Jatropha Curcas and Its Potential Applications; A Compilation Paper on Plantation and Application of Jatropha Curcas

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Abstract: *Biofuel has been regarded as potential alternative fuel for partial substitution of petro-diesel. Jatropha curcas, which is one of the sources of bio-diesel, are easily available in tropical and sub-tropical areas. A number of plantation practices and engine test runs have been conducted across the world, which has been successful to demonstrate it as alternative source of fuel. The article here thus tries to compile some of the important aspects of Jatropha, like plantation requirements, applications, which is hoped to be an aided tools for researchers and farmers to internalize in their respective areas for the promotion of jatropha curcas to provide complimentary support in substituting petro-diesel in future, especially in developing countries like Nepal.*

1. Introduction:

Jatropha curcas (Linnaeus) belongs to the family Euphorbiaceae and is thus closely related to other important cultivated plants like rubber tree and caster etc. The plant is believed to be a native of South America and Africa but later spread to other continents of the world by the Portuguese settlers (Gubitz et al, 1999). The Arabs have been using this plant for medicine purpose. Today it is found in almost all the tropical and sub-tropical regions of the world. There are more than 200 different names for its great significance to man and the various possibilities of its uses. When the botanist Carl Von Linne first classified the plants in 1753, gave it the botanical name "Jatropha curcas" from the Greek word "Jatros" meaning a "Doctor" and "trophe" meaning "nutrition". Even Linne had realised the potential of this plant for medicinal purposes (Gubitz et al, 1999). The plant is regarded as a shrubs/small tree with height generally ranging from 3-5 metre (m). It has been estimated that the life of the plant is up to 50 years. Different varieties of the plant can be found which are generally Cape Verde, Nicaragua, Ife-Nigeria, non-toxic Mexico (The Biomass Project, 2000).

The productivity of the plant was found varying from 1.5 to 6 tons/ha/year (Goswami, 2006). The harvesting period of jatropha seed are considered from 5 months old, whereas the productivity is stable after 1 year old. Similarly, yield of Jatropha seed per tree has been found as 0.5 to 5 kg per tree per season. (Lele, 2006).
Some of the basic requirements and practices adopted for the cultivation of jatropha as being reported in different literatures are as follows;

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2. Plantation of Jatropha Curcas

2.1 Soil requirement

Jatropha curcas can be grown potentially over wastelands which require re-vegetations. Jatropha curcas is a wild growing hardy plant well adapted to acid and moisture demand and can come up stony, gravelly or sallo and even calcareous soils. It can be conveniently propagated from seeds as well as branch cuttings. It is therefore, possible to plant large areas with Jatropha curcas without requiring nursery plants raised in polythene bags, therefore, saving foreign exchange as the row material for polythene bags has to be imported. However, it can also be grown as a profitable non-edible oil crop on irrigated and partially irrigated lands as a perennial crop (Radich, 2004).

2. 2 Climates requirements

Jatropha can be grown over a wide range of arid or semi-arid climate conditions. For the emergence of seeds, hot and humid climate is preferred. Therefore, fairly warm summers with rains are beneficial for proper germination of seeds. The flowering is inducing in rainy season with reduction in temperature and plants bear fruits in winter. Jatropha can be cultivated with success in areas with scanty to heavy rainfall (Gubitz et al, 1999).
Jatropha can be grown in habitat of tropic/subtropical areas, with a suitable rainfall of 200-1500 mm/year (The Biomass Project, 2000).

2.3 Spacing and seeds rate

For planting 1 hectare, around 5 to 6 kg of seeds is enough. The distance between the two rows should be 2 metres and the distance between two plants should also be 2 metres. This spacing will accommodate 2500 plants/ha under irrigated or partially irrigated conditions. On rainfed wastelands, high-density plantations at 2m. x 1m. or 1.5 x 1.5 metre accommodating 5000 or 4444 plants per hectares respectively, was desirable ((Radich, 2004; Gubitz et al, 1999).

2.4 Propagation

Jatropha can be propagated from seeds as well as from cuttings. Seeds or cutting twigs can be directly planted in the main field. Otherwise, seedlings grown in polybags are transplanted in the main field.

(i) Direct Planting: The lands should be ploughed once or twice depending on the nature of soil. In the case of heavy soils, deep ploughing is given whereas in light soils, shallow ploughing is enough. The seed/cutting should be planted in the main field with the onset of monsoon. Two seeds should be dibbled at each spot at a spacing indicated above. When the seedlings are 4 weeks old, weaker seedlings should be removed to retain one healthy seeding on each spot and the seedlings so removed could be used for gap filling (Gubitz et al, 1999).

(ii) Transplanting: Main field is prepared by digging small pits of 30 x 30 x 30 cm at specified spacing indicated under Para 4.3 above. Pits are filled with soil and compost or organic manure at the rate of 400 g per pit. Kilogram capacity filled with soil and organic manure mixture 7:10:05 at the rate of 100 g per poly bag plus 400 g soil. Two seeds should be sown around 6 cm deep in each poly bag and watering should be done regularly. When the seedlings are around 4 weeks. Weaker of the two seeding should be removed and used for gap filling (Gubitz et al, 1999).

2.4.5 Inter-Cultivation

The field should be kept free from weeds at all the times. Around 3-4 weedings in the initial period are enough to keep the field free weeds until the crop crosses the grand growth period stage. Light harrowing is beneficial (Gubitz et al, 1999).

2.6 Irrigation

In case the monsoon is proper and well distributed, additional irrigation during rainy season is not required. During dry period, the crop should be irrigated as and when required.

3. Jatropha Oil Extraction

Two main methods of extracting the oil have been identified. They are the chemical extraction method using solvent extraction with n-hexane and the mechanical extraction method using either a manual ram-press or an engine driven- expeller. It has been reported that solvent extraction with n-hexane could produce about 41% yield by weight of oil per kg of the jatropha seed. In addition to this, it has been reported that the dry seed of J. curcas would yield about 30–38% of crude oil using an engine driven – expeller (Forson et al, 2004).

Similarly, testing undertaken in the Technology Consultancy Centre (TCC) of the Kwame Nkrumah University of Science and Technology (KNUST) for the extraction of Jatropha oil, using a simple mechanical ram-press, showed that shelling of about 32 kg of unshelled seeds, obtained resulted into 20 kg of the shelled fruit. From the shelled fruit, 19.6 kg of dough was obtained after the milling process, which subsequently yielded 6.88 kg of oil representing about 21.5% of crude oil by weight per kg of the unshelled dry weight of the J. curcas seed. On the assumption that a dry seed of J. curcas contains about 55% of oil, the efficiency of the mechanical extraction process used was estimated to be 39% whereas a value of 98% is reported for extraction with n-hexane. It is suggestive from the test that the mechanical ram-press used needs some form of improvement (Forson et al, 2004). The process adopted for the oil extraction includes, initially, shelling of Jatropha seeds to remove seed coat. The shelled seeds were milled into dough using the corn mill machine. It has been reported that the moisture content has to be maintained at 12% weight basis (wb). If the moisture content is less and above than 12 %, water addition and removal respectively has to be done. The dough was then rolled into balls of 1 kg by weight. Seeds balls were heated to 70-80^0 C in an oven. Heated rolled were then pressed using the ram press and then filtered (Forson et al, 2004).

3.1 Bio-diesel Production and Energy requirement

Carretto et al illustrated that by means of emergy[2] analysis, quantification of the environmental support to the bio-diesel production, can be evaluate at the level of the biosphere. It has been reported that the total energy requirement to harness 1 MJ of bio-diesel is equal to 1.398 MJ of primary energy, of which 35% is derived from fossil fuels. The sectoral consumption of energy for the production of bio-diesel has been reported as constituting 6% (Agriculture), 15 % (Crushing), 77 % (Conversion), and 2 % (Transportation) (Carretto et al, 2004).

Similarly, emission charged on the production of bio-diesel comprises of 13% (Agriculture), 13 % (Crushing), 7 % (Conversion), Enduse (65%) and 2 % (Transportation) (Carretto et al, 2004).

[2] Moore. R.L, 1943 introduced concept of emergy, i.e " the total amount of exergy of one kind (usually solar) that is directly or indirectly required to make a given product or support a given flow"

3.4 Application of Jatropha Curcas

Jatropha plant has been found for using on different aspects in different communities in the world. It has been found that the plant is used as an ornamental purpose, chiefly in Africa and America, growing in gardens for their ornamental foliage and flowers. It is also commonly grown as a live hedge around agricultural fields as it can be easily propagated by seeds or branch cutting as is not browsed by goats or cattle. It can be cut or lopped at any desired height and is well adapted for hedges around agricultural fields. (Gubitz et al, 1999).

However, on the basis of different literatures, some of the economic activities through the use of Jatropha can be broadly classified as follows,

3.4.1 Potential as an oil crop

Gubitz et al reported that analysis of Jatropha curcas seeds shows that it contains; moisture 6.62; protein 18.2; fat 38.0; carbohydrates 17.30; fibre 15.50; and ash 4.5% (Gubitz et al, 1999). The oil content is 35 to 40% in the seeds and 50 to 60% in the kernel (Gubitz et al, 1999). The oil contains 21% saturated fatty acids and 79% unsaturated fatty acids (Gubitz et al, 1999). It has also been found that there are some chemicals element in the seeds which possess poisonous and purgative properties and render the oil non edible for human consumption. It is also been stated that technologies are now available, whereby it could be possible to convert Jatropha oil into an edible oil which could prove to be a boon for developing countries (Gubitz et al, 1999). The oil is obtained from decorticates seeds by expression or solvent extraction and is known in trade as Jatropha. In general, the oil is reported to be mixed with groundnut oil for adulteration. This indicates the possibilities of obtaining edible oil from Jatropha oil base (Gubitz et al, 1999).

3.4.2 Potential for industrial use

Jatropha oil has very high saponification value and being extensively used for making soap in India and other countries. At present Jatropha curcas oil is being imported to meet the demand of cosmetic industry. In china, a varnish is prepared by boiling the oil with iron Oxide. In village it is used as an illuminant as it burns bricants and candles as in case of castor oil. It is used for wool spinning in England. The protein content Jatropha oil cake may be used as raw material for plastics and synthetics fibres. It would also be advantageous to make use of Jatropha oil as hydraulic oil (Gubitz et al, 1999).

3.4.3 Potential as medicinal plant

The latex of Jatropha curcas contains an alkaloid known as "Jatrophine" which is believed to be having anti-cancerous properties. Curcas oil possess purgative properties (urging does 0.3 to 0.6 cc or 5 to 10ml). It differs from castor oil in that it has a low viscosity. It is used as castor oil in that it has a low viscosity. It is used as an external application for skin diseases and rheumatism, it is reported to be abortificient and also efficacious in dropsy, sciatic and paralysis.

It can also be found that the Tender twigs of the plant are used for cleaning teeth. The juice is reported to relive toothache and strengthen gums. The leaf juice is used as an external application for piles. It is also applied for inflammations of the tongue in babies. The twig sap is considered stypic and used for dressing wounds and ulcers. An emulsion of the sap with benzyl benzoate is said to be effective against scabies, wet eczema and dermaties. A decoction of leaves and roots is given for diarrhea. The root is reported to contain yellow oil with strong antelmintic action. The root bank is used to external application for sores. A decoction of the bark is given for rheumatism and leprosy. Similarly, roots are also reported to be used as antidote for snakebite (Gubitz et al, 1999).

3.4.4 Potential as raw material for dye

The bark of Jatropha curcas yields a dark blue dye which is reported to be used in Philippines for colouring cloth, finishing nets and lines. The dye may be extracted from leaves and tender stems and concentrated to yellowish syrup or dried to blackish brown lumpy mass. The dye imparts to cotton different shades of tan and brown which are fairly fast. Further research in this field can open up great possibilities (Gubitz et al, 1999).

3.4.5 Potential for enrichment of soil

Jatropha oil cake is rich in nitrogen, phosphorous and potassium and can be used as organic manure. This indicated the potential of this plant in initiating the process of reduction of surplus livestock maintain by the rural folk in India, mainly for the purpose of obtaining cow -dung as manure. Tender branches and leaves are also used as manure for coconut trees. Jatropha oil cakes can, hopefully, replace synthetic fertilizers by undertaking plantations of Jatropha curcas on wastelands, Jatropha curcas leaves provide plentiful organic matter and increase the microbial activity including earthworms which is an indication of ecological improvement of site (Gubitz et al, 1999).

Figure: Seed Cake after Oil expulsion

3.4.6 Potential as a feed stoke

Jatropha leaves are used as fed for the tusser silk worm. The oil cake is rich in protein but contains some toxic principle and as such it is considered unfit for use as cattle feed. But it is reported that the poisonous principle appears to exist in the alcohol soluble fraction of the oil. With suitable research it could be possible to convert the nonedible oil-cake into protein rich cattle and poultry feed on a massive scale (Gubitz et al, 1999).

3.4.7 Potential as insecticide/pesticide

The seeds are considered anthelemintic in Brazil. They are ground with palm oil and used as rat poison in Gabon. Aqueous extract to leaves is reported to have insecticidal properties. In Ghana, the leaves are for fumigating houses against bed bugs. The ether extract shows antibiotic activity against Staphylococcus aureus and Escherichia coil. The juice of the whole plant is used for stupefying fish in Philippines (Gubitz et al, 1999).

3.4.8 Potential as profitable agro forestry crop

Owing to its multiple uses, there exists unlimited potential for extensive and convenient marketability of Jatropha oil, for indigenous as well as foreign markets. It has unlimited potential for import substitutions as well as export other countries for cosmetic industry and as a vehicle fuel. Simple and cost effective technology of growing Jatropha with or without irrigation makes it promising and profitable agro forestry crop both under rainfed and irrigated conditions ensuring optimal utilization of land, man power, water and financial resources. It is a crop with low capital investment, short gestation period, long productive period, unlimited employment potential in the rural areas; potential for certain of productive assets; boosting of village based industries; providing nonconventional energy in a decentralized manner and above all having a potential for wastelands development (Gubitz et al, 1999).

3.4.9 Potential as non conventional energy crop

Jatropha oil is an environmentally safe, cost effective and renewable source of non-conventional energy as a promising substitute to Hydelpower, diesel, kerosene, LPG, coal and firewood etc. The fuel properties of the jatropha oil closely resembles with the diesel oil. It was found that the specific gravity of jatropha oil is 0.9180 (gr/ml) compared to diesel oil 0.8410 (gr/ml). Calorific value of the jatropha oil is 41 MJ/kg and diesel oil is 45 MJ/kg (Rosenblum, 2000, Gubitz, 1999).

Similarly, it has been reported that the flash point of jatropha oil and diesel is 240^0 and 50^oC respectively. In addition to this, cetane number of Bio-oil and Diesel is 51 and 50 respectively. Likewise, the Sulphur weight (%) of Jatropha oil and Diesel is 0.13 and 1.2 respectively (Radich. 2004, Giibitz. 1999)

One study, published in 1998 and cited by the National Biodiesel Board, found that one-half of samples of petroleum diesel sold in the United States did not meet the recommended minimum standard for lubricity. It was reported that Biodiesel has better lubricity than current low-sulfur petroleum diesel, which contains 500 parts per million (ppm) sulfur by weight. The petroleum diesel lubricity problem is expected to get worse when ultra-low-sulfur petroleum diesel (15 ppm sulfur by weight) is introduced in 2006. A 1- or 2-percent volumetric blend of biodiesel in low-sulfur petroleum diesel improves lubricity substantially. It should be noted, however, that the use of other lubricity additives may achieve the same effect at lower cost (Radich, 2004).

3.5 Energy Harnessing through Jatropha Oil

In many parts of the world, testing of different stationary engines was undertaken on using Jatropha Oil. Moreover, different testing was carried out to study the performances of jatropha oil in diesel engines in varying operational conditions. In addition to this as an alternative to kerosene oil as well.

3.5.1 Diesel engine test

Performance evaluation of using Jatropha oil has been carried out in compression ignition engine in different parts of the world. Among them some of the engine tests are described as follows; A Constant speed tests carried out using the Jatropha – diesel blend to study engine performance in terms of specific fuel consumption, Brake thermal efficiency and exhaust gas temperature in a single cylinder open combustion chamber C.I engine, Kirloskar make, with bore/stroke ratio of 80:110 mm showed that the blend containing up to 30 % (v/v), Jatropha oil was found to have viscosity close to diesel. It was established that 50 % jatropha oil can thus be substituted for diesel for use in a compression ignition engine without any major operational difficulties (Pramanik, 2003). The specific fuel consumption and the exhaust gas temperature were reduced due to reduced viscosity of the vegetable oil. Acceptable thermal efficiencies of the engine were obtained with blends containing up to 50 % volume of jatropha oil (Pramanik, 2003).

Similarly, Gubitz et al, 1999 reported that in one of the test run on using jatropha oil in diesel engine, the engine performance were satisfactory. A Kubota four stroke cycle diesel engine (7hp/2400rpm), with a simple horizontal piston, cylinder volume 400c and a water cooling system, and a yanmar diesel engine (Horizontal 4 cycle, 7hp/2400 rpm of pre-combustion type) usually run on liquefied petroleum and diesel respectively, were tested for comparative performance against running Jatropha oil (Gubitz et al, 1999). The engine performance and fuel consumption were favourable. The result of inspection of Kubota diesel engine parts when run on Jatropha oil for 1000 hours are also reported to be satisfactory (Gubitz et al, 1999). When compared with diesel oil for exhaust gas tests, difference in smoke and carbon monoxide content were not only negligible but the values were also lower then the accepted values per the standard specification of the Environment Board. Similarly, no Sulphur dioxide was found in the exhaust fumes of the engine run on Jatropha oil as against 125 ppm. Sulphur dioxide found in the exhaust gas of the engine run on diesel oil. The results for tests of diesel engines run of Jatropha oil and comparative properties of Jatropha oil as opposed to Diesel oil indicate that Jatropha oil has the desirable physico-chemical and performance characteristics to be used as a substitute of diesel oil. Only minor modification in the ignition system or working out a suitable chemical mix may be necessary as Jatropha oil has a higher initial flash point. Jatropha oil is a non-edible oil and has a cetane number which is comparable to diesel and makes it an ideal alternative fuel as compared to other edible vegetable oils and indicates that no major modification in the diesel machine may be necessary (Gubitz et al, 1999).

The initial flash point of Jatropha oil is 110^0 C as compared to 50^0 C in case of diesel. Due to higher flash point Jatropha oil has certain advantages over petroleum crude like greater safety during storage, handling and transport. However, the higher flash point may create only initial starting problem of the machine. Similarly, higher viscosity of Jatropha oil could pose problems of smooth flow of oil in fuel supply pipes and nozzles. However, it may be possible to overcome these defects by ' esterification' of Jatropha oil, which is very effective way of overcoming the high viscosity and smoke emissions of vegetable oils by forming their ethyl and methyl esters (Gubitz et al, 1999).

Brake Specific Fuel Consumption (BSFC) was found to increase with higher proportion of Jatropha oil in the blend compared to diesel in the entire load range. Calorific value of Jatropha oil is lower compared to that of diesel, therefore increasing proportion of Jatropha oil in blend decreases the calorific value of the blend which results in increased BSFC. Thermal efficiency of Jatropha blends was lower than that with diesel. However, thermal efficiency of blends up to J20 (Jatropha Oil 20 %) was very close to diesel. Oxygen present in the fuel molecules improves the combustion characteristics but higher viscosity and poor volatility of vegetable oils lead to their poor atomization and combustion characteristics. Therefore, thermal efficiency was found to be lower for higher blend concentrations compared to that of mineral diesel. The exhaust gas temperature with blends having higher percentage of Jatropha oil was higher compared to that of diesel at higher loads (Agrawal et al, 2005).

The kinematic viscosity of Jatropha oil is 51 and it should be possible to bring it down close to the viscosity of diesel to make it an ideal substitute to diesel either by evolving a suitable mix with ethanol or a suitable hexane (Gubitz et al, 1999).

3.5.2 Kerosene Cook Stoves test

Kerosene is the most common and favourite fuel of the average South Asian community for cooking food particularly in low income section of the populace. Kerosene consumer constitute a significant majority in the sub-urban areas smaller and remote towns and villages where LPG is either not available or its regular supply is uncertain. Due to unaffordable prices of LPG, by the low income groups and non-availability of fuel wood and other sources of energy, a large section of our populace in cities and towns depend upon ratined supply of Kerosene for meeting their domestic needs mainly for cooking. Due to increasing demand and limited supplies of kerosene, one can see long queues for procuring the limited quota of kerosene. The womenfolk are the most harassed lot, who have to manage the house hold with meager quota of kerosene as the increasing demand for cooking fuel is unable to keep pace with the indigenous production of kerosene.

Preliminary experiments carried out a Nashik, India have revealed that Jatropha oil can be used as a direct substitute to kerosene as fuel for cooking and heating while used in the specially designed stove with almost matching fuel efficiency. It was also observed that smoke of Jatropha oil is almost odourless and non-pungent unlike kerosene and the fumes do not leave an unpleasant smell in the food as it happens in case of kerosene fuel (Gubitz et al, 1999).

3.7 Disadvantages of Jatropha Oil as an energy Crop

It was found that Jatropha Oil (bio-oil) together with Biodiesel (tran-esterified form of bio-oil) also has some performance disadvantages. The performance of biodiesel in cold conditions is markedly worse than that of petroleum diesel, and biodiesel made from yellow grease is worse than soybean biodiesel in this regard. At low temperatures, diesel fuel forms wax crystals, which can clog fuel lines and filters in a vehicle's fuel system. The "cloud point" is the temperature at which a sample of the fuel starts to appear cloudy, indicating that wax crystals have begun to form. At even lower temperatures, diesel fuel becomes a gel that cannot be pumped. The "pour point" is the temperature below which the fuel will not flow. The cloud and pour points for biodiesel are higher than those for petroleum diesel (Radich. 2004).

It was reported that Biodiesel may be incompatible with the seals used in the fuel systems of older vehicles and machinery, necessitating the replacement of those parts if biodiesel blends are used. The initial use of B20 (proportion of Bio-diesel 20% and petro-diesel 80%) or B100 (Bio-diesel 100%) in any vehicle or machine requires care. Petroleum diesel forms deposits in vehicular fuel systems, and because biodiesel can loosen those deposits, they can migrate and clog fuel lines and filters (Radich. 2004). Another disadvantage being reported is that it tends to reduce fuel economy. Energy efficiency is the percentage of the fuel's thermal energy that is delivered as engine output, and biodiesel has shown no significant effect on the energy efficiency of any test engine. Volumetric efficiency, a measure that is more familiar to most vehicle users, usually is expressed as miles traveled per gallon of fuel (or kilometers per liter of fuel). The energy content per gallon of biodiesel is approximately 11 percent lower than that of petroleum diesel. Vehicles running on B20 are therefore expected to achieve 2.2 percent (20 percent x 11 percent) fewer miles per gallon of fuel (Radich. 2004).

4.0 Conclusion

Multiple benefits of Jatropha plants and oil expelled from its seeds are not only useful in saving the environmental pollution but also supports for employment generation and entrepreneurship developments. Potential use of jatropha as an energy crops, agro-forestry crops, soil conservation measures and industrial application are the attractive factors to cultivate the plant in the unused and barren land. The input required for raising jatropha plant to harness oil is very minimal, which reduces the investment required to generate a unit quantity of biofuel. As energy crop, proper processing and blending with petro-diesel has already demonstrated it as an alternative fuel to operate stationary and motive diesel engines. The thermodynamic properties of the biodiesel also show that it can be potentially used in the diesel engines. By-products of bio-diesel like glycerine, oil cake can generate favourable economic return, which make the cultivation of jatropha and production of oil economically feasible. Apart from Jatropha, different plant species like Karenji, rubber seeds, neem seeds, pongmia, rapeseeds etc are the potential source of biodiesel that can be economically harnessed and operated in diesel engines in appropriate blending ratios.

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