Is jatropha the solution to the world's fuel needs or the most over-hyped crop this century?

# Jatropha – the future or disaster in the making?

**by Phil thane**

A perfect biofuel crop would grow where food crops cannot, need no irrigation, no fertiliser and little care. It would grow fast, converting almost all the solar energy it soaks up into biomass and would be easy to process into high class fuel.

Some say jatropha fits this bill, but it also comes with its own set of challenges.

## What is jatropha?

Monique Simmonds of the world famous Royal Botanic Gardens in Kew, London summarises the science:

The genus jatropha comprises approximately 170 species that occur in the tropics and subtropics; the majority are indigenous to Central America, about 70 species are indigenous to Africa, and one species (J. mahafalensis) is endemic to Madagascar.

Several species grown as ornamentals or for medicine and oil have been introduced to areas outside their range, becoming naturalised and, in some cases, invasive. Jatropha curcas, which is native to Central America and has been introduced throughout the tropics, is of particular economic importance as a source of oil.

Jatropha curcas is a shrub or small tree which can grow as high as 8m in the right conditions with perennial rootstock and deciduous, broadly ovate leaves. Each shrub carries both male and female flowers which are pollinated by moths. The fruit are smooth, broadly ellipsoid capsules about 3cm x 2cm, initially green ripening to yellow in about 80–100 days. Each fruit contains three mottled black seeds.

The seeds have a fat content of 32–45%. The seed oil is inedible due to its toxicity, although this differs among varieties and teams such as that led by Harinder P.S.Makkar, at the University of Hohenheim, Germany, are working to develop a non-toxic variety.

**Principal fatty acid composition of jatropha curcas seed oil**

**(Susiarti et al. 1999)**

**Fatty acid content %**

| Palmitic acid | Palmitoleic acid | Stearic acid | Oleic acid | Linoleic acid |
|---|---|---|---|---|
| 3.5-15.6 | 0.7-0.9 | 6.7-7.5 | 34.3-46.3 | 30.8-43.1 |

**Comparative data for oil yield**

**(Fairless, 2007)**

**Litres of biodiesel produced per hectare**

| Oil palm | Jatropha | Rapeseed | Sunflower | Soyabean |
|---|---|---|---|---|
| 2400 | 1300 | 1100 | 690 | 400 |

Source: D1-BP Fuel Crops

Jatropha saplings raised in a nursery before planting out

## Growing jatropha

Jatropha curcas can be cultivated in dry conditions, poor soil and in disturbed environments. Its toxicity protects it from most pests, and it is able to withstand long periods of drought. Jatropha plants do not tolerate water logging. It has been observed growing in very high (3000mm) rainfall

areas but such levels are likely to cause fungal attack and restrict root growth in all but the most free draining soils. Jatrophas are not frost resistant.

Plants raised from seed develop a tap root and are therefore more resistant to drought than cuttings, whereas the latter set seed earlier. Plants reach productive maturity within four to five years and may live to 50 years.

## Jatropha as a commercial crop

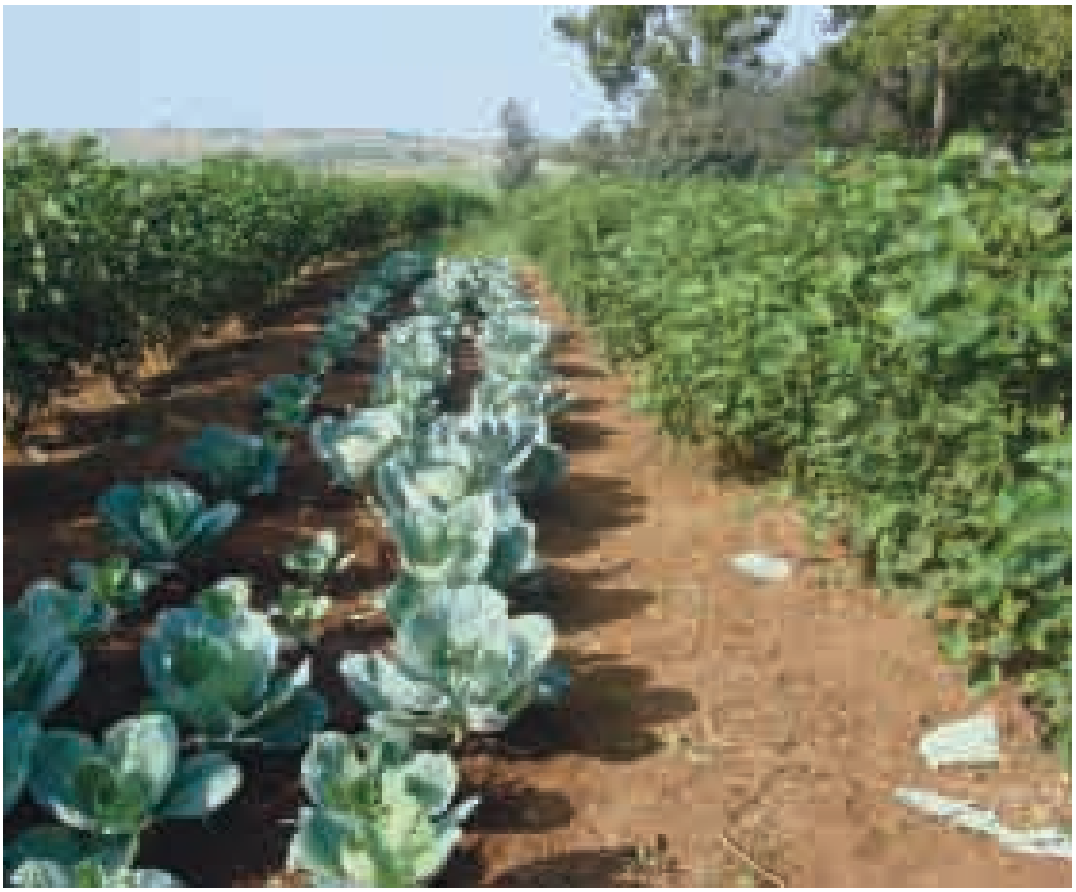
The ability of jatropha to grow in poor land unsuited for food production is attractive to fuel producers as it offers an apparent escape from the arguments about fuel crops leading to food shortages in developing countries.

But for maximum oil yields, jatropha requires optimal growing conditions and regular pruning to promote flowering and fruit set. Given the right conditions seed set may reach 6kg per plant but there is little scientific data to support the contention that jatropha is a high yielding oil crop where water and nutrient availability are limited.

While jatropha can survive with as little as 250 to 300mm of annual rainfall, at least 600mm is needed for it to flower and set fruit. The optimum rainfall is between 1000 and 1500mm, according to Richard Brittaine, who is working on a publication for the UN FAO examining the potential for increasing sustainable production of jatropha.

Rainfall induces flowering, in regions with a single rainy season a single flowering and harvest per year is the norm but in some areas there may be two crops per year and regions with regular rainfall throughout the year jatropha can flower continuously.

The best soils for jatropha oil production are aerated sands and loams of at least 45cm depth. Heavy clay soils are less suitable and should be avoided, particularly where drainage is impaired. Ability to grow in alkaline soils has been widely reported but the soil pH should be within 6.0 to 8.0/8.5. There is evidence from north-west India that jatropha is tolerant of saline irrigation water although yield under these conditions is not documented.



Source: D1-BP Fuel Crops Ltd

Intercropping with shade tolerant vegetables makes the plantation more profitable

As jatropha is adapted to growing in poor soils it is often described as having a low nutrient requirement. But to grow a productive crop, correct fertilisation and adequate rainfall/irrigation are required. However, too much fertiliser and rainfall/irrigation can induce high total biomass production at the expense of seed yield. Some growers report that the application of organic fertilisers, super phosphate and NPK increase jatropha seed and oil yields but there is not yet sufficient data on how jatropha responds to different fertilisers under different growing conditions to make specific recommendations for optimal crop nutrition.

On degraded land a higher yield response has been obtained from organic manures than inorganic fertilisers. Researchers at the Central Salt and Marine Chemicals Research Institute, Gujarat, India, found that on waste land application of 3t/ha of jatropha press cake (the residue left following oil extraction), containing 3.2% N, 1.2% P2O5 and 1.4% K2O, to young plants, increased yields significantly; by +120% and +93% at two different planting densities.

The optimum levels of inorganic fertilisers have been seen to vary with the age of tree.

An analysis of the nutrient value of harvested fruit will indicate the application rate of nutrients required to maintain soil fertility levels, assuming all other biomass is retained in the field. From the nutrient composition calculated by researchers at Plant Research International, Wageningen, the Netherlands, the fruit equivalent of 1 t dry seed/ha removes 14.3 – 34.3 kg of N, 0.7 – 7.0 kg P, and 14.3 – 31.6 kg K per ha.

## Improving the crop

Little reputable work has been done so far to develop commercial strains of jatropha, compared to food oil seed crops which have been selectively bred for thousands of years, though companies such as D1 Oils are working on it.

Brittaine has identified the plant breeder's goals for improving yield as:

- Increased ratio of fruit to other biomass
- More female flowers leading to more fruit
- Heavier seeds
- Higher oil content in the seeds
- Synchronous flowering and seed maturity
- Increasing production per ha by increasing numbers of branches, flowers, seeds and fruits

In addition there are other objectives that, if met, would make jatropha more commercially desirable:

- Improving oil quality
- Developing non-toxic varieties; for human safety reasons, and to add value to the seed cake as fodder.
- Improving plant architecture; more branching for increased yield, lower plant height for easier harvesting and a smaller canopy for intercropping.
- Drought resistance. Production under water stress conditions.
- Production with low soil nutrients e.g. nitrogen fixing

It is one thing to draw up a wish list but improving plant varieties is never a quick process and jatropha presents some special challenges.

In order to cross breed and select progeny with useful characteristics producers need genetically diverse plants to start with, but all the jatropha in India and Africa are genetically very similar having developed from a limited number of plants that originated from Central America.

Importing new stock from the species origin will help but preliminary findings published online (Nature Proceedings) showed a 70% similarity between samples from Mexico and Costa Rica and those from other regions. This clearly limits the potential of intra-specific breeding programmes for Jatropha curcas. However, the same study raises the prospect of increasing variety by breeding inter-specific hybrids, in this case using jatropha curcas crossed with jatropha integerrima.

Time is perhaps the the biggest problem when trying to develop plants is that they take five years to reach maturity. Modern genetic marker techniques speed up the screening process but plants still need to be grown to maturity to validate the selections.

The situation is further complicated by epigenetic mechanisms which create large variations between genetically identical plants so that characteristics such as seed size and oil content vary between individuals despite their similar or identical genetic composition.

The Energy and Resources Institute (TERI) in India has developed mycorrhyzal inoculations that increases the uptake of phosphorus and micro-nutrients, improve germination, and result in earlier fruiting and higher yields. Mycorrhizae are fungi that have a symbiotic relationship with the roots of many plants, they take a small amount of carbohydrate from the plant to build their own structures and in return the plant gets access to the huge surface area of the mycelium which is able to draw in water and nutrients much more effectively than the plant's own root system.

Source: D1-BP Fuel Crops Ltd

Jatropha fruit ripening

## Jatropha oil as feedstock for biodiesel

The basic properties of a Fatty Acid Methyl Ester (FAME, commonly known as biodiesel) are determined by the original triglyceride chemical structure. Jatropha has the right blend of properties to make it comparable with canola and soya oil FAME. In summary:

- The unsaturated fatty acid profile lies between soya and canola oils
- There is less saturated fatty acids than in palm oils
- Total phosphorous and gums is less than soya and canola
- Iodine value lower than soya and canola oils but higher than palm oil
- CFPP around ±1°C

## Large scale production

For many in the oil and energy business jatropha came out of the blue at just the time concerns were being raised about fuel crops displacing food crops, raising the price of agricultural land in developing countries and promoting the destruction of forests to create plantations. A crop that grows like a weed in waste ground with low water

## Hidden Gem in Madagascar

**One major** investor in jatropha is Gem Biofuels, founded in 2004 to take advantage of the agricultural and socio-economic conditions in Madagascar to produce jatropha oil for use as a biodiesel feedstock.

Operations are based in the south of the island where the jatropha tree grows wild. Gem has secured 50 year agreements giving exclusive rights over 452,500 hectares to establish plantations, ranging in size from 2,500 - 50,000 hectares with a further 40,000 hectares of natural forest containing substantial numbers of mature jatropha trees.

By 2007 Gem planted 13,300 hectares of jatropha with a further 50,000 hectares last year and is on target to achieve 200,000 hectares planted by 2010. Based on this, Gem's production is expected to be 45,000 tonnes per annum (tpa) of crude jatropha oil in 2009 rising to 210,000 tpa by 2014, as its trees mature. Until recently all planting has been an entirely manual process but during the campaign just ended Gem piloted mechanised ground preparation and planting techniques.

The mechanised approach shows promise, but Gem took the decision to curtail the programme at 21,600 hectares due primarily to the inefficiency of the local tractors used. Gem believes that mechanisation is the way forward and intends to invest in better equipment which it expects to result in operating cost savings of 30%.

Source: D1-BP Fuel Crops Ltd

Mature jatropha shrub bearing fruit

and nutrient requirements seemed like the answer to the industry's prayers.

Unfortunately that created a lot of hype, unsound business plans and unwise investments. Most of these crashed and burned pretty quickly leaving jatropha's reputation damaged, even though the plant does have a long term future as a useful energy crop.

One company taking a long-term view of jatropha production is D1-BP Fuel Crops, a 50/50 joint venture between D1 Oils and BP, created in 2007. D1 has its own plant breeding programme – its new strain of jatropha offers yield increases of 20% over previous varieties – and had at the time access to 172,000 hectares of existing plantations in India, southern Africa and southeast Asia.

This has now risen to 220,000 ha. BP has capital and a need for biodiesel to blend with its petroleum product. The joint venture is expected to become the world's largest commercial producer of jatropha feedstock, producing up to 2 million tonnes of jatropha oil a year.

In February 2009 the research arm of D1 Oils announced that it has developed and is patenting a process that expels oil from jatropha seeds and at the same time purifies the seedcake (meal) left after oil extraction to produce high protein animal feed. Obviously this is a major step forward in making jatropha commercially viable.

As yet, there is no machine on the market that could be used to harvest the grain, but the company is investigating mechanisation, however, this is some time off. Like other crops, mechanisation of harvesting will certainly have a significant impact on production costs. It is too early yet to say what those savings may be until we have identified an appropriate vehicle.

It is anticipated that the extraction of oil will occur near to the plantations. Obviously, the scale of the planted area will dictate the size of the expeller required. However, it is fairly certain that industrial scale will be required.

According to research carried out by Ecofys, the sustainable energy consulting company, on behalf of D1 Oils, biodiesel produced from jatropha in north east India delivers carbon savings of over 60% compared to fossil fuel diesel. This analysis uses the greenhouse gas methodology of the UK Renewable Transport Fuel Obligation (RTFO) and assumed that the extracted oil would be transported 750km by truck to the coast and then 14,500km by ship. The efficiency of road and sea transport was based on the RTFO default value.

The recently announced breakthrough on using jatropha presscake as fodder will take some time to progress from lab scale model to production use. In the meantime D1-BP is looking into the use of presscake as a fuel for biomass power generation. Where limited grid supplies are available it could be used to power expellers and other plant, and in some scenarios excess power could be made available to the local grid. Alternatively presscake, together with leaf litter and prunings are ploughed back into the plantation soil to reduce the need for fertilisers.

One of the key considerations of any oil business is the Health, Safety, Security and Environment (HSSE) of its employees and other stakeholders. D1-BP Fuel Crops is aware that jatropha is poisonous, and believes it is essential to minimise risks to agricultural workers.

But as Brian Morgan, marketing and communications manager at D1-BP Fuel Crops points out jatropha is not the only crop that could affect human health if not handled correctly; soya contains lectin, which must be removed in processing, and cassava is toxic unless washed. The key is removal of potentially harmful compounds through processing and education about potential risks.

## The verdict

Jatropha is not a miracle crop. It can grow profitably where few other crops can but it still needs some water and nutrients. Providing it is seen as a long term investment and grown responsibly it can make a contribution to future energy needs but it is not going to solve climate change or make investors fabulously wealthy over night. ●

**References and links**

D1-BP Fuel Crops: **www.d1bpfuelcrops.com**
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