in Mali. Two versions of expellers were studied: 1) a hand operated ram press; and 2) a motor driven Sundhara expeller powered by two different engines 2) a cheap Indian motor (Lister) that frequently broke down, and b) a more solid German Hatz motor that required very little maintenance.

Motor driven expeller

The results of the financial analysis indicate that for the Lister version an internal rate of return on investment (IRR) of 49 % can be projected. For the Hatz version, the profitability of the oil mill is lower (26 % IRR) due to the more expensive equipment, but also carries a much lower risk of mechanical breakdowns.

Status of Jatropha Curcas for Biodiesel Production

Yields and Economics

Jatropha is being heralded as a tree crop for biodiesel production and increasing incomes of small farmers on marginal lands; however, when you plant crops on marginal lands/soils, you can expect to get marginal yields. Plants mine nutrients from the soil, and to maintain yields, these nutrients need to be replaced. This often means applying chemical fertilizers that even if available, are not affordable to many small farmers. When doing realistic planning on the “real” economics of a Jatropha project, one must also calculate that fact that optimal seed yield of Jatropha won’t be obtainable for several years. Furthermore, marginal farmers most often have access to only a minimal amount to land for food crop production; therefore, what will they have to eat until a sound market for Jatropha oil is developed?

The jury is still out on the actual seed and oil yields one can count on from Jatropha plantings. IPGRI concludes that “The low yields revealed in several projects may have been caused by the fact that unadapted provenances had been used. If investigation of its genetic diversity and its yield potential had been covered by adequate scientific research, this problem could have been overcome.”

In the literature reviewed, it could not be determined if adequate research on germplasm improvement is taking place to optimize the per plant yield of nuts and oil content. Since Jatropha clones are readily propagated through cuttings, germplasm improvement to optimize yields should be easier than with many other plants/trees. One must be very careful in selecting a good source of Jatropha germplasm for projects

Status of Jatropha Curcas for Biodiesel Production

since there is little truth in advertising, and presently the best profitability is in selling seed, cuttings or seedlings produced from plants that are probably not genetically improved and may vary widely in yield. Cloning creates cytoplasmic uniformity in plants making them more susceptible to disease and insect infestation.

Both male and female Jatropha trees are reported; therefore, logically, one might assume that they might produce different yields, but yield differences were not noted.). [ECHO Editor: I suspect that what is meant is that some plants are female and others are bisexual, as is the case with many commercial papaya varieties. Otherwise it is hard to see how the male-only plant would bear fruit.] In an Australian-funded project, the Nicaraguan plant material -- a male sterile plant – was observed to have produced more fruits than the hermaphrodite types. And according to the **IPGRI** document, male sterile plants will facilitate breeding efforts for higher seed production. Also, it is probable the nontoxic varieties yield less than the toxic varieties (both in tonnage of nuts and percentage of oil).

Furthermore from the literature it is extremely difficult to determine what actual per hectare yield of nuts one can rely upon when growing Jatropha. Most figures cited were projections that often are inflated and over optimistic in order to procure funding for projects. Also, the estimated oil content of the nuts cited in the literature varies considerably, which adds to the difficulty of calculating the profitability of growing Jatropha. Furthermore, optimizing oil extraction from the

Status of Jatropha Curcas for Biodiesel Production

seeds requires expensive machinery. One can find on page 36 of the IPGRI study a list of yields cited by a number of sources.

Rather than being based on sound economic planning, many undertakings of Jatropha plantings seem to be based on subsidized project development and the speculative selling of Certified Emission Reductions for potential carbon sequestration trading payments. The cited value of carbon sequestration by Jatropha is questionable, since even if it is closely-spaced the wood is not very dense (densities 0.35 to 0.22, see above Charcoal). In the literature, the reports of yields vary greatly and are confusing. This can be attributed to one or a combination of the following factors including: yields are sometimes given in terms of fruits, seeds, nuts, or kernels; confusing terminology used in making yield estimates, e.g., some are made in tons (t) while others are in metric tons (MT); variance in germplasm; unstipulated spacing between plants; no specific data on soils (ranging from marginal to fertile, and if fertilizer was applied); no information on rainfall and other climatic conditions, and if irrigation is being used Reports on yields include that from plantations (mostly projected yields), but it is not mentioned if they were established by vegetative propagation or by direct seeding, on fertile or marginal soils, and if the plantations were irrigated or not.

When irrigated, Jatropha trees are said to produce seeds throughout the entire year. Often, there is no mention of the age of the trees/shrubs, nor is the variety/cultivar given. Jatropha trees are said to begin producing a measurable amount of nuts at 18 months, but are not expected to reach maturity and optimal yields until after 6 years. The IPGRI report gives a

Status of *Jatropha Curcas* for Biodiesel Production

conversion factor of 30 kg of fruits yielding approximately 18 kg of seed. One might assume that the fruit to seed ratio may be higher in areas of higher rainfall. In one reference, IPGRI estimates that a yield of at least 2-3t (not MT) of seeds/ha can be achieved in semiarid areas; however, in another citation, IPGRI reports that in Hisar, Bangalore, India, a “quite high seed yield” (1,733 kg/ha or 1.733 MT) was observed in one cultivar. IPGRI confuses the issue by reporting the yield in tons and not MT (this could have been an editing mistake, ed.), while giving the area in hectares.

Gaydou, et. al. (cited by Duke) gives a seed yield approaching 6–8 MT/ha with approximately 37% oil, and such yields could produce the equivalent of 2,100–2,800 liters fuel oil/ha. According to Gaydou, there are approximately 10,000 ha of *Jatropha* in Madagascar, each ha producing about 2,400 liters of oil for a total potential production of 24,000,000 liters. One reference reports that *J. mahafalensis* (not *Jatropha curcas*) as the species found in Madagascar, nevertheless, it is predicted to have equal energetic promise. Nevertheless, there has been a request from Madagascar for information on converting *Jatropha* wood to charcoal; therefore, one might assume that the *Jatropha* plantings may not be profitable and producing as much oil as predicted. A *Jatropha* plantation in Nicaragua is said to produce 5 metric tons per hectare. A plantation project in South Africa attached to SORSA (see later in this section) very optimistically projects a yield of 12 tons per hectare after 6 years of growth. As a footnote, Duke adds: “The higher yields reported in my online energy book are all to often for

Status of *Jatropha Curcas* for Biodiesel Production

[http://www.hort.purdue.edu/newcrop/duke_energy/dukeindex.html]

the best germplasm with the best farming techniques and in the best terrains; rarely if ever all available to the less-than-best class.” Added 18 August 2006 -- Correspondence with Dr. K.S. Varaprasad, Officer-incharge of India’s National Bureau of Plant Genetic Resources reveals that “ICRISAT does not have any germplasm that yields 7 tons of seed per hectare. In fact, there are no systematic studies on *Jatropha*, but recently we have started work at ICRISAT; however, a few germplasm accessions have been collected by NBPGR, and those are now being characterized for their potential and other parameters.”

The Washington State University (WSU) assessment states that 12 MT of nuts per ha could be expected from trees after 6 years growth; however, no data is given to support this optimism. If such yields were possible, it would only be achievable under ideal conditions, using genetically improved germplasm, fertilizer, irrigation, and other necessary inputs. Henning reports that in an experimental plantation of *Jatropha* in KwaZulu-Natal, South Africa, some 18-month-old trees were already producing large amount of seeds. The trees were about 1.50 meter in height, and they were producing approximately 2.5 kg of seed per tree. A much larger project involves the construction of a refinery for biodiesel in KwaZulu-Natal, with an associated *Jatropha* plantation to furnish some of its supplies of seed, while other sources purchased from small farmers. In the pilot zones in Mali the average length of hedges was found to be 15.000 m (neither the spacing between the plants nor the width of the hedgerows is given). Each meter of hedge produces 0.8 kg

Status of Jatropha Curcas for Biodiesel Production

of seeds and an estimated 12 tons of seed can be collected from hedgerows in the average village. Henning also reports that by promoting the integrated utilization of the Jatropha plant, the Jatropha System can provide direct financial benefits to the rural economy. To illustrate this with a rough calculation, assume the average village of the pilot area has 15 km of Jatropha hedges, which represents 12 tons of seeds. These 12 tons of seeds may generate 2,800 US\$ of cash income when the oil is extracted by an efficient expeller and the products are sold. (Labor costs to harvest the nuts and to expel the oil are not included in this calculation, nor is taken into consideration who will profit since the hedgerows are part of a village and not individually owned; e.d.). In Mali, the men own the land, thus they also own the Jatropha hedges. As such, it is likely that little of the profit from the sale of the seed will go to the women and benefit the children.)

9,000 kg of presscake @ 0.03/kg = 270 US\$

2,400 liters of oil @ 0.60/l = 1,440 US\$

600 kg of sediment @ 0.15/kg = 90 US\$

Total 1,800 US\$

If we take the real example of an entrepreneur in a small village near Bamako, who buys the seeds for soap production and hires the people for the production process (extraction with Bielenberg ram press, soap production, see table above), the cash income for the village population including the entrepreneur, amounts to 3,630 US\$. If only seeds are processed and the oil and the by-products presscake and sediment are sold, a total sum of about 1.800 US\$ will stay in the village. If the oil is

Status of Jatropha Curcas for Biodiesel Production

processed by an entrepreneur to soap and the soap is sold, then the total of about 3,600 US\$ will stay in the village. According to Henning, if these figures are extrapolated and used to calculate the economics of Jatropha plantations, a profit in the range of cotton farming is within reach (extrapolation is risky at best, ed.). However, in the above calculations the price of the seeds to the processor is mainly the cost of labour to collect them (no profit to the owner).

At the time of Henning's report, if the seeds were processed as biodiesel, only under special conditions would it be competitive as a substitute for diesel in Mali or in Zambia. Similarly at that time in Tanzania, Jatropha oil was being traded in only small quantities for 2 US\$ per litre, about 3-times the price of diesel fuel at the filling station; therefore, the oil was made into soap, or sold to soap makers, and the profit used to buy diesel. Besides genetic differences on the tonnage per hectare yield and the actual amount of oil contained in the seed, the extraction process of the oil from the seed is a major determinant of the actual amount of oil that can be obtained. To optimize oil extraction from the seed, expensive expellers must be used, and the oil has to be processed before it is usable as a fuel, and both processes increase project costs, and decrease profits.

IV. Limitations of Jatropha Biodiesel

Oil extraction:

A key determinant of the economics Jatropha as a source of biodiesel fuel is the efficiency with which oil is extracted from the seed. It also determines the economics of soap production. The handoperated ram press used by many small-scale producers to extract oil yields only 20 to 30% (assuming what is meant is that the oil content of seeds ranges from 35-40%, and of that amount, only 1/2 to 3/4ths of the potential oil is extracted; ed.), and processing is very slow (pressing between 100-500kg of seed per day). Yields of up to 35% can be obtained using a diesel or electrical powered spindle press, and depending on the size of the press, up to 5 MT of seed can be processed per day. However, with the initial capital cost of a spindle press being at least 4 times higher than that of a ram press, its purchase is beyond the capability of most small-scale processors. Moreover, since diesel oil or processed Jatropha oil is needed to fuel the spindle press extrapolator, which eats up much of the profits, this makes it less attractive to such processors. Thus at the time of the reports, functioning enterprises in the industry were generally small- scale processors of oil and soap.

Oil storage:

According to Marc Portnoff, senior scientist at the Carnegie Mellon Center for Advanced Fuel Technology, Jatropha oil does not store well without processing, perhaps for only a few months; therefore, this would

Status of Jatropha Curcas for Biodiesel Production

make it difficult to provide fuel to power the year-around operation of small industries such as grain mills, oil presses, water pumps and electricity generators (Presentation at the *Environmental Vulnerability in Haiti: A Stakeholder Workshop to Discuss Findings and Recommendations with USAID's technical Assessment Team*, 8/02/06, Woodrow Wilson International Center for Scholars) [ed. This paragraph was added 18 August 2006]

toxicity

Duke reports, “The poisoning is an irritant, with acute abdominal pain and nausea about 1/2 hour following ingestion. Diarrhea and nausea continue but are not usually serious. **Depression and collapse may occur, especially in children.** Two seeds are strong purgative. **Four to five seed are said to have caused death**, but the roasted seed is said to be nearly innocuous. (It is unclear if this citation refers to the toxic variety or variety reportedly found in Central America and Mexico; ed.) Bark, fruit, leaf, root, and wood are all reported to contain HCN Seeds contain the dangerous toxalbumin curcin, rendering them potentially fatally toxic.”

Nontoxic Mexican variety:

A non-toxic variety of Jatropha is reported to exist in Mexico and Central America. Birgit Schmook (cited by Henning) reports that the seeds in the zone around Misantla, Veracruz are very appreciated by the population as food once they have been boiled and roasted. Levingston

Status of *Jatropha Curcas* for Biodiesel Production

and Zamora (cited by IPGRI) report that Jatropha seeds are edible once the embryo has been removed; nevertheless on principal, consumption of seeds should be avoided. Ochse (cited by Duke) reports, "the young leaves may be safely eaten, steamed or stewed." They are favored for cooking with goat meat, said to counteract the peculiar smell. Becker (cited by Henning) suggest that "This non-toxic variety of Jatropha could be a potential source of oil for human consumption, and the seed cake...a good protein source for humans as well as for livestock." (However, there are much better oil and protein sources available at competitive prices than that from Jatropha, ed.)

Invasiveness:

Jatropha has the potential to be weedy because of its toxic seeds that can spread rather easily and create dense stands on uncultivated lands. It is reported as a weed in many places including Australia, Brazil, Fiji, Honduras, India, Jamaica, Panama, Puerto Rico, and Salvador.

Disease and insects:

Agriculture Handbook No. 165 lists the following as affecting *Jatropha curcas*: *Clitocybe tabescens* (root rot), *Colletotrichum gloeosporioides* (leaf spot), and *Phakopsora jatrophicola* (rust). Termite infestation has also been reported in overage trees. On page 41 of the IPGRI paper there is a list of 13 additional pests and diseases observed on Jatropha by different authors.

Status of *Jatropha Curcas* for Biodiesel Production

Host for cassava viruses

In the IPGRI paper, several scientists are quoted on stating that *Jatropha curcas* can transmit cassava superlongation disease (*Sphaceloma manihoticola/Elsinoe Brasilinesis*); and another species, *J. multifida*, is an alternate host plant for African Cassava Mosaic Virus, which is transmitted by whiteflies (*Bemisia tabaci*), and it can be assumed that this also applies to *Jatropha curcas*.

CONCLUSIONS

Industry Performance and Outlook

WSU reports that in Africa there are two commercially interesting *Jatropha* products, high quality soap and biodiesel. At this point only the former is developed. Soap making takes place on a cottage industry scale and is a boon to the people concerned, offering a chance to earn an income in economic environments where there are few such opportunities. The benefits accrue to the oil pressers and soap makers as well as to the farmers who provide the seed. The fact that the seed has a value is an added encouragement to the use of *Jatropha* shrubs as live hedges that already yield benefits in the form of livestock control and soil erosion reduction.

There are opportunities for small-scale enterprise if loans and equipment are available. When estimating the economic benefits of *Jatropha*, one must also include those to rural development, especially if diesel and other fuels are either not available or priced too high for the economically disadvantaged. When processed, not only can the fuel be

Status of Jatropha Curcas for Biodiesel Production

used for electric generators and pumps for potable water for schools or health-clinics for improved health and education and for small-scale irrigation, small motorized grain mills, but the seed-cake can be used as fertilizer to increase agricultural yields. WSU report states that creating a small-scale Jatropha enterprise may be "...something of a 'Catch 22' situation... Processors may be unwilling to look for new customers, including export customers and expand output because they can not be assured of obtaining enough raw- material from farmers, and farmers may be reluctant to expand supplies because they cannot be assured that processors will buy it." It has happened in the past.

Household food security

There is no data available concerning the amount of food saved by Jatropha hedges. In Mali the Malian Cotton Producing Society estimates that approximately 10 % of the crops are eaten by roaming cattle. Probably the real value is higher, because food crops are grown in gardens within or near the village, where the density of roaming animals is higher. It is assumed that the hedges also act as a wind break reducing moisture loss from winds. However, the hedges may also have a negative impact on crop yields due to lateral root development that would cause the Jatropha to compete with adjacent food crops for moisture and other nutrients. Nevertheless, there is no indication that any scientific studies have been conducted to prove or disprove any of the above.

Status of Jatropha Curcas for Biodiesel Production

Potential conservation benefits

The primary conservation benefits to be derived from production of Jatropha relate to improved soil management. In Africa the tree's most widespread use at present is as a live fence. In addition to protecting crops from livestock, this use reduces wind erosion and pressure on timber resources and increases moisture retention. Nevertheless, Jatropha does mine soil nutrients. Jatropha oil projects are expected to provide income and organic fertilizer to increase crop yields, as well as being an ecologically friendly source of alternative energy to rural farmers.

Jatropha oil as diesel substitute:

In **Senegal**, Enterprise Works (formerly Appropriate Technology Inc.) assessed the feasibility of using Jatropha oil to power small motorized grain mills and village electric generators (use in water pumps is also feasible). They concluded that with diesel at a historically low price in 1998-99, the use of Jatropha oil as a fuel substitute was not generally economically feasible, and turned to use the oil for soap production. At that time, Enterprise Works found that even though diesel fuel was less expensive than Jatropha oil on commercial markets, some villagers preferred to use Jatropha oil when it reduced their cash expenditures. In **Zambia** a 1998 feasibility study concluded that Jatropha oil can be produced for less than 3.000 ZMK (1000 ZMK = \$0.41 US), but this is a prohibitive price for the use of the oil as diesel substitute.

Status of *Jatropha Curcas* for Biodiesel Production

Carbon sequestration payments

According to Henning, a 5,000 ha *Jatropha* plantation near Luxor, **Egypt** was initiated by a British biodiesel firm based on an important financial aspect (i.e., money) that the project expects to receive from the trade of emission certificates for CO₂ sequestration. Since no data have been made available by the project, here is Henning's estimation of the money the project might apply for: 1 ha has about 1,600 plants and each has after 7 years about 200 kg of biomass, including roots with dry matter content about 25 %. This gives a biomass of 80 tons dry matter per ha. About half that weight is carbon dioxide, i.e. 40 tons. (**Given the fact that *Jatropha* is a very light wood, with a density ranging from 0.33 to 0.37, this figure seems extremely high, ed.**).

The trade of emission certificates pays between \$3 and \$4.00 US per ton of CO₂ sequestration, which is about \$150 US per ha. Thus, the 5,000 ha plantation can generate an estimated \$750,000 US additional income due to carbon sequestration payments. [ECHO Editor: I do not see any value in reducing atmospheric carbon dioxide on any meaningful timeframe unless the sequestered carbon remained sequestered for decades or centuries.]

Henning states that it is not clear why the government of Egypt and private firms are so interested in producing biodiesel with *Jatropha* oil, for he had not seen any economic calculations showing that the biodiesel produced from *Jatropha* oil might be cheaper than the diesel fuel. Perhaps it is speculation on the trading of carbon credits and payments

Status of Jatropha Curcas for Biodiesel Production

for carbon sequestration, and preparation for a sharp increase in fossil fuel prices. Thus, they want to get the technology ready to produce renewable fuel, and with the continuing rise in fuel prices, this seems economically viable. Henning also reports that “In Ghana, biodiesel is won by esterification of the oil with ethanol. Ethanol – unlike methanol which is a petroleum product and would have to be imported – can be won from local agricultural products as sugar cane. The centralized nation-wide marketing of the biodiesel is done by the Ministry of Energy. This appears to make sense for Ghana, because the petroleum importation is governmental, too. However, the project operators maintain the right to market an unlimited quantity of biodiesel on their own.”

“Glycerin, the by-product of the esterification process, is to be purified and can then be sold on an extensive market. During the first stage, the demand in Ghana will be sufficient to buy the entire production. The market price is \$500-600 US/ton. The presscake is modified and sold as biological fertilizer, also primarily on the local market; but import agents from neighbouring countries in West Africa, such as Nigeria, have already confirmed their interest to be supplied.” “Oil-presses: stamping presses operating with 70-100 tons of pressure are needed for the cold-pressing of the Jatropha nuts. Minimum capacity: 50 tons of nut s/day, equivalent of the expected harvested quantity of ca. 1000 tons/month during 2003/2004.”

Status of *Jatropha Curcas* for Biodiesel Production

India's biodiesel production model

India private sector has a long history of exploiting oilseeds and has developed the infrastructure necessary to profit from this industry. Costly machinery, such as expellers, is amortized rather quickly since the industry isn't based on any one oil seed crop, rather its based on a number of different oil seeds that are processed year around, and the machinery is run constantly. Furthermore, the government now provides a guaranteed market and price since it has dictated that fuels must contain 10% biodiesel oil. Therefore, supply and demand for biodiesel in India is much different than in other countries with projects that attempt to create entirely new production systems.

Comments from the field added to ECHO Website August 18, 2006

Madagascar: Mark_Freudnerger@dai.com

Dear Mike:

I was delighted to read your perceptive paper on jatropha and I took the liberty as well of sending it around to various colleagues and to Reinhard Henning, the coordinator of the jatropha systems website. He has made some small comments and clarifications. I will send you his comments because these points are well taken and they add to factual clarity. The ERI program in Fianarantsoa, Madagascar has been working on the question of propagation and uses of *Jatropha curcas* over the past two years. We have been carefully moving forward in doing test plantings, trying out different extraction techniques, and exploring the economic

Status of *Jatropha Curcas* for Biodiesel Production

and social questions you bring up. A couple of interesting issues are coming up:

■ Presence of *Jatropha curcas*:

The plant is widespread in Madagascar, but not apparently as an invasive. It is very much used as a pole plant for vanilla, pepper, and other climbing plants in many tropical areas of the country. An indigenous species, *Jatropha malfensis*, grows in the arid parts of the country. Villagers like *Jatropha curcas* because it allows these climbing plants to grow well but also be protected from heavy winds generated by cyclones. The jatropha bends over but then rights itself very easily. It does not grow too high and thus does not require much trimming. I've been surprised to see farmers in Fianarantsoa grow local varieties of ignames around jatropha plants. This reduces the labor costs of cutting branches for poles. Jatropha does not seem to be invasive because it does not tolerate well bush fires. This limits invasiveness but also makes large plantations of jatropha a risky business!

■ Oil from Jatropha:

The local market for jatropha oil is quite interesting. The oil is extracted using very energy and labor- intensive techniques (boiling the seeds and skimming off the oil) and then sold in the local markets as an oil used in traditional shampoos. Women are the primary processors of the oil. Malagasy women highly value the oil for their hair as it apparently has some medicinal qualities. The price for oil is about \$1.50 a litre - about

Status of Jatropha Curcas for Biodiesel Production

three times higher than what commercial firms like D-1 are currently offering. Villagers also express keen interest in jatropha oil and the seeds as lighting and thus a substitute for kerosene. As the price for kerosene increases dramatically, villagers are increasingly turning to local oils and wood for indoor lighting. We have found that villagers are deeply interested in the simple techniques of burning jatropha oil in small lamps. They also note that the smell of jatropha oil is nicer than kerosene. It should also be recollected that in large parts of Madagascar, kerosene is not available for sale in local markets because of the poor transportation system. In times of particularly deep scarcity, villagers will even burn the seeds of jatropha attached to skewers. This works like a candle. Pure jatropha oil can also be consumed directly in the Lister or other Chinese and Indian motors. This negates the necessity of being involved in the esterification process. I agree that German motors are more efficient and durable than the Chinese or Indian motors, but local manufacturers and artisans are very skilled at repairing these Third World engines. These are the engines on the market, not the more expensive, but more efficient, European models.

■ *Seedcake:*

As in many parts of the world, we are finding that farmers are probably more interested in the jatropha seed cake than they are the oil. The seedcake is widely known as a very valuable form of fertilizer equivalent in fertility to chicken manure. Farmers involved in traditional oil processing carefully guard the seed cake and use it to fertilize rice fields

Status of Jatropha Curcas for Biodiesel Production

as well as up-land crops. Recently, I met with farmers who are also using the seed cake to fertilize coffee plants. They did comparison trials and found jatropha to be extremely interesting compared to more traditional forms like mulching or use of cow manure. I agree that it is crazy to use jatropha seedcake for charcoal unless the seedcake begins to be a pollution hazard. Right now, we envisage LOCAL level and small-scale processing so that the seedcake remains in the local environment and thus can be returned to the soil in the immediate vicinity of production.

■ *Oil Extraction:*

The major problem with jatropha is the difficulty of extracting the oil from the seeds. We are testing the Bielenberg press here in Fianarantsoa. I am very well aware of the critique that it is not economically profitable. We copied the press from a model made in Tanzania using local manufacturers. They have to our surprise made very high quality presses. But, we tried other hand press models and they don't work very well. Our conclusion so far is that the Bielenberg hand press is the only thing out there that extracts oil by hand, that it can be made by local artisans, and that it appears to be far more productive than the traditional oil extraction techniques. This later point is important because the costs of firewood are very high for boiling the jatropha seed using the traditional techniques. We are putting in place a system for farmer's associations to rent out the presses so that

Status of Jatropha Curcas for Biodiesel Production

local groups can make oil for soap and lighting. We agree that mechanized presses are by far more economically profitable, but so far these machines are expensive, difficult to obtain, and break down as well. We're testing some Chinese models and we hope that D-1 will introduce some higher qualityn German models. Right now, availability is severely constrained because of lack of supply, lack of credit, and skepticism.

■ *Land Tenure:*

Your points are very well taken. As one who has worked on land tenure issues for years, this is one of our major concerns. I think the verdict is indeed out about whether farmers in Madagascar will plant massively jatropha. If the price of the seed and oil is high enough, I think they will plant and indeed resolve bit by bit the tenure insecurities. This has happened with many cash crops in the past. I don't think it will be very easy for industrial scale plantations to be launched in Madagascar because of competing uses of land for pastoralism and also because of the xenophobic nature of Malagasy landowners. They will not take to international interests buying up vast swaths of land for jatropha. If jatropha expands, it will be due to the massive planting by small farmers in various tenure niches. Our project is trying to start up a series of tenure case studies on jatropha to look at exactly the questions you raise. I do agree that jatropha in one form or another will contribute to various tenure issues. But, this happens with any new crop that generates economic value. Equity, gender, and tenure issues always crop up.

Status of Jatropha Curcas for Biodiesel Production

■ *Agroforestry combinations:*

The points are very well taken. We are very interested in the possibilities of intercropping jatropha on highly degraded hillsides with various grasses and legumes. Under wide spacing conditions, we are interested in improving hillsides for grazing (either free or cut and carry) plus also producing jatropha seeds for local, regional, and possibly international markets. I read with great interest your concern that jatropha might compete with grazing lands. Yes, it's a very valid point. But, in the areas where livestock raising is in decline (ie: vast parts of eastern tropical Madagascar) and hillsides are highly degraded in a fire climax situation, we are exploring whether jatropha agroforestry combinations are a way to encourage pasture improvement, reduction in fire, but also progressive recapitalization of the livestock system. What kinds of grasses or legumes could be grown with jatropha that won't compete with the plant? We've hired a Malagasy agronomist who will look at this question and we're testing out several different cropping patterns with farmers now. The major concern is fire. Fire is a weapon, a management tool, and a major worry. If monocultures or grass-jatropha systems are encouraged, this makes the landscape possibly very liable to fire. Farmers might invest in planting jatropha but find that just at the moment of starting the harvest process, jealous neighbors could burn down the plantation! For this reason, we are more interested in jatropha uses in firebreaks, hedges, boundary markers, intercropping of jatropha with vanilla and other vine crops. etc.

Status of *Jatropha Curcas* for Biodiesel Production

■ *Energy Flows and Jatropha:*

Good point that jatropha yields will be dependent upon the input of fertilizers, either organic or inorganic. I don't yet know how to respond to this issue. Our major inquiry is what does one do with the highly degraded *tanety* fire climax lands that are hardly used for pastoralism and that possess relatively small value. If market conditions are right, farmers would probably invest more labor in manuring, mulching, and possibly adding inorganic fertilizers to jatropha. I hope not the latter! But, from an ethical perspective, I do hope that agroforestry combinations can be devised so that jatropha is one complementary contribution to landscape restoration. Its very clear that no improved varieties of jatropha exist at this time. We don't even know what the yields per tree are at this time. For this reason, ERI is trying to start up an applied research process to learn more about yield dynamics in different growing conditions. Not an easy topic.

■ *Market Orientations:*

ERI is promoting the expansion of jatropha with caution. We do not encourage farmers to produce solely for the international market, but rather to develop niche local markets in the immediate future for the oil and seedcake . As international market dynamics and structures develop, jatropha from Madagascar might be well positioned. We just don't yet know. We think that there is much future in the village level soap market because locally made soap, at a cheaper price and with greater

Status of Jatropha Curcas for Biodiesel Production

availability than industrial manufactured soaps, could resolve a huge health problem. Soap availability for hand washing is very limited in villages because of high cost. Oil for lighting and simple diesel motors is also promising. Again, expansion into these markets hinges upon the availability of locally manufactured hand and mechanized presses. We suspect that the national and international market will emerge, but probably, Madagascar cannot compete with India, South Africa, or other countries where industrial scale plantations are being planted right now. But, the verdict is not yet in. If fair prices are offered to Malagasy farmers for oil processed locally, I think that jatropha production could take off. I agree fully with you that value added must occur at the local level among villagers, local level middlemen, and local cooperatives and associations. Its very risky to focus on capturing a share of the international market. It is too volatile, too many middlemen are in the business, and market dynamics are not clear. However, IF international prices remain high for biofuels due to Kyoto agreements, European Union price subsidies on biofuels, and other incentives, the international market might become interesting for Malagasy farmers and exporters. Its too early to tell. So, these are some thoughts that jumped out from reading your excellent paper. I thank you for taking the time to write it and I hope that my comments based upon our unfolding experiences are useful.

Mark Freudenberger
Regional Coordinator
Ecoregional Initiatives Fianarantsoa

Status of *Jatropha Curcas* for Biodiesel Production

B.P. 1068

Fianarantsoa 301

Madagascar

tel: 75.510.21 or 75.502.09

fax: 75.507.63

Mark_Freudenberger@dai.com

Page 20 of 22

From: Trent Bunderson

Sent: Friday, April 28, 2006

Subject: Comments on Jatropha curcas

I was happy to see John Pratt's comments on Jatropha based on our experiences under MAFE. Mike Benge's concerns are justified. I would add that over the past 2 years, I have been contacted by a number of private sector firms (most from S Africa, but also in Malawi) to mobilize Jatropha planting efforts, either on private plantations or with communities. In all cases, I have asked questions regarding the relative benefits/returns to communities and farmers involved vs. the companies that produce and sell the oil or fuel. Some of these questions include:

- yields and prices for the seed produced under Malawi smallholder conditions(yields usually quoted at 10 tons/ha or more, which is hard for me to accept; and prices of US\$50 per ton, which is believable because it is very low);
- relative returns to the farmer vs. other crops grown for the costs involved;
- returns to the private companies for oil/fuel produced;

Status of *Jatropha Curcas* for Biodiesel Production

- who benefits from carbon credits documented and how is this done and shared;
- negative effects on the farm family system and the village environment;
- long-term commitments by the companies that purchase and process the seed so that they don't simply disappear soon after the trees start bearing fruit - In my opinion, some of the companies involved are not exactly scrupulous.

I have never received satisfactory answers to these questions. Until this happens in a clear and transparent form, we will not promote Jatropha as a wonder tree. I know there are big plans to plant Jatropha in huge plantations in Mozambique and Tanzania, I know of 2 separate ones, each of 11,000 ha. In the meantime, we will watch and see how things develop, and who actually benefits. Best regards,

Trent Bunderson

Malawi: From: John Pratt

Sent: Friday, April 28, 2006 9:28 AM

Subject: Re: Jatropha curcas biodiesel miracle

Dear Autman

Thanks for this assessment. It's good to see WSU/Peter Wyeth investigations being quoted. I agree with Mike Benge's skepticism. There are some investors in companies making money out of playing up this scheme but it's time they laid out for scrutiny their detailed business plans and financial feasibility assessments for the whole process from planting to blending into vehicle fuel. It's fine to find an economic use

Status of Jatropha Curcas for Biodiesel Production

for a by-product of existing Jatropha hedgerows/living fences (or wild trees) but, as Mike points out, quite wrong to promote plantations whose viability would depend on a single processor without all the numbers being laid on the table - and then the numbers would need to be very good, alongside a gaze into the crystal ball of long-term energy prices. Jatropha plantations promotion could, as he infers, make farmers poorer rather than richer. We concluded so at MAFE in 2002 - but then oil prices were a fraction of what they are today.

Philippines:

Pat Dugan

(excerpt) “In collaboration with several of our government agencies here, Fred Po has conducted studies on production of bio-diesel fuel from different sources including Jatropha. Prior to the recent oil price increase, his calculations indicated that bio-diesel from Jatropha might not be competitive at the pump with regular diesel, but could be competitive at the village level if the fuel is used in-situ to power Lister-type engines. Fred also said the Jatropha can be processed at the village level using relatively simple technology.”

Zimbabwe

Mike: We have been investigating the possibility of growing Jatropha in Zimbabwe, with great difficulty so far. I am in total agreement with most of what you say. If this crop is going to be grown to benefit anybody it has to be done on a viable commercial basis with the best possible

Status of Jatropha Curcas for Biodiesel Production

inputs. The Zimbabwean government's stance at the moment is that the crop must be grown in marginal areas. Thus you break your back to plant and look after the stuff for 4 years with very little return. The poorer subsistence farmers can hardly feed themselves, now they are being told that if they plant these trees they will become rich, however it takes 4 years to see any income. No way they are going to plant it. Many of the marginal areas in Africa are natural forests or grasslands. The government is saying lets change these natural areas to Jatropha plantations. No way I am going to do that when there is fertile land in decent rainfall areas available. The government states that this land (nonmarginal) must only be available for food production. We have also found it difficult to find good information on the available seed and varieties. We do not want to go ahead and plant trees that will be outdated in 2-3 years.

We have done our own costings as per current costs in the country and we predict that you will not get away with anything under US\$1500-2000 per hectare prior to production in season 3-4. Thus you only see benefit in around season 6-7 on your investment. It does look good after this though. This is a problem as the banks will not finance you for more than 18 months and there is a land tenure issue.

I am also finding it difficult to get exact information on yields dependant on agricultural practices used.

All this said and done I have no doubt that globally we need to secure our energy future and growing Jatropha for end use as diesel is one way. The region imports all its fuel requirements thus making it more viable

Status of Jatropha Curcas for Biodiesel Production

than in countries that produce their own crude oil. It will allow smaller commercial companies to produce fuel to compete with the oil companies. Stuart Hall

Haiti

Email exchange between the author and Marc Portnoff, Senior Scientist at the Carnegie Mellon Center for Advanced Fuel Technology, who is promoting a Jatropha project in Haiti. All, Mike raises a valid point about how does one interpret the "body of knowledge" that is in the literature. The papers on oil properties and uses seem to be based on good science. As I am not an agriculturist, Mike may be correct that the papers concerning yields are not hard science but anecdotal. Maybe Gael could offer comment on this point.

It is clear, that most of the scientific work being done in India, China, and Indonesia are more targeted to plantations where water and other Ag inputs are planned. In most of these cases, the scientific studies have not been completed. For example, the Indonesian Institute of Agriculture at Bogor (working with Japanese scientists) has only been working with Jatropha since 2003. They report actual yields of 4 kg/plant/year and are forecasting 7-8 kg/plant/year. These however are e-mail correspondences. I have no peer review scientific papers to confirm these numbers.

Marc Portnoff

Senior Scientist

Carnegie Mellon Center for Advanced Fuel Technology

Status of *Jatropha Curcas* for Biodiesel Production

Note:

Most of the information used in this document was drawn from a limited number of documents found on the internet and are cited below. There is a plethora of papers written on Jatropha (**some selling “snake oil”**), and the most extensive bibliography as well as research contacts can be found in the IPGRI study. Some of the studies are dated; therefore, there may be more up to date accurate data on yields and economics based on more recent calculations of the cost of diesel fuel. Specific sources of information are not cited in this paper, but they can be found by reading the following documents.

V. Biofuel Development Programme in Chhattisgarh*

In the scenario of ever increasing petroleum prices in international market, Planning Commission, Govt. of India launched “National Mission on Biodiesel” with a view to find cheap and renewable liquid fuel based on vegetable oils. The report of “National Mission on Biodiesel” was submitted in the year 2003 identifying *Jatropha* (Ratanjot) as the proper oil-seed for extracting required vegetable oil for converting it into the biodiesel as a replacement to petrodiesel.



A: oil extraction

Status of Jatropha Curcas for Biodiesel Production

It may be mentioned here that *Jatropha* oil till then found very few takers being non-edible in nature and coming from forests spread over large area. As per “National Mission on Biodiesel” report, following objective were to be achieved on continuous basis :-

- ◆ Utilizing barren Govt. land besides farmers’ fallow land.
- ◆ Generate additional employment for the rural masses
- ◆ Increase green cover for overall environmental improvement
- ◆ Augmenting farmers’ income from their fallow land through sale of seed.



B: oil purification

- ◆ Producing biodiesel to achieve energy security goals

Status of Jatropha Curcas for Biodiesel Production

- ◆ Using biodiesel for running DG Sets in far-flung rural areas for power generation

Potential for Biofuel in Chhattisgarh

In line with “National Mission on Biodiesel”, Chhattisgarh State Govt. has taken-up an exhaustive programme for planting *Jatropha* on 10 lac hectares fallow and degraded forest land available in the State by the year 2012. This includes land belonging to farmers also, which is lying unutilized for want of proper soil strata.

Govt. of Chhattisgarh has setup a specific agency named “Chhattisgarh Biofuel Development Authority (CBDA)” on 26.01.2005 for promotion of biofuel programme in the State. The aims and objectives of CBDA are

- i) Promote R and D facility for undertaking need based research, develop appropriate technology and extension packages to attain the targeted output.
- ii) Increase rural income and ensure women empowerment
- iii) Generate rural employment
- iv) Promote Renewable Energy through harnessing of biofuel energy.
- v) Growing TBOs and extracting Biofuel through identification of areas conducive for TBOs.
- vi) Reduce the import bill of oil for the country/State
- vii) Promote availability of organic manure.
- viii) Reduce toxic emission during combustion of Biofuel, which is practically free of sulphurous compound.
- ix) Reduce green house gas emissions through substitution of fossil fuels with plant oils based fuels.

Status of *Jatropha Curcas* for Biodiesel Production

Chhattisgarh has 44% of its geographical area under forest cover, which produces numerous types of tree borne oil seeds (TBOs) such as *Jatropha*, Karanj, Mahua, Kusum in abundant quantities and thus provides ample opportunities for promotion of biofuel programme in Chhattisgarh State. Substantial fallow land is

* *Shri R.K. Chaturvedi Project Officer, CBDA, Chhattisgarh* also available for undertaking fresh plantation of TBOs such as *Jatropha*, Karanj etc. It is estimated that by undertaking plantation of *Jatropha*/Karanj on 10 lac hectares of fallow land in the State of Chhattisgarh, following production will accrue -

Jatropha seed = 100 lac ton

Biodiesel = 30 lac ton

Deoiled cake (Bio manure) = 70 lac ton

Glycerol = 5 lac ton

Biogas = 35000 lac cu.m.

Electricity = 700 MW

Thus there is huge potential in Chhattisgarh for biofuel projects through private investment.

Status of *Jatropha Curcas* for Biodiesel Production



C: reactor

Policy initiatives of Chhattisgarh Government

The Govt. of Chhattisgarh is targeting degraded forest land, Govt. fallow land and barren/unused land belonging to farmers for plantation of TBOs, so that the set objectives are met within the time frame. Various policy initiatives taken by the State Govt. are summarized as under -

Status of *Jatropha Curcas* for Biodiesel Production



D: biodiesel tank



Supply of Jatropha sapling to farmers

Status of *Jatropha Curcas* for Biodiesel Production

Supply of Jatropha sapling to farmers

Raising *Jatropha* saplings on nurseries/farms belonging to Forest Department, Agriculture Department, Forest Development Corporation, Chhattisgarh State Renewable Energy Development Agency (CREDA), Agriculture University etc. and distributing these *Jatropha* saplings for plantation on unused/barren land belonging to farmers of the State. Upto 500 *Jatropha* saplings are distributed free and thereafter Rs.0.50 per plant is charged from the farmers. One farmer can take upto maximum of 5000 *Jatropha* saplings for planting on his barren land.

Land and allotment policy for investors

To accelerate TBO plantation as well as biodiesel production, Govt. of Chhattisgarh has come out with an innovative policy for allotting land to private investors who propose to undertake a composite projects involving TBO plantation as well as setting up of a biodiesel plant of appropriate capacity. To this effect Govt. Notification No. F-4-59/Seven/2005 dtd. 03.09.2005 has since been promulgated. Salient points of this notification are -

- a) Wasteland in different districts shall be identified by the district committee constituted under the Chairmanship of District Collector.
- b) An Indian Company or Partnership Firm or Registered Society would be eligible to get Govt. wasteland on lease for *Jatropha*/ Karanj plantation and installation and running of biodiesel processing unit.
- c) Wasteland not exceeding 200 hectares may be allotted to the lessee by

Status of *Jatropha Curcas* for Biodiesel Production

the State Govt. on recommendation of District Collector. However, State Govt. may allot more than 200 hectares of the wasteland also.

d) Wasteland shall be allotted for 10 years initially subject to its renewal for further period of 20 years.

e) Lessee shall invest 50% of total project cost within first 2 years and invest total project cost within 3 years of allotment.

f) Security deposit of Rs.10 lacs has to be deposited for land allotment upto 200 hectares which is refundable without interest to the lessee in case entire project cost is invested within 3 years of allotment and project is also completed.

g) The annual lease rent is -

1st year = Rs.100/- per hectare

2nd to 5th year = Rs.225/- per hectare

6th and 7th year = Rs.500/- per hectare

8th year and onward = Rs.1000/- per hectare

h) If during the course of lease period, the lessee contravenes any provision/condition of the lease, State Govt. may, after giving an opportunity of being heard to the lessee, cancel the lease.

Support price for purchase of TBOs

To ensure that farmers going in for planting *Jatropha* on their fallow land get proper price for their TBOs produce, Govt. of Chhattisgarh has declared support price for procurement of the same. The support prices fixed for various seeds/oil are as under :-

Status of Jatropha Curcas for Biodiesel Production

Jatropha seed = Rs.550 per quintal

Karanj seed = Rs.500 per quintal

Jatropha/Karanj oil = Rs.18 per litre

Chhattisgarh State Minor Forest Produce Federation, Raipur has been made State Procurement Agency, which is procuring the *Jatropha*/Karanj seeds through its 913 primary forest cooperative societies spread all over the State.

Progress Achieved So Far

CBDA has promoted *Jatropha* plantation on unutilized land of the farmers by providing *Jatropha* saplings free of cost or on nominal supply price and simultaneously inviting private investment for *Jatropha* plantation on Government land besides setting up biodiesel processing units, in a big way. Various achievements made so far are summed up as under -

- i) Identified Govt. waste/fallow land for *Jatropha* plantation.
- ii) Formation of task force in each district under Chairmanship of District Collector.
- iii) Raised 6 crores *Jatropha* saplings in nurseries of different departments and got them planted on about 24000 hectares of barren/fallow land belonging to farmers and also on Govt. fallow lands during the year 2005.
- iv) During the year 2005-06 arranged 95 farmer's trainings for *Jatropha* cultivation.

Status of *Jatropha Curcas* for Biodiesel Production

- v) Got more than 200 stage shows arranged in rural areas for sensitizing farmers about the benefits of biofuel programme.
- vi) Biodiesel plant of 3 KL/day capacity set up at Raipur.
- vii) Govt. support price for Karanj/*Jatropha* Seeds and their oil declared.
- viii) Chief Minister's official vehicle running on pure biodiesel.

Action Plan For The Current Year (2006-07)

During the current year, action plan for Biofuel Development is as under

- i) *Jatropha* plantation
 - a) 16 crores *Jatropha* saplings will be planted/distributed during the year 2006 as per last year's procedure.
 - b) Pilot demonstration plantation on 300 acres fallow land in each district
 - c) Encouraging private investors for contract farming
 - d) Allotting Govt. waste land on lease to private investors for *Jatropha* plantation to ensure uninterrupted raw material supply for their Biodiesel Plant.
- ii) Exemplary farmer's/departmental plantation to be suitably awarded.
- iii) Scheme finalized for setting up biodiesel based power generators for rural electrification in a cluster of 50 remote villages.
- iv) Govt. Notification issued for allotting Govt. Revenue fallow land on lease to private investors (Company, Partnership Firm or Registered Society) to undertake *Jatropha*/Karanj plantation and also to setup Biodiesel plant. So far 152 proposals have been received from the

Status of Jatropha Curcas for Biodiesel Production

investors out of which in 92 cases process of allotting land on lease at the level of District Collectors is going on.

v) “State of the Art” Laboratory for exercising quality control on *Jatropha*/ Karanj oils and biodiesel, being setup with a total outlay of Rs.1.5 crore in association with a local NGO.

Projected Socio Economic Benefits To Chhattisgarh State

Once targeted area of 1 million hectare is brought under *Jatropha* plantation by the year 2012, various socio economic benefits accruing out of biofuel programme to the State will be as underi) As on an average 1 hectare of *Jatropha* plantation yields 2 KL biodiesel, approximately 20 lac tons of biodiesel will be produced, valued at Rs. 5000 crores every year (at current rate of Rs.25/- per litre). The present annual consumption of diesel in Chhattisgarh State is around 8.0 lac KL.

ii) For undertaking *Jatropha* plantation on 10 lac hectares of fallow land, manual labour to the tune of almost 3000 lac mandays would be required for digging the pits, planting the saplings, intercultural operations and other agricultural operations for first 2 years. This alone will translate into almost Rs.1800 crore as the labour wages for rural masses (as per current labour rate). Manual labour involved in post harvest operations besides processing oil for making biodiesel, would be over and above this.

iii) The proposed large scale *Jatropha* plantation will substantially reduce green house gases in the atmosphere by absorbing CO2 from

Status of *Jatropha Curcas* for Biodiesel Production

atmosphere. This will also provide opportunity to the State for trading CO₂ internationally, to the countries having much higher pollution level, in the light of Kyoto protocol. On an average 1 hectare of *Jatropha* plantation absorbs 10 tons of CO₂ from the atmosphere and as such 1 million hectares shall result in absorption of 10 million tons of CO₂ from atmosphere. Even on the basis of prevailing trading rate of \$ 7.00 per ton of CO₂, State will be in a position to trade CO₂ to the extent of more than Rs.300 crore, internationally every year.

iv) By processing *Jatropha* crop of 1 million hectare, apart from getting 20 lac tons of biodiesel, 40 lac tons of premium quality of bio-manure would be received for use in agriculture sector. This bio-manure (possessing 6% N) besides providing much needed major and micro nutrients to the soils will also help in preserving soil humus, so much necessary to preserve soil quality which is getting imbalanced due to persistent use of chemical fertilizers. Even by taking a nominal cost of Rs. 2/- per kg for this bio manure, the value of bio manure so produced will be in the region of Rs. 800 crore annually.

v) Other benefits accruing out of the biofuel programme shall be overall environmental improvement, improved soil fertility of barren land, achieving energy security goals locally, saving appreciable cost being incurred on transportation of fossil fuel at present, besides generating additional employment at village level through large scale plantation and also installation of oil expeller/ transesterification units expected to come up in large numbers.

Biodiesel through *Jatropha Curcas* A Critical Analysis

Biodiesel is an eco-friendly, alternative fuel prepared from renewable resources i.e. vegetable oil (edible or non edible) and animal fat. These natural oil and fat is made of triglycerides. The triglycerides when treated have striking similarly to petroleum-derived diesel and are called “Biodiesel”. As India is already deficit in edible oil requirement, nonedible oil may be material of choice for producing biodiesel. For this purpose *Jatropha curcas* considered as most potential source. Biodiesel is produced by transesterification of oil obtains from the plant.

Jatropha curcas has been identified by planning commission’s Task Force as the most suitable Tree Borne Oil (TBO) seed plant for production of biodiesel both in view of the non-edible oil available from it and its presence throughout the country. The capacity of *Jatropha curcas* to rehabilitate degraded or dry lands, from which the poor mostly derive their sustenance, by improving water retention capacity, makes it additionally suitable for up-gradation of land resources. With the agricultural correlation *Jatropha curcas* is seen as the solution for pollution. It is a non-toxic, 100% natural, bio degradable supplement for diesel, excited by the possibility of its wide-scale use in transport, electrical equipment and other machines that runs on diesel. CBMD is an organization, which is promoting the Biodiesel issue since its inception; to provide technical knowledge to the stakeholders (like scientists, farmers, students, Entrepreneurs etc.) by organizing need based conferences, seminars, workshops and training programs. We have

Status of *Jatropha curcas* for Biodiesel Production

also partnered in plantation of the *Jatropha curcas* by farming, across the country. The tests on these plants revealed their significance on growth; yield, disease resistance, dormancy etc. in these areas. CBMD's plantations span in different agro climatic zones, comprising the Chhattisgarh Plain Zone, Arid Western Plain Zone, Malwa Plateau Zone and Southern area in the country. On the basis of these programs, trainings and plantations team of experts conducted **SWOT-** analysis.

SWOT Analysis

(i) Strength (Biodiesel)

- It is a Renewable energy source.
- It Balances Carbon dioxide in Environment.
- Lesser polluted emissions than fossil fuel.
- The fuel Production Technology (Extraction and transesterification process) is Simple and Proven Technology in Indian Conditions.
- It is a non-edible oil source
- It's a perennial crop having 30 years long life span.
- High oil content in seeds comparatively other TBO varieties.
- *Jatropha curcas* plant is disease resistant plant.
- It is not sensitive to climatic change.
- It can be grown in arid area.
- Due to dormancy character, Survives in Various weather conditions.
- Plant leafs and deoiled cake can be used as organic manure.

Status of *Jatropha Curcas* for Biodiesel Production

(ii) Weakness

- Lack of good quality seeds and planting material.
- Wild behavior
- Most of the information's are assumptions.
- Non-availability of Genuine and Authentic Data And Information
- No tried and tested cultivation experiences.
- Variable output
- Variable oil content
- Long gestation period of crop.
- No model available for effective use of by-products
- Having Vegetative Propagation Properties removal from Farm is difficult
- No Commercial output available with out ample Farming Inputs.
- No economic viability for mono crop.

(iii) Opportunity

- ◆ Ever increasing Crude oil price.
- ◆ Employment generation capacity in Rural areas
- ◆ Better utilization of cultivable waste land
- ◆ Low gestation period comparative to other non-edible oil sources
- ◆ Having carbon credit value (Kyoto protocol)
- ◆ Required in large quantity to sustain huge demand.
- ◆ With use of Biotechnology encouraging primary results.

Status of *Jatropha Curcas* for Biodiesel Production

(iv) Threat

- Over publicity
- Abundance of misleading information
- Mall practice in input materials
- Costly Input materials.
- Low (NO) support price for seeds.
- No sustainable Procurement Mechanism available in the Market.
- Requirement of seeds in large quantity even to fulfill demand of 5% blending with diesel.

Conclusion

As a substitute for fast depleting fossil fuel Bio diesel had come to study in future. It should also serve to reduce and maintain the price of fuel. As the constraint described under SWOT Analysis our country has good opportunity to produce Bio diesel and save the foreign exchange. *Jatropha* can help to increase Rural Employment and Income. It will also provides us self-sustainability and help us in alleviation of poverty from rural areas. *Jatropha* is suitable for cultivable wasteland by which can retain soil fertility of fallow lands. Scientific methodology should be developed to achieve economic viability for cultivators (Farmers) by addressing cultivation myths like sustainable yield, water requirement, Input material etc.

- The experiments carried over through out the country are few in numbers and varied. Hence may not be enough to reach any

Status of Jatropha Curcas for Biodiesel Production

substantial Conclusion. However *Jatropha* plantation is not advisable High yielding cultivable land to Marginal farmers.

- The sustained and commercially viable production of oil seeds and diesel, there after in large volume is yet to be tested.
- Higher level of research is required for sustained and regular out put from *Jatropha* plants.
- Commercial viability of *Jatropha* plantation can be attained through proper mix of intercropping with the *Jatropha* plants.
- The behavior of *Jatropha* plants is varied in different agro climatic Zones as well as regions across the country. Hence it shall be daring to give monotonous verdict in favour of *Jatropha*. At some places its production was very good but some regions its growth and yield were not satisfactory.
- Use of other non-edible oil source shall be experimented for bio diesel production like Pongamia (Karanj), mahua, ber etc,
- With effective use of Biotechnology, problems related to seeds, yield and oil content could be addressed.
- Fulfilling demand of 5% blending may not be possible in immediate future.
- *Jatropha* cultivation and bio diesel production should be looked upon as a tool for fulfilling Energy need for a village.

Expected Future for Jatropha Curcas:

Status of *Jatropha Curcas* for Biodiesel Production

Biodiesel has distinct advantage as an automotive fuel. Initial cost may be higher, but by using of intercropping techniques and other multilevel production technologies will play a critical role in reduction in production cost and making the fuel economically viable. The following points may be considered for its development in India.

- Pilot projects and R&D work on Biodiesel needs to be encouraged and supported to establish techno-economic viability of largescale production.
- Establishment of production and processing specification, with test methods.
- Govt. should provide energy education on biodiesel program, related information, and database for with authentic information dissemination among the stakeholders.
- Scientific organizations should determine standard relationship between inputs and yield in different climatic, environmental and social situation.
- Bio-technological interventions for development of good quality of planting materials should be encouraged.
- Govt. should establish a dedicated agency for consolidated efforts in promotion and development of bio diesel with adequate authority and funding.
- This agency should develop various services and schemes for technological and financial availability for *Jatropha* plantation and biodiesel projects.
- Need for establishing scientific procurement mechanism.

Status of *Jatropha Curcas* for Biodiesel Production

- Model for fulfilling village energy needs through *Jatropha* plantation and biodiesel production shall be experimented at some places through Panchayatraj institutions.
- Govt. should include collection of non-edible oil seeds in various schemes such as *Grameen Rozgar Yojana*.
- *Jatropha* plantation and seed collection in various forest regions should be encouraged by ministry of Forest.

BIBLIOGRAPHY

- [1] info@biodieseltechnologiesindia.com
- [2] SOUMITRA BISWAS, G.SRIKANTH & NIRMALA KAUSHIK
- [3] Technology Information, Forecasting and Assessment Council (TIFAC) Department of Science & Technology, New Delhi
Source The Hindu -03 Aug 06
- [4] Dr. R.S. Kureel *Director National Oilseeds and Vegetable Oils Development Board 86, Sector-18, Gurgaon*

Status of *Jatropha Curcas* for Biodiesel Production

[5] Vaibhav Dange *Director* Dhanpat Suthar *National Co-ordinator* And P. Santosh Reddy *Project Co-ordinator* *Centre for Bharatiya Marketing Development (CBMD)*, *1st Floor Shiv Shakti Mandir Complex, Sec-8, R.K.Puram, New Delhi-110022* www.cbmd.org, cbmd@cbmd.org

[6] Dr. R.S. Kureel *Director National Oilseeds and Vegetable Oils Development Board* *86, Sector-18, Gurgaon*

[7] Duke, James A.. 1983. *Jatropha curcas* L. (Euphorbiaceae) Physic nut, Purging nut. *Handbook of Energy Crops*. unpublished. Personal correspondence with the author on 04/10/06.

[8] Gaydou, A.M., Menet, L, Ravelojaona, G., and Geneste, P. 1982. Vegetable energy sources in Madagascar: ethyl alcohol and oil seeds (French). *Oleagineux* 37(3):135–141.

[9] TROPILAB INC's webpage (www.tropilab.com/jatropha-cur.html) as cited by Duke (above).

[10] WSU. Wyeth Peter. December 2002. *An Industry and Market Study of Six Plant Products in Southern Africa, Jatropha or Physic Nut*. International Programs, Washington State University, funded by the United States Agency for International Development University of Hohenheim. 1999. Studies on the utilization of *Jatropha curcas* seed cake as an animal feed.

[11] Enterprise Works (formerly Appropriate Technology International). March 1996 to March 2000. *Senegal Jatropha Oil Project*.

[12] IPGRI. Heller, Joachim. 1996. *Physic nut. Jatropha curcas L. Promoting the conservation and use of underutilized and neglected*

Status of *Jatropha Curcas* for Biodiesel Production

crops. Institute of Plant Genetics and Crop Plant Research (IPGRI),

[13] Gatersleben/International Plant Genetic Resources Institute, Rome.
Henning, Reinhard K. (undated) *Jatropha curcas L. in Africa.*
Global Facilitation Unit for

[14] Underutilized Species. Rothkreuz 11, D-88138 Weissenberg,
Germany (henning@bagani.de)

[15] USDA. Personal correspondence with Mike Wiemann. USDA
Forest Service's Forest Products Lab. Madison, WI.

[16] Mike Benge, Senior Agroforestry Officer, USAID (Ret.)
bengemike@aol.com Posted on ECHO's website with permission
of the author. July 2006 and updated August 2006

[17] Duke, James A.. 1983. *Jatropha curcas* L. (Euphorbiaceae) Physic
nut, Purging nut. Handbook of Energy Crops. unpublished.
Personal correspondence with the author on 04/10/06.

[18] Gaydou, A.M., Menet, L., Ravelojaona, G., and Geneste, P. 1982.
Vegetable energy sources in Madagascar: ethyl alcohol and oil
seeds (French). *Oleagineux* 37(3):135–141.

[19] TROPILAB INC's webpage (www.tropilab.com/jatropha-cur.html) as cited by Duke.

[20] WSU. Wyeth Peter. December 2002. *An Industry and Market Study
of Six Plant Products in Southern Africa, Jatropha or Physic Nut.*

[21] International Programs, Washington State University, funded by the
United States Agency for International Development.

[22] University of Hohenheim. 1999. Studies on the utilization of
Jatropha curcas seed cake as an animal feed.

Status of *Jatropha Curcas* for Biodiesel Production

[23] Enterprise Works (formerly Appropriate Technology International). March 1996 to March 2000.

[24] *Senegal Jatropha Oil Project* .

[25] IPGRI. Heller, Joachim. 1996. *Physic nut. Jatropha curcas L. Promoting the conservation and use of underutilized and neglected crops.* Institute of Plant Genetics and Crop Plant Research (IPGRI), Gatersleben/International Plant Genetic Resources Institute, Rome.

[26] Henning, Reinhard K. (undated) *Jatropha curcas L. in Africa.* Global Facilitation Unit for Underutilized Species. Rothkreuz 11, D-88138 Weissenberg, Germany (henning@bagani.de) USDA. Personal correspondence with Mike Wiemann. USDA Forest Service's Forest Products Lab. Madison, WI. Mike Benge, Senior Agroforestry Officer, USAID (Ret.) bengemike@aol.com Posted on ECHO's website with permission of the author. July 2006 and updated August 2006.

[27] Nitske, W.R.; Wilson, C.M. *Rudolf Diesel: Pioneer of the Age of Power;* University of Oklahoma Press, 1965, p.139.

[28] Shay, E.G. *Biomass Bioenergy* 1993, 4, 227-242.

[29] Anonymous, *Industrial Uses of Agricultural Materials*, published by the Economic Research Service, USDA, September 1995, pp. 15-20.

[30] Shearer, B. *Chemical Marketing Reporter*, March 25,1996, p. 10.

[31] Ahouissoussi, N.B.C.; Wetzstein, M.E. *Industrial Uses of Agricultural Materials*, published by the Economic Research Service, USDA, September 1995, pp. 35-41.

Status of *Jatropha Curcas* for Biodiesel Production

[32] Alternative Fuels Committee of the Engine Manufacturers Association *Biodiesel Fuels and Their Use in Diesel Engine Applications*, August 1995.

[33] Lane, J.C. In *Kirk-Othmer, Encyclopedia of Chemical Technology*; Third Ed.; John Wiley & Sons: New York, NY, 1980, Vol. 11; pp. 682-689.

[34] *Diesel Engine Reference Book*; Lilly L.R.C., Ed.; Butterworths: London, 1984, pp. 22/9-22/12.

[35] *Biodiesel Report*; National Biodiesel Board: Jefferson City, MO, March 1996.

[36] Ervin, C.A. *Federal Register*, **1995** (July 31), **60**, 38976-38977.

[37] Goering, C.E.; Schwab, A.W.; Daugherty, M.J.; Pryde, E.H.; Heakin, A.J. *Trans. ASAE* **1982**, **25**, 1472-1477 & 1483.

[38] Bagby, M.O.; Freedman, B.; Schwab, A.W. *ASAE Paper No.* 1583, 1987 Int. Winter Meeting ASAE.

[39] Batel, W.; Graef, M.; Mejer, G.-J.; Möller, R.; Schoedder, F. *Grundl. Landtechnik* **1980**, **30**, 40-51.

[40] Freedman, B; Bagby, M.O. *J. Am. Oil Chem. Soc.* **1989**, **66**, 1601-1605.

[41] Freedman, B; Bagby, M.O., Khoury, H. *J. Am. Oil Chem. Soc.* **1989**, **66**, 595-596

[42] Harrington, K.J. *Biomass* **1986**, **9**, 1-17.

[43]. Bagby, M.O. In *Proc. 9th Int. Conf. Jojoba Uses, 3rd Int. Conf. New Industr. Crops Prod.*; Princen, L.H., Rossi, C., Eds.; Assoc. Advancem. Industr. Crops. publ. 1996; pp. 220-224.

Status of *Jatropha Curcas* for Biodiesel Production

[44] Knothe, G.; Bagby, M.O.; Ryan, T.W.. III; Callahan, T.J.; Wheeler, H.G. *Soc Automot. Eng., [Spec. Publ.] SP* **1992**, SP-900, 37-63.

[45] Ryan, T.W., III; Dodge, L.G.; Callahan, T.J. *J. Am. Oil Chem. Soc.* **1984**, *61*, 1610-1619.

[46] Clark, S.J.; Wagner, L.; Schrock, M.D.; Piennaar, P.G. *J. Am. Oil Chem. Soc.* **1984**, *61*, 1632-1638.

[47] Klopfenstein, W.E. *J. Am. Oil Chem. Soc.* **1985**, *62*, 1029-1031.

[48] Freedman, B.; Bagby, M.O. *J. Am. Oil Chem. Soc.* **1990**, *67*, 565-571.

[49] Douros, T.; Schindlbauer, H. *Erdoel, Erdgas, Kohle* **1987**, *103*, 228-230.

[50] Freedman, B.; Bagby, M.O.; Callahan, T.J.; Ryan, T.W., III *Soc. Automot. Eng. Techn. Pap. Ser.* **1990**, Paper No. 900343.

[51] Pande, S.G.; Hardy, D.R. *Fuel* **1990**, *69*, 437-442.

[52] Ladommatos, N.; Goacher, J. *Fuel* **1995**, *74*, 1083-1093.

[53] Krisnangkura, K. *J. Am. Oil Chem. Soc.* **1986**, *63*, 552-553.

[54] *Handbook of Chemistry and Physics*; Weast, R.C.; Astle, M.J.; Beyer, W.H., Eds.; 66th Ed.; CRC Press: Boca Raton, FL, 1985-1986; pp. D-272 - D-278.

[55] Bruwer, J.J.; van D. Boshoff, B.; Hugo, F.J.C.; du Plessis, L.M.; Fuls, J.; Hawkins, C.; van der Walt, A.N.; Engelbrecht, A., paper presented at 1980 Symposium, South African Institute of Agricultural Engineers.

[56] Bruwer, J.J.; van D. Boshoff, B.; Hugo, F.J.C.; Fuls, J.; Hawkins,

Status of *Jatropha Curcas* for Biodiesel Production

C.; van der Walt, A.N.; Engelbrecht, A.; du Plessis, L.M., paper presented at the 1980 National Energy Symposium, American Society of Agricultural Engineers.

[57] Bruwer, J.J.; v. d. Boshoff, B.; Hugo, F.J.C.; Fuls, J.; Hawkins, C.; v. d. Walt, A.N.; Engelbrecht, A.; du Plessis, L.M. *Comm. Eur. Communities, [Rep.] EUR 1981*, EUR 7091, Energy Biomass Conf., 1st, 934-940.

[58] Schwab, A.W.; Bagby, M.O.; Freedman, B. *Fuel 1987*, 66, 1372-1378.

[59] Knothe, G.; Dunn, R.O.; Bagby, M.O. *INFORM 1996*, 7, 827-829.

[60] Mittelbach, M. *Liq. Fuels, Lubr. Addit. Biomass, Proc. Altern. Energy Conf.*; Dale, B.E., Ed.; American Society of Agricultural Engineers, St. Joseph, MI, 1994.

[61] Andrews, A.S.; Quick, G.R. *Energy Agric.* **1984**, 3, 323-332.

** The research review is based on the M.Phil dissertation entitled “**Potential of *Jatropha curcas*, (TBO) for Energy Production in INDIA**” submitted by Mr. Mr. Abhimanyu Singh TO Periyar Institute of Distance Education (PRIDE), Periyar University, Salem for the examination of 2006-2007 under the guidance of Dr. S. Anand Giri, Professor & Head, Chemistry Department, DIT, Grater Noida.

Status of *Jatropha Curcas* for Biodiesel Production

DR. S. ANAND GIRI