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03 March 2015

Future Harvest
21st Century Jatropha

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Future Harvest

The US Federal Reserve, in furtherance of its programme of Quantitative Easing, is thought to have bought US bonds worth some $3.7tn since November 2008. Over much the same period Hardman estimates that the research into the crop Jatropha, detailed in this report, has been made possible with circa $150m of funding. It may not sound much in relation to US QE, but in the context of a new agricultural species not widely known, it is a very significant investment. Jatropha is not yet an important crop; it is not a cornerstone of agriculture in any country or region today but nevertheless it links four life science investors including a national research laboratory, one of Europe's largest energy utilities, a leading US petro-chemicals company, one of the world's leading names in automobile manufacture and a global producer of industrial chemicals, in a series of well-established research & development programmes directed at transforming the crop and our perceptions of it.

Jatropha is a species with significant and valuable agricultural attributes, it is hardy, fast growing, early to fruit, productive and diverse in its physiology; the development and breeding strategies to harness the crop's potential are also diverse and drawn from 40 years or more of aggregated scientific research. Some breeding strategies are based on shaping the adaptability of the plant to suit specific environments or cultivation models while others are radical; think of Jatropha being grown as an annual crop in North America or Europe, at 30,000 plants per ha. Today growers can make choices based on a variety of characteristics including suitability for the intended cultivation site, disease & pest resistance, harvest period, oil yield, maturation period and toxicity levels – a remarkable progression from even 5 years ago when one professional plantation development chose its wild sourced planting material on the basis of seed weight.

The promise that Jatropha could yield commercial quantities of high quality vegetable oil in growing environments in which traditional oilseed crops would fail, is what first brought the plant to prominence. Still it is the case that the plant's capacity to produce a high quality feedstock for the biodiesel sector underpins interest and investment in its future. Today biodiesel makes up some 3.4% of global fuel used in road transportation and it accounts for around 31% of all biofuels produced, but it represents only 0.5% of global crude oil produced annually. Biodiesel is accepted as a clean, safe fuel and its use is mandated in more than 60 countries as a national policy response to the requirement to reduce carbon dioxide emissions. We may all be facing an existential challenge to reduce our carbon footprint, but many of the developing economies are also energy poor and users of environmentally damaging energy sources including wood and charcoal. It is in the energy poor developing economies in particular that carbon light fuels such as Jatropha oil derived biodiesel can produce a measurable beneficial social, economic and environmental impact. Beyond the energy poor developing economies, Jatropha oil has been noted for its particular suitability for renewable jet fuel (RJF). The fuel bill for the global aviation industry has benefited from the collapse in the price of crude oil; whereas the industry was spending some $240bn annually, this bill has been pared back to circa $140bn in the current pricing environment. However under political and consumer pressure the European airline sector is seeking to achieve substitution of conventional fuel with biofuels of some 3%-4% by 2020. The global opportunity for jet biofuel could be in excess of $4bn pa.

While Jatropha oil is well suited to satisfying the requirements of the market opportunities identified above, the economic model for its production has not yet been proven. Today this model depends on manual labour, making it highly suited to many of the energy poor developing economies across the tropical and arid regions. Traditionally Jatropha has been viewed as a crop for production under an out grower model, and this model has logic, but with careful management and suitable modern planting material, it should be possible to produce Jatropha oil economically under plantation management. Local production can be made even more economically attractive if married with refining at source; a range of affordable and robust transportable mini-refinery technologies offer the prospect of producing local biodiesel to be cost competitive with imported petroleum based fuels. Hardman estimates that Jatropha based biodiesel could be produced at source from US $0.87/litre-US $1.00/litre. However, some observers argue that Jatropha oil is simply too good 'to burn' as biodiesel, that greater value could be recovered for its properties in the $30bn a year surfactants market or as an industrial lubricant, a market worth more than $8bn pa and for which the oil is deemed to be highly suitable. While there is abundant demand for Jatropha oil, supply is the challenge that the crop science companies detailed in this report, are focused on resolving.

The traditional perception of Jatropha as a fuel crop has obscured the significant potential utility of Jatropha kernel meal (JKM). With as much as 1.5x more protein than soya meal and with a superior amino acid pattern, JKM represents an attractive new ingredient for use in animal feed rations including for fish on which JKM has been trialled with excellent results. As detailed herein, Jatropha varieties may be either toxic or non-toxic. Meal produced by the more commonly cultivated toxic varieties would need to be processed for the complete removal of the toxic phorbol ester fraction prior to incorporation in animal feed. While a commercially scaled methodology for this process has not yet been established, a number of technologies have been developed to support such a process including at least one patented methodology that has been used to produce small industrial sized quantities of meal. The global oilseed meal sector has an annual value of some $100bn of which soya meal accounts for $80bn. With the appropriate certifications from national and international standards bodies, JKM has the potential to compete well with soya meal. The initial demand for JKM is likely to be supplied with non-toxic JKM, in markets contiguous to source, which in many cases will not be well supplied with high quality protein mixes for animal feed.

Unlike other tropical tree crops such as oil palm or natural rubber, there is no library of documented records for the economic production of Jatropha under plantation cultivation – it is a crop almost entirely produced by small holders. Any analysis of the economics of Jatropha under plantation cultivation must begin by defining the setting for such cultivation. The vision of the crop for use in marginal or degraded lands in semi-arid environments is one of a diverse group of proposed scenarios for its cultivation. Our assessment of the state of development of the crop suggests that yields of seed per ha may be achievable in a range of 2mt to 6mt and possibly more under intensive management in superior growing conditions. Production costs will look very different across this range of models and so too will revenues per ha. In the more difficult cultivation environments marked by poverty and poor logistics, lower revenue outcomes will be offset by very much lower labour costs and possibly benefited by opportunities to attract premium prices for Jatropha oil and perhaps biodiesel produced at source. In the easier cultivation environments, higher labour costs should be offset by better values for meal and biomass. EBIT margins in a range of 11.6% to 21.2% look realistically achievable across our different models, with tight management and reliable planting material, and possibly better. This has all still to be proven and in that context it is interesting to note that a number of the companies detailed herein (including JOil with a demonstration farm already under development in Burkina Faso) are in the process of establishing industrially scaled demonstration farms to prove the proposition that emerges from the data reviewed herein, namely that Jatropha has the potential to become an important crop for 21st century agriculture.

Jatropha curcas

Jatropha curcas Linn. (referred to hereinafter as Jatropha), or physic nut as it is commonly known in many parts of the world, was described by Carl Linnaeus in 1753 as a member of the Euphorbiaceae family – a family known for their milky white sap and phytotoxins. Jatropha is a perennial, deciduous, stem-succulent shrub or small tree with growth up to 5 metres which is able to remain productive for up to 50 years. It is considered to be native to Central America which has a sub-tropical humid climate with no marked winter; even the coldest month averages above 18 °C, with summers of 27 to 28 °. Rainfall at 1,100 to 2,000 mm is high and regular. The Central American region is however characterised by a marked dry season of several months from which Jatropha has evolved its capacity to withstand long dry spells. This may explain why Jatropha is such an adaptable species; it has been cultivated on degraded lands in semi arid regions across Africa and Asia. Fruit yields however, are highly dependent on climatic and soil conditions. Under conditions which are highly suitable to the plant, it has been reported to yield between 2-5 tonnes of seed per ha per year from year 5. A remarkably deep rooting plant [down to 12 feet] it is a useful plant in soil remediation, bringing deep mineral fertility to the soil via leaf litter.

The plant produces bunches of 2-3 cm diameter fruits, which contain usually 3, sometimes 4, black 1 cm long seeds or grains of approximately 0.6-0.9gms each. The grains have thick black hulls protecting the grain kernels. The kernels are rich in oil and protein. After processing, one metric tonne (mt) of Jatropha grain typically results in 250kg - 350 kg of oil, 350-400 kg of high energy hulls (35% shell is most typical in commercial lines) and the balance in a Jatropha kernel meal containing circa 65% protein.

According to Vasudevan and Briggs [2008 J Ind Microbiol Biotechnol], "Jatropha has tremendous potential for biodiesel production..."with potential for an "..average yield of biodiesel of more than 99%". Free fatty acid content in fresh Jatropha oil is low in a range of 2%-3% making it highly suitable for refining for biodiesel. Biodiesel produced from crude Jatropha oil can substitute in part for costly fossil fuel imports for landlocked energy poor countries. As a result Jatropha is being studied as a sustainable fuel source, especially in rural communities in Africa and Southeast Asia. CJO can be extracted from Jatropha seeds either hydraulically using a press or chemically using solvents (Heller, 1996). Chemical extraction is reported to permit up to 40% oil extraction rate (OER).

The fatty acid composition of CJO contains four important fatty acids: palmitic, stearic, oleic and linoleic acid. However, the seeds contain a toxic protein called curcin (lectin) and diterpene esters (phorbol esters), both of which are harmful to humans and most other animals. Curcin hinders protein synthesis in vitro (Stirpe et al. 1976) and is quite similar in structure to ricin (but not toxicity as ricin is 1,000x more toxic) which is the toxic protein of the castor bean (a member of the Euphorbiaceae genus), to which Jatropha is related.

According to Brittaine & Lutaladio, (Integrated Crop Management Vol.8-2010) there are some 170 known species of Jatropha and these are predominantly associated with Central America. Scientific literature notes three particular varieties:

- Nicaraguan – a large species but a poor producer of fruits;
- Cape Verdean – commonly found throughout Africa & Asia;
- Mexican – noted for lower toxicity & non-toxic varieties.

Jatropha can be planted as a commercial crop in a band up to 25 degrees north and south of the Equator on a range of soil types. Planters we have spoken to confirm that Jatropha does best in deeper free draining soils with annual rainfall of more than 1,000mm pa. The crop is very sensitive to frost and periods of continuous rain. Crop performance, as with most plants, is significantly influenced by the availability of sunlight, warmth, water, and soil nutrients in the growth site environment. Altitude appears to be an important determinant, affecting the maximum, minimum and mean temperatures and surrounding humidity. Jatropha can grow at altitudes of up to 2,000m on the Equator, but needs intensive management to yield useful volumes of fruit. In its native region it is thought to have occurred at altitudes below 500 metres.

Brief History of Cultivation

Jatropha was spread over a large part of the world by Portuguese sea traders in the 17th Century and it was adopted by farmers in Asia and Africa for its utility as a hedging species, especially for retaining livestock and for wind breaks. These early cultivators also found the seeds a useful source of oil and the plant became recognised in folk medicine for its therapeutic and insecticidal properties. During the 20th century Jatropha came to the attention of various NGOs addressing rural poverty in African and Asia. Because of its versatility, Jatropha was regarded as a useful crop in programmes to alleviate rural poverty in developing economies; aside from its virtue as a hedging material it produced oil, obtained by cold pressing for community use in heating / lighting / cooking and for powering simple agricultural equipment.

Brittaine & Lutaladio, (Integrated Crop Management Vol.8-2010) noted that in 2008 "Jatropha was planted on an estimated 900,000 ha around the world, 760,000 in Asia, 120,000 in Africa and perhaps 20,000 in Latin America. This chimes with what Hardman has learned anecdotally: that up to 1 million ha were planted in a period of 5 years or more to 2010, but of which as much as 800,000 ha had been planted in environments unsuited to commercial cultivation, much of it in India in the form of small holder & out grower plantings. It is generally accepted that some 800,000 ha was planted out in India, 200,000 ha in Indonesia and other Asian countries including Myanmar and around 100,000 ha in Africa. Some 70% is estimated to have been planted by small holders. Anecdotal reports indicate that around 200,000ha have been planted out in suitable areas, again spread over India, Indonesia, & Africa principally. Since 2010 the planted area is likely to have changed little in total size, with new plantings merely offsetting the withdrawal of other previously planted land.

Climate Preference

Optimum temperatures for Jatropha are generally considered to be between 20 degrees – 32 degrees Celsius. Very high temperatures are thought to depress yields as flowers can be damaged by extreme temperatures and thus fail to develop seeds; this has been the experience of some farms in Northern India where temperatures exceed 38 degrees Celsius. It is important that night temperatures do not fall below 15 degrees if the plant is to avoid stress and this confirms the plant's preference for lower altitudes. Jatropha has shown to be well adapted to high light intensity (Baumgaart, 2007, cited Jongschaap, 2007). Optimum rainfall for seed production is thought to be in the range of 1,000mm to 1,500mm, but high yields on trial sites have been reported in very high rainfall areas (2300mm) in Asia. Similarly the plant is reported to perform well in drier regions 400mm-800mm where irrigation is provided. We have received reports of 4 mt / dry seed / ha harvested on selected wild stock in various locations in South America (Northern Argentina, Paraguay, northern Minas Gerais) in a bimodal 800mm rainfall environment and without irrigation. (Cazenave Y Asocciados SA). Water conservation techniques including use of water capture pits, slanted ditches, mulching and provision of ground cover plants might all be useful in lower rainfall zones.

Research has indicated that in very high rainfall areas Jatropha is vulnerable to fungal attack (Foidl, 1996, cited Achten 2008) and perhaps for this reason the plant is not found in the more humid regions of its native Central America. Indonesian growers have also reported to us that the plant tends to greater vegetative growth and lower fruit yields, in high rainfall tropical environments, but this may have as much to do with the planting material used as it does with climate. Evidence from existing cultivations demonstrates that commercial cultivation benefits from bimodal rainfall patterns; rainfall induces flowering and thus in areas of unimodal rainfall the plant flowers continuously which has implications for management of harvesting and crop maintenance. A 3 – 4 month dry season, as is typical of West Africa and parts of Asia, provide the plant with a period of dormancy which allows for tree & field maintenance and which then encourages more concentrated harvesting periods. While Jatropha will survive in semi-arid conditions it is generally observed that it requires at least 600mm to flower and set fruit.

Soil Preference

Research indicates that Jatropha is happiest in aerated loam & sandy soils of at least 45 cm in depth (Gout, 2006). Heavy clay is not deemed suitable for the plant because of its ability to deform root development and its tendency for water-logging, which renders Jatropha vulnerable to fungal attack. We have seen the crop growing relatively successfully in clay soils however, but where these have been terraced and drained to avoid water-logging. Soil pH is deemed to be best in the range 6.0-8.5 (FACT, 2007). Jatropha has a deep penetrating tap root that has been measured at up to 1.4 metres (Krishnamurthy et al, ICRISAT, January 2012) and otherwise reported at up to 5 metres in the plant's native region (Foidl et al, Bioresour Technol 1996). This is likely to reflect the different responses to the plant to different soil structure conditions, with deep penetrable soils its preferred environment.

Pest & Disease

Jatropha attracts a substantial insect and disease burden in many African locations, and this is especially burdensome for the plant when it is stressed; low rainfall environments therefore carry a double danger for plant performance. Systemic treatment of the seed and young plants, regular field monitoring / scouting and identification of infestation early are necessary plantation procedures along with an appropriate integrated pest management system.

Under scaled monoculture cultivation it has been found that pest & disease control is important. Good farming practices, including the encouragement of natural predators of Jatropha related pests, and chemical products represent the main strategies for crop protection, but selective breeding also has an important role. The diverse geographies in which Jatropha grows mean that different strategies and different resistances will be required region by region and this focus on localization forms a key focus for Jatropha breeders & developers.

Common Pests & Diseases include:

- Mealybugs are insects found in moist, warm climates. They feed on plant & tree sap and act as a vector for several plant diseases. They will attack all parts of the Jatropha plant including leaves, stems and fruit and cause significant loss of productivity.
- Leaf Miner is the larva of an insect that lives in and eats the leaf tissue of plants. The vast majority of leaf-mining insects are moths & sawflies.
- Rainbow Shield Bugs suck sap from developing seeds and can cause significant loss of crop (20% plus) and reduction in quality through increase of FFA in oil. The insect is highly mobile predator of a wide range of crops in Sub-Saharan Africa.
- Cutworm attacks seedlings and young plants at ground level causing plants to die
- Scarabaeid Beetle larvae attack the roots of young plants; some plants have resistance
- Stem Borer weakens the stems of the plant and renders it vulnerable to breakage and disease; a problem in Indonesia
- Leaf hopper is a considerable threat to *Jatropha curcas* in tropical & sub-tropical regions. The larvae and adult insects suck the plant sap from the lower surfaces of the leaf which may curl, dry and die. *Jatropha curcas* with low carotene content in leaf tissues appears to be more tolerant to this pest. The pest also does not like thick wax found in the flower.
- Mites of cotton, tomato, legumes, citrus, papaya, cassava, & peanuts will apparently attack Jatropha. Mites are commonly found at the lower surface of the leaf, and will weaken the leaf by sucking sap. These mites have natural enemies and can be partly controlled by good cultivation techniques including clearance of fallen leaves & branches.
- Stink bug is a pest of tropical regions which attacks the plant when it flowers and thus causes lower yields. Other crops attacked include rice, tomato, legumes, chili, cotton, potato, soybean and maize.
- Tip Borer Caterpillar - bores the tip of the plant and the fruit. It is a particular problem of Southeast Asia, Australia and Pacific Islands. It will typically attack the plant in the flowering season, the larva attack both young and old plants.

Jatropha is also susceptible to a variety of plant diseases including:

- Mosaic virus is a newly emerging disease that impacts productivity, and which may be spread by whitefly. Leaves develop a yellowgreen mosaic with a tendency to curling, deformity and size reduction. Plants may become stunted with fewer and increasingly sterile flowers and entire plantations can be wiped out without an appropriate response. JOil has generated GM plants with resistance to the disease.

- Seedling Spot is a disease that typically occurs during the West African rainy season. The disease manifests in a circle spots on both leaf surfaces and can affect up to 40% of the plant including the stem and at this point it is usually fatal. It is reported that some accessions enjoy resistance.
- Alternaria ricini is another disease encountered during high levels of humidity. If the attack occurs during flower forming, the buds may die, or if at the end of flowering the fruit will fail to form. In some cases the entire plant will become infected and die. Seed treatment is considered to be effective.
- Melapsora ricini or rust spot, may occur on the lower surface of the leaf. This is a common disease of the genus Euphorbiaceae, of which Jatropha is a member.
- Cercospora leaf spots cause black or brown spots on both leaf surfaces.
- Fusarium wilt, commonly associated with oil palms in West Africa may attack Jatropha in the seed bed or in the field. Strategies to control Fusarium will include selection of resistant varieties, avoidance of water-logging and good hygiene across the plantation.
- Botrytis is indicated by a blackish spot on the flower. It is caused by Botrytis ricini which become a serious problem in the rainy season when the fruit capsule is formed. The pathogen will spread to all the flowers and the fruit capsule.
- Bacteria Spots are caused by Xanthomonas ricinocota bacteria which may attack the cotyledon and the leaf. The symptoms include the characteristic black spots.
- Root Rot and Collar Rot are diseases caused by fungi inhabiting the soil. Most typical of heavy clay soils or other poorly drained soils, these fungal infections can devastate a Jatropha plantation without appropriate control measures.

Breeding & Development Strategies – No More 'Potluck'

As detailed below, the Jatropha planters of last century took 'potluck' with planting materials, but planters today can choose from a variety of 'proven' materials including from edible varieties or common toxic varieties. These may include elite varieties chosen from the multi-year study of extensive germplasm collections; individual plants may even be cloned, or the planting materials on offer may be the result of deliberate hybridisation strategies including introgression breeding where the genes of another Jatropha species are bred into *Jatropha curcas*. The Singapore based company, JOil hopes even to supply a genetically modified (for superior oil quality) Jatropha variety from 2016.

Jatropha is a species with significant and valuable agricultural attributes, it is hardy, fast growing, early to fruit, productive and diverse in its physiology; the development and breeding strategies to harness the crop's potential are also diverse and drawn from 40 years or more of aggregated scientific research.

Within this report we highlight the very short generation time of Jatropha – in tropical climates, or under irrigation, it is possible to complete two breeding cycles in one year. For a woody perennial species this is remarkably short and contrasts with crops like oil palm which typically will not produce plantable seed until its third or fourth year. This has been a boon for breeders. Whereas the Jatropha cultivation referred to in 'Plant With A Bad Name' – last century Jatropha - was almost exclusively attempted with unimproved wild sourced material, the crop science sector has been rapidly progressing the development of the species over more than a decade, potentially positioning it as an important new crop for agriculture in this century. Some breeding strategies are based on shaping the adaptability of the plant to suit specific environments or cultivation models; others are radical and seek to transform the crop and our perceptions about it; think of Jatropha being grown as an annual crop in North America or Europe, at 30,000 plants per ha. In this century, planters will not be taking 'potluck' when selecting Jatropha planting materials, the leading breeders are developing varieties for a diverse range of cultivation environments and product requirements.

Potluck

Starting in 2010 a private enterprise planted more than 2,000 ha of Jatropha in the South Western third of Mozambique. The company sought to become a major producer of CJO by 2020. The company had planted the estate with seeds sourced from wild Tanzanian stock. *Seeds were selected on the basis of size.* This was a professional plantation development on good quality arable land and supported by an experienced team of farm managers. From an initial yield of circa 1mt/ha dry seed at year 3 from planting, the company hoped to be able to achieve yields of 5 tonnes per ha by year 6 from planting. The business was sold in 2012 and the Jatropha plantations remained largely untended. Such harvesting as has been reported to Hardman subsequently recovered no more than 1mt/ha. The data most probably do not reflect the capacity of the fields under regular agronomic management – but the essential message is clear – the new owners (who were relatively Jatropha savvy), determined that notwithstanding the significant capital investment in the plantations by the previous proprietor, it was not economic to manage these wild stock plantations for commercial yields.

Today the proposal to plant 2,000 ha with wild sourced Jatropha would be dismissed as agronomic and economic madness. The negative example of ventures like the one described above has certainly provided would be developers with a lesson in what not to do, but more importantly the emergence of a group of professional crop science companies focused on the development of economically viable Jatropha varieties, has provided planters with a choice of elite or hybrid planting materials. Growers can now make choices based on a variety of characteristics including suitability for the intended cultivation site, disease & pest resistance, harvest period, oil yield, maturation period and toxicity levels – seeds no longer have to be chosen on the basis of number per kilogram.

'Plant With A Bad Name' – Last Century Jatropha

The first phase of Jatropha plantation development largely took place during the last decade of the 20th century and the first 10-12 years of this century – we refer to this as 'last century'. Developments were both of the out grower model and of the agro-industrial model. Planting materials, mostly seeds, were sourced typically from collections comprising wild accessions. The agro-industrial plantations were not expected to fruit sufficiently to support the cost of harvesting much before year 3 from planting. From an initial yield of circa 1mt dry seed per ha at age 3 years the hope was to achieve yields of 4-5mt/ha by age 5-6 years. The expectation was that the plant would increase yield by up to 1mt/ha after year 3 through to maturity at circa year 8. This suggested that a best case yield of 7mt/ ha might have been possible, to give oil yields of 2.0-2.2mt/ha. Plantation development stuttered however and many of these Jatropha farms simply vanished from view so reliable data for achieved yields has not been available. The assumptions on which seed yields had been made previously were based on observation of wild stock collections or wild sourced stock and sometimes based on single tree performances. However the cross bred/open pollination offspring of these accessions or individual trees, could not be relied upon to be as productive as their source parent - perhaps due to different genetics, and perhaps also due to differences in cultivation environments.

'Plant With A Future' – 21st Century Jatropha

When published in November 2012, 'Plant With A Future' concluded that Jatropha's "biology and genetic profile have been subjected to intense scrutiny as molecular and genetic scientists collaborate with agronomists to breed and develop Jatropha cultivars suitable for large scale mechanised farming". In an article (A New *Jatropha curcas* Variety (JO S2) with Improved Seed Productivity – Sustainability 2014, 6, 4355-4368) detailing its open pollinated variety JO S2, JOil noted that "One key reason for the failure of Jatropha plantations is the use of non-improved planting materials". In the paper JOil details the selective breeding process it took to develop JO S2, a variety with "much better seed productivity than wild accessions" as demonstrated by field trials in Singapore and India. On two sites in Southern India JO S2 produced up to 2.95mt/ha dry seeds in its first year and up to 4.25mt/ha in its second year. Whereas breeders can be sensitive about the publication of proprietary data, this paper describes the JO S2 trialling in considerable detail – a sign perhaps of the growing maturity and confidence of companies in this sector.

New plantings today are most likely to be with elite varieties (chosen from germplasm libraries after multi-year observation and trialling), the clones of elite varieties, and commercial hybrids. The commercial hybrids and the clones of high performance elite varieties can be expected to provide much greater production uniformity and are thus easier to manage agronomically than plantings with the seeds of open-pollinated, wild sourced collections. These new plantings increase the chances of achieving a managed agronomic outcome.

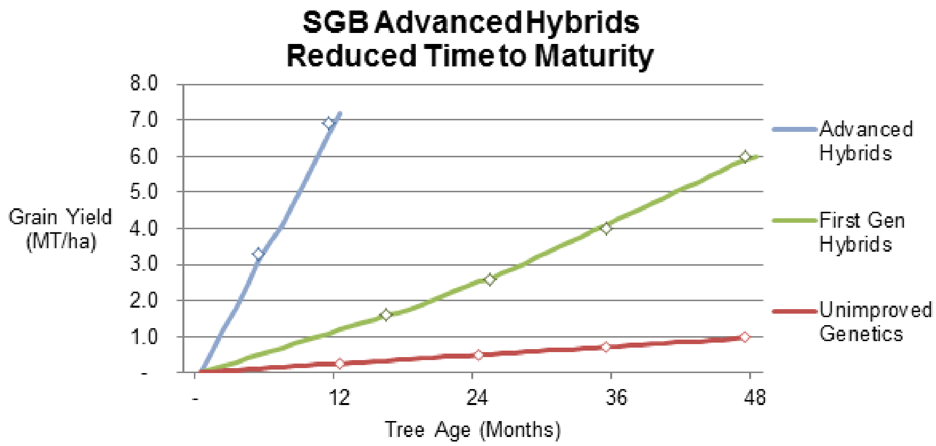
The four most influential Jatropha crop science companies, profiled in this report, began to be formed as distinct entities from circa 2005/6, but their leading figures had in some cases been working with Jatropha since the 1980s. Professor Becker of JatroSolutions and Dr George Francis of JATROPOWER, for example, both made important contributions to Jatropha research and development at the University of Hohenheim in Stuttgart before founding their current Jatropha crop science companies. Today it is reasonable to assert that Jatropha has been the subject of more than 40 years of aggregated focused crop science. Individual lines of commercial hybrids may be the products of focused research and development programmes spanning up to 9 years and more.

Short Generation Time

Compared with globally important tree crops such as palm oil and natural rubber, both supported by circa 100 years of applied crop science, Jatropha is still in an early phase of development. Yet the species lends itself to accelerated development due to the ease of sexual reproduction and its short generation time. Despite being a woody perennial species, Jatropha can finish one round of flowering and seed setting in as short as 6-7 months (seed to seed), especially in the humid tropics or in irrigated environments. It is now technically possible to achieve two improved breeding steps within a 12 month period.

Developers have noted also that some cultivars demonstrate a significant proportion of their yield potential in year one, although this will not be all that may be possible at peak maturity. It has also been noted that age of maturity in some new lines has been shortening, with optimum cropping now considered to be possible in years 3-4. This possibility of early detection of potential productivity helps accelerate development programmes, although the seasonality of fruiting remains a retarding factor.

Whereas last century Jatropha required 4-5 years and more to reach full productivity, some breeders, including SGB, report that certain of its modern hybrids have been shown to achieve almost full productivity between years 1 and 2 under irrigation. SGB reports that its most advanced JMax Hybrids produce first year yields (7 mt/ha) during trials which are on a par with the yields of First Gen hybrids at Year 4 (6.0mt/ha), evidencing an apparent acceleration to maturity in these hybrids.



The above Figure provides a comparison of grain yield over time of SGB's current advanced JMax Hybrids (blue line) in comparison to that of both its best performing first generation JMax Hybrids (green line) and the unimproved landrace variety (red line). Yields are reported on a per hectare basis and are extrapolated from the actual yields obtained in the plantation research trials of the advanced JMax Hybrids (Gen 1, planted in August of 2013) and the breeding evaluation of the first generation hybrids (Gen 0, planted in July of 2010). Note that the total yield at the end of year 1 for the advanced JMax Hybrids are nearly the same as that obtained in Year 4 for the best performing first generation JMax Hybrids. While both trial sites were located in Guatemala, the actual site locations and agro-climatic conditions were not identical. Irrigation was utilized in both trials.
Source: SGB Inc

Jatropha's markedly shorter generation cycle compared to African oil palm (*E. guineensis*) or natural rubber (*H. brasiliensis*), can be viewed as a commercial and technical advantage. Jatropha crop scientists are now exploring if there may be potential to further shorten the time to productive maturity by focused breeding, and even perhaps scope to develop an annual cropping variety. The crop science sector is now actively reviewing the potential for possibly three alternative development routes for the crop:

1. As a perennial tree crop
2. A short rotation shrub crop of 2-3 years
3. As an annual crop with very high planting densities.

Perennial Tree Crop

A breeding & development cycle for the introduction of a new commercial cultivar may take just 2.5-3.0 years. Ultimately however, the productive and economic profile of these perennial cultivars can only be fully understood over a 5-10 year period, embracing both the plant's immature and mature years. Only a long period of monitoring the plant (under diverse cultivation conditions) will provide the fullest understanding of its yield profile, its resistance to cropping induced biotic stress, climate variability and disease & pest predation. A significant hardy tree requiring few inputs would of course have a longer maturation period but for low density plantations, perhaps with intercropping with other cash crops, such a variety would suit the model of sustainable Jatropha in environments deemed not suitable for food crops.

Short Rotation Crop

A small sized shrub suitable for high density plantation planting would require more inputs to produce commercial quantities of seeds in its early years and with development focusing on its suitability for mechanical harvesting and maintenance.

Annual Crop

The capacity of some lines to produce significant volumes of seeds in their first year is a trait that could reasonably be pursued as one of the principal development paths for the crop. Both JOil and SGB are exploring if there is a pathway to annualising Jatropha through high density planting coupled with breeding for specific plant morphology and mechanization of the crop. High density planting would also suit cultivation sites characterised by marked dry and wet seasons; a Jatropha crop that could be produced in the wet season and then harvested in the dry season with the remaining plants then being gathered for use as biomass, would have considerable application. JOil has conducted trials with suitable varieties in both Singapore and India.

High density planting (ranging from 5,000 to 30,000 stands per ha), particularly via direct seeding, has the potential for economic production of commercial volumes of seed per hectare within the annual cycle of a farm. As the crop would be rotated annually, space and light competition from high density concentrations would cease to be a problem. This would call for a shorter stature and limited canopy. Such a development would both extend the range of the crop to temperate and continental climate zones (from which it would otherwise be excluded due to its vulnerability to night time temperatures much below 7 degrees Celsius) and would reduce the commercial risks for farmers experimenting with the crop. Indeed the experience of the Jatropha crop science sector with the plant's proven capacity for very short cycle regeneration has the potential to disrupt much of the earlier thinking about the cultivation of the species, and to provide solutions to economic concerns about the management of Jatropha plantations / orchards including specifically harvesting and pruning.

Germplasm

Germplasm is a term used to describe living genetic resources such as seeds or tissue, maintained for the purpose of breeding, preservation, and other research uses. The Merriam-Webster Dictionary more narrowly defines germplasm as "germ cells and their precursors serving as the bearers of heredity and being fundamentally independent of other cells". Germplasm is the foundation for any crop improvement programme.

During the 17th Century *Jatropha curcas* was reportedly distributed widely around the globe by Portuguese traders. Over 300 years the plant has been cultivated on a variety of land in the tropical and savannah belts across Asia, Africa, the Americas and parts of the Pacific including the islands of Fiji. Homozygosity testing with available markers has demonstrated that a number of wild accessions exhibit a very high degree of uniformity and may be considered as "purebreds". This is likely to be a result of the population having been propagated by cuttings from a single plant resulting in entire local populations being genetically similar. A notable exception for this is Central

America, the source region of the species, and in this region genetic diversity is reported to be high.

The starting point for a breeding & development programme is the careful evaluation in the field of selected Jatropha accessions from within the germplasm 'library' or collection, and/or screening of the collection using molecular techniques. Field screening is typically a two year process (or longer) of observation and record keeping. Data to be recorded may include:

- accumulated annual yield
- growth including height & diameter of canopy
- number of flowering branches & number of primary branches
- dormancy rate during dry season/drought
- oil content
- profile of oil
- time from seed sown to first flowering
- degree of homozygosity
- toxicity levels
- amino acid pattern of kernel meal

These monitored features of the crop will also likely be assessed under differing environmental conditions. Assembled into breeding & observation orchards, or field experiments, these various accessions are closely observed over 2 years or more, for both desirable and undesirable traits. While the first objective of breeder developers has been on finding plants with desirable traits, the linked objective has been to develop an acute understanding of the agronomy required to optimise Jatropha's potential under cultivation.

Amongst the different breeders & developers there is some variation in respect of the number of collected accessions in their respective germplasm 'libraries' and also some difference of emphasis. An accession is typically defined as a collection of plant material from a particular location, perhaps marked by certain distinguishing features. SGB, with its research station centred in Guatemala, has built up a collection of 600 distinct Jatropha accessions – mostly drawn from the Central American region. The company has been impressed with the diversity of phenotypes (the composite of an organism's observable characteristics or traits, such as its morphology, development, biochemical or physiological properties etc) and genetics across its germplasm library and notes that it has identified more than 12,000 genotypes (the genetic makeup of a cell, an organism, or an individual usually with reference to a specific characteristic under consideration).

JATROPOWER also boasts a significant global germplasm collection of some 650 provenances including Central America, Mexico, SE Asia, India, Africa and Madagscar. This comprises material acquired with the Quinvita breeding programme, some 500 genotypes with distinct provenances in all, plus 150 accessions collected by JATROPOWER under its own programme prior to the Quinvita acquisition.

Another large collection was assembled over a 10 year period by Professor Becker and his team, first at Hohenheim University and then with JatroSolutions. JatroSolutions germplasm library contains some 800 provenances. After genotyping each accession, JatroSolutions chose 150 common toxic accessions for its "inner" breeding-programme and 50 non-toxic accessions. Each of these 200 genotypes has been trialled in three replications at the company's test locations in Asia, Africa and the Americas.

JOil has a conservatively defined collection of some 200 accessions. The company's strategic thrust has been to introduce increasing diversity into its collection through a rigorous breeding programme, including the production of new varieties from crossing and self pollination of natural accessions, and also from interspecies hybridisation. At the end of 2014 JOil reported that it had bred more than 1,000 distinct variants.

Breeding & Development Methodologies

Traditional Breeding For Elite Varieties

Traditional breeding comprises the crossing of different plants through controlled or open pollination, targeting development of desirable traits through successive generations of crosses & back crosses, followed by evaluation, selection and propagation. The objective is to develop cultivars capable of producing commercial quantities of high quality oil. Such cultivars should exhibit a capacity for desirable characteristics including:

- Faster growth
    - For higher yields at early age
- High female : male flower ratios
    - Higher yields through greater quantities of fruit
    - Wild Jatropha has a very high ratio male : female flowers
- Superior branching
    - More flower bearing branches
    - Inter-nodal fruiting versus tertiary fruiting
- Stronger tissue / fibre for stronger branches & trunks
    - Trees need to be able to support heavy crops and mechanical harvesting under commercial plantation management
- Open shorter bushy morphology
    - More sunlight to flowering branches, greater yield per plant, and easier harvesting
- Tighter flowering pattern and thus more uniform fruit maturation & ripening
    - Wild Jatropha flowers and fruits continuously in the right conditions but commercial plantations require more concentrated harvesting periods for efficiency and cost control
- Increased resistance to biotic and abiotic stress factors.

Hybridisation Strategies

Hybrid seed technology is common across the commercial crop sector for the achievement of improvements in crop productivity, crop uniformity (which is critical for tight agronomic management), and for the protection of IP. Hybrid seed can be produced via open pollination, by controlled pollination and even by the use of cloning to produce identical sets of breeding parents or even planting material from exceptional individual plants.

The development of reliable hybrid seed is a complex, painstaking process of breeding and it involves a great deal of trial and error. The breeders of Jatropha are benefited considerably in this process by the plant's short generation time. Because *Jatropha curcas* will produce fertile & viable seed at 6 months in Singapore conditions, it has been possible for JOil to achieve two improved breeding steps within a 12 month period.

To develop a successful hybrid, a variety with significant heterosis (the improved or increased function of any biological quality in a hybrid offspring), can involve perhaps hundreds of crossings over three years or more. The development of male sterile or female only specimens in monoecious species greatly increases the speed and efficiency of developing commercial hybrids with a high degree of uniformity. Both JOil and SGB have announced the development of such specimens. F1 hybrids, (the first filial generation of offspring of distinctly different parental types) should ideally derive from one female only / male sterile parent. Male sterility is a recessive trait controlled by a single gene.

JATROPOWER commenced its hybridisation programme in 2010 with 25 elite non-toxic parent pairs from which it produced its first F1 and F2 populations. The company routinely confirms the hybrid nature of its F1 plants through marker analysis. The company reports gains in seed productivity and drought resistance in these plants. The company intends to put to practise the cost-effective technology acquired from Quinvita to generate F1 hybrid seeds in the medium term. The technology involves a proprietary pollination control system based on a genetic, recessive, male sterility trait expressed stably in a wide germplasm base. A marker closely linked to the male sterility gene has been identified, which will facilitate marker assisted selection, thus reducing the development cycle.

JOil has operated two hybridisation strategies: intra-species breeding and inter-species breeding, with this latter methodology being far the more difficult as it typically results in sterile (mule) offspring. JOil's breeding & development cycle for the development of a new commercial cultivar is some 2.5-3.0 years. The company is planning to provide its hybrid seeds for sale in 2016. Today JOil boasts a seed bank comprising its currently available commercial material with immediate availability to plant 20,000 ha.

JatroSolutions, in common with its peers, also focuses on breeding for traits with the use of molecular marker technology to ensure that commercial cultivars are genetically consistent with their performance specifications.

SGB reports the development of a proprietary hybrid seed production methodology (patent pending) employing the use of female only parental lines and insect pollinations. SGB reports that this has enabled it to rapidly produce seed at a low cost in response to customer demand.

Intra-species Hybridisation

Intra-species hybridisation involves the pollination of female *Jatropha curcas* flowers with pollen of the same species, while inter-species breeding involves the crossing of *Jatropha curcas* with other Jatropha species. Varieties identified with desirable traits after routine observation, will be crossed using hand pollination to produce a first generation of hybrid plants. The seedlings from this crop will then be put through field trials. These hybrids are evaluated in the field for morphology, yield and agronomic traits. Those hybrids with the best performance evaluations over a full year/ cropping cycle will then be selected for further hybridization under controlled pollination. Clones of selected hybrids can be field tested in diverse cultivation sites before being made available for commercial release. In all this is a 3 year development programme.

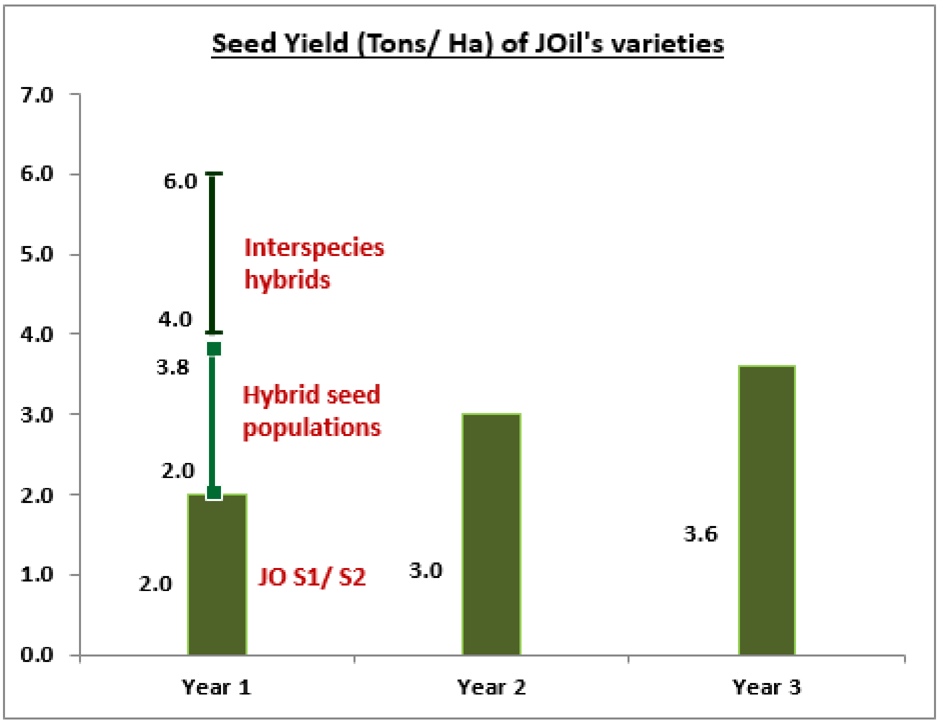
A second intra-species breeding strategy is based on open pollination. At first stage, seeds are collected from the best performing individual trees amongst the accession collection, which are germinated and plants derived are put through field evaluation. Again open pollinated seeds will be harvested from the best trees and germinated for the next round of field evaluation. This process can continue for multiple generations. When a population of plants are competitive in seed productivity and uniformity, and also consistent in other agronomic traits, their seeds can be considered for commercial sale.

Inter-species Hybridisation

Inter-species hybridisation, or introgression breeding, involves the transfer of favourable genes from one distinct species into the gene pool of another by the repeated backcrossing of an inter-species hybrid with one of its parent species. Introgression differs from simple hybridization because it results in a complex mixture of parental genes, while simple hybridization results in a more uniform mixture, which in the first generation will be an even mix of the two parental species. Inter-specific breeding has the objectives of broadening genetic diversity and introducing highly desirable traits from one species to another.

Managed introgression is a long-term process; it may take many hybrid generations before the backcrossing occurs. This is what JOil reports having achieved with its JO-H2 *Jatropha curcas* x a wild Jatropha species x *Jatropha curcas*. The JO-H2 variety is a third back cross to a selected *Jatropha curcas* parent. This initial back cross enabled TLL/JOil to construct the first genetic map of Jatropha, (Wang CM, Liu P, Yi C, Gu K, Sun F, et al. (2011) A First Generation Microsatellite and SNP-based Linkage Map of Jatropha. PLoS ONE 6(8):e23632. Doi:10.1371/journal.pone.0023632), and a selection of materials for further breeding. The cultivar is compact in size with strong branches and a lower than typical male: female flower ratio. It is described as having a relatively tight flowering pattern, and JOil reports that it has exhibited relatively heavy early seed yields with good levels of oil content.

These inter-species hybrids are demonstrating strong yielding characteristics as demonstrated in the chart below.



Source: JOil (S) Pte Ltd

Male Sterility/Female Only

Jatropha is a monoecious species producing inflorescences with separate male and female flowers, but having a preponderance of male flowers (in the range of 10:1, male:female). Sterility in the male flowers, or a complete absence of male flowers makes controlled hybridisation much easier. SGB reports that it has been able to identify and subsequently select and stabilize a trait referred to as "Female Only"; namely plants that produce inflorescences composed of only female flowers. The company now reports that it has over 100 inbred 'female only' lines coming from about 50 of the original 600 accession families in the germplasm collection, representing 80% of the genetic diversity of SGB's germplasm collection.

Similarly the JOil breeding team reports that three male sterile lines have been developed. The company advises that the most promising line has the male sterility characteristic controlled by a single recessive gene, as confirmed by genetic analysis in progenies. This was used to generate 20 F1* hybrid seed populations with other good accessions or pure Jatropha varieties as male parents. A one year field trial in Singapore was conducted to identify those plants showing significant heterosis and uniformity in the field. Those specimens are now undergoing more extensive trialling in both Singapore and India.

JATROPOWER advises Hardman that it has three pistillate (female only) Jatropha plants, two from its proprietary portfolio and one from the purchase of the Quinvita IP. Quinvita is reported to have reached the third back crossing and JATROPOWER intends to progress this research to develop a set of pistillate elite plants that will make hybridisation cost effective.

JatroSolutions also confirms male sterile accessions in its Jatropha population. The use of male sterility for the production of Jatropha hybrids is reportedly the subject of intensive research within JatroSolutions' breeding programme. The company has recently published on the subject of male sterility and other hybrid production techniques for Jatropha. (Montes, J.M., A. Bulach, M. Martin, E. Senger. (2015). Quantitative Trait Variation in Self- and Cross-Fertilized Seeds of *Jatropha curcas* L.: Parental Effects of Genotypes and Genetic pools. BioEnergy Research. DOI: 10.1007/s12155-014-9576-8)

Molecular Strategies & Genetic Marker Technologies

SGB reports that it has developed molecular strategies to organise and analyze its germplasm library. Accessions of different provenances are grouped according to their genetic 'relatedness', represented in molecular clades. In biology, cladistics is a taxonomical technique for arranging organisms according to how they branch during their descent from a common ancestor. A group of organisms is analysed and classified into a tree-like diagram called a cladogram, showing hypothesised lines of descent. The analysis may use morphological similarity, but most often DNA differences (molecular data) and biochemical data. Cladistic techniques are based on the concept of descent with modification. In support of its breeding activities, SGB also advises Hardman that it has applied 'sophisticated genotyping and molecular breeding tools' designed to shorten breeding cycles and to accelerate the time to market of its elite planting material. SGB reports that its genotyping platform enables rapid and precise *DNA barcoding* with unique molecular identifiers of parental and hybrid lines. This not only provides IP protection for hybrids deployed commercially, but also enables quality control during seed production.

Employing DNA analysis techniques JATROPOWER has been able to identify suitable markers that can reliably distinguish between common toxic and non-toxic accessions of *J.curcas*. These markers help in further enumerating the inheritance pattern of the non-toxic trait and its homozygosity. The non-toxic markers identified in JATROPOWER's research have been made available to the Jatropha community via a research publication (Plant Science 207 (2013) 117– 127). The company expects to identify the marker that is closest to the non-toxicity allele. The company also has identified markers closely linked to the male sterility gene in *J. curcas*.

JOil advises Hardman that it has built up a collection of some 1,000 genetic markers. It uses these, along with its other genomic information to assist with the breeding programme and to track the success of the breeding programme for traits in the new varieties developed.

Genetic markers - breeding improvements can be accelerated with assistance of genetic markers. The use of markers is typically in conjunction with a defined and desirable trait, reduced toxicity for example.

Breeding For Traits

All four of the crop science companies profiled within this report are seeking to identify and exploit useful natural traits found amongst the Jatropha varieties within their respective germplasm collections. Some development programmes have been defined by preferred traits – JATROPOWER for example has focused significant, but not exclusive, research on the identification and analysis of the non-toxicity trait in edible Jatropha. Other traits being primarily pursued by the company in addition to seed productivity include early flowering, synchronous ripening, oil content and oil composition and sturdiness under adverse climatic conditions.

Source: SGB Inc

Within the report we detail commercial cultivars developed by JatroSolutions for their specific traits such as:

- Drought tolerance
- Broad adaptability
- Early flowering
- Higher than average oil content
- Resistance to leaf rust
- Compact stature
- Strong constitution.

Other programmes have focused on field management issues including:

Direct Seeding: SGB reports an achieved rate of germination of between 90%-95% when direct seeding its high vigour hybrid seeds. There are a number of benefits associated with direct seeding:

- more rapid establishment of the tap and brace roots
- avoidance of root coil and J-root development
- shortened time elapse from planting to flowering
- avoidance of nursery costs
- reduction in planting costs

Mechanisation: as plant uniformity approaches 95% a crop becomes suitable for mechanisation of field management. Combined with direct (and mechanised) seeding, mechanisation of harvesting and pruning has the potential to increase operating efficiencies and to reduce costs. The breeding methodologies detailed herein have varietal uniformity as a key objective.

Planting Density - An Annual Crop

Both JOil and SGB believe that there is a pathway to potentially annualizing Jatropha through high density planting coupled with breeding for specific plant morphology and mechanisation of the crop. JOil is actively breeding for small stature and canopy; it is seeking to develop a plant that not only has a smaller footprint, but which channels more of its synthesised energy into fruit production. A successful annual model would open up the prospect of growing Jatropha for cropping and harvesting during the wet/dry seasons common across many parts of the tropical belt and even in more temperate latitudes currently inhospitable to perennial Jatropha due to the species vulnerability to freezing. SGB company has conducted various high density trials to determine the impact on flowering and fruiting at densities ranging from 2,200 sph to 30,000 sph. JOil has a narrower focus at around 5,000 sph, with the goal of taking as much as 5mt of seeds / hectare in one cropping season.

Reduced Time to Maturity

Both JOil and SGB have reported shortened maturity periods (1-2.5 years) in certain of their respective hybrid varieties. This trait also offers the scope to develop an annual cropping variety. The pattern of precocity in Jatropha appears to be accentuated in environments where the plants have abundant water; in semi-arid and dry environments the pattern of maturity is more typical at 3-4 years. But in contrast with wild and unimproved varieties this pattern represents an advance. SGB reports that its JMax Hybrids are able to realise something close to full assumed productivity between years 1 and 2 from germination. Shortened maturity is a highly desirable commercial trait as it provides a much more attractive value proposition to its farmers with the promise of revenue generation commencing in Year 1, as opposed to having to 'nurse' the plantation for 4 years or more to maturity.

Gene Technologies

Gene related technologies are important to crop breeders for understanding how certain traits are driven. The focus is on genes that have commercial value. So in Jatropha the genes that control the synthesis of oil and phorbol esters are of real commercial interest. JOil's partner, TLL has developed a suite of technologies aimed at permitting the expression of target genes as required to underpin the commercial viability of the crop. This begins with gene identification which is based on the development of gene function analysis - a system for the evaluation of specific genes for their commercial usefulness.

The partners have focused on those genes critical for the synthesis of Jatropha oil, toxins and flower development. These genes were targeted to generate commercially important traits in Jatropha. Examples include targeting genes critical to Jatropha oil synthesis and flower development to modify fatty acid composition and timing of flowering, tuning a transcription factor serving the role of a master switch toward more oil biosynthesis in seed. Seed toxins curcin and phorbol ester biosynthesis genes have also been cloned and their functions verified. Interception of these genes leads to development of low toxicity Jatropha. Using these techniques TLL/JOil have developed a GM Jatropha variety that produces oil with high oleic acid content (up to 75% of oil content as compared with up to 45% found in non-GM varieties) in seed. This high oleic acid GM Jatropha was achieved by down regulating a *Jatropha curcas* desaturase gene in a seed specific manner. High oleic acid Jatropha oil is expected to yield higher quality biodiesel (high cetane number) with better oxidation stability. Other traits in development include high seed oil content, BT Jatropha that is resistant to insect attack and Jatropha with very low toxicity (both curcin and phorbol esters).

Propagation Technologies

Because early phase Jatropha hybrids were not expected to breed true, JOil has also had a focus on propagation technologies. Using gene technologies & traditional breeding activities to achieve important advances in the performance of its Jatropha collection, and which are sometimes strongly expressed in certain plants, JOil has been developing propagation technologies in order to produce industrially scaled quantities of clones from these mother plants.

Tissue Culture

JOil Tissue Culture technology is designed to facilitate the mass production of true-to-type clones of all its high yielding, hybrid varieties and of its genetically modified Jatropha plants. This technology is being used to propagate planting material from JOil hybrid lines including JO H1 and JO-H2. Seed derived offspring from these materials will likely produce diverse segregations, resulting in highly variable performance, whereas cloning ensures that every plant is true copy of its proven high performing parent. The technology was initiated by TLL, but commercialised by JOil. The clones produced have been widely tested for uniformity in morphology and seed productivity.

JOil's strategy is to produce a scalable well tested technology that can be licensed out to OEM partners. In order to be able to supply industrial scale volumes (millions) of Tissue Culture derived seedlings into its targeted geographic markets, JOil has been establishing partnerships with local 'OEM' commercial suppliers of planting materials for the horticulture sector. It has established partnerships in: India, China, Thailand, Philippines, Kenya, Indonesia & Singapore. JOil supplies plant tissues (explants) from elite 'mother plants' to its partners in different locations. JOil also supplies the production technology and pre-made media for in vitro culturing of the explants. These partners are supplied with explants or young plants in culture and the necessary cultures / media in which the plants will be developed. JOil then receives back shoots suitable for rooting or grafting, or hardened seedlings ready for planting out.

JOil's claim to lead in the field of in vitro propagation of Jatropha is undisputed; the company has developed 11 protocols using 17 explants. Plants ready for planting out in the fields can be produced within 4.5 months using somatic embryogenesis techniques developed by JOil.

Jatropha Oil as Fuel Feedstock

The promise that Jatropha would yield commercial quantities of high quality vegetable oil in growing environments in which traditional oilseed crops would fail, is what first brought the plant to prominence. Still it is the case that plant's capacity to produce a high quality feedstock for the biodiesel sector underpins the interest and investment in its future. Biodiesel is accepted as a clean, safe fuel and its use is mandated in more than 60 countries as a national policy response to the requirement to reduce carbon dioxide emissions. Today biodiesel makes up some 3.4% of global fuel used in road transportation and it accounts for around 31% of all biofuels produced, but it represents only 0.5% of global crude oil produced annually. As the cost of crude oil has plummeted in the past year, so mankind's output of carbon dioxide has continued to rise. The Kyoto Protocol targets carbon dioxide output at 450 ppm (if global temperature increases are to be held at 2 degrees Celsius by 2050), but current trends suggest that 950 ppm is more likely by that year.

If we are all facing an existential challenge to reduce our carbon footprint, many of the developing economies are energy poor and users of environmentally damaging energy sources including wood and charcoal. It is in the energy poor developing economies in particular that carbon light fuels such as Jatropha oil derived biodiesel can produce a measurable beneficial social, economic and environmental impact. In this context it is notable that JOil is developing a demonstration farm in energy poor and land locked Burkina Faso with the first 100 acres planted in 2014.

Beyond the energy poor developing economies, Jatropha oil has been noted for its particular suitability for renewable jet fuel (RJF). The fuel bill for the global aviation industry has benefited from the collapse in the price of crude. Whereas the industry was spending some $240bn annually, this bill has been pared back to circa $140bn in the current pricing environment. However under political and consumer pressure the European airline sector is seeking to achieve substitution of conventional fuel with biofuels of some 3%-4% by 2020. The global opportunity for jet biofuel could be in excess of $4bn pa.

Jatropha oil is well suited to satisfying the requirements of all three of the market opportunities identified above. The economic model for its production has not yet been proven. Today this model depends on manual labour, making it highly suited to many of the energy poor developing economies across the tropical and arid regions. Traditionally Jatropha has been viewed as a crop for production under an out grower model, and this model has logic, but with careful management and suitable modern planting material, it should be possible to produce Jatropha oil economically under plantation management. Local production can be made even more economically attractive if married with refining at source; a range of affordable and robust transportable mini-refinery technologies offer the prospect of producing local biodiesel to be cost competitive with imported petroleum based fuels.

Biodiesel

Biodiesel is a clean burning, biodegradable, non-toxic and virtually sulphur-free biofuel. It contains no petroleum products, but it can be blended with any level of petro-diesel to create a blend and can be used in diesel engines without modification. Technically, biodiesel is Fatty Acid Methyl Ester; it is formed by the process of transesterification whereby a fat or oil is mixed with methanol and a catalyst (potassium methoxide) to produce biodiesel. The production of biodiesel overcomes the viscosity problems associated with pure vegetable oil in engines; it transforms the triglyceride molecules (made up of three fatty acids plus glycerol) into fatty acid methyl esters (FAME) that have similar physical and chemical properties to petroleum diesel [hence the name biodiesel]. It is formed by removing the glycerol molecule from vegetable oil in the form of glycerin (soap). Once the glycerin is removed from the oil, the remaining molecules are, to a diesel engine, similar to petroleum diesel fuel. There are some notable differences. The biodiesel molecules are very simple hydrocarbon chains, containing no sulphur, ring molecules or aromatics associated with fossil fuels. Biodiesel is made up of almost 10% oxygen, making it a naturally "oxygenated" fuel. Its advantages are commonly listed as including:

- biodiesel can be used in existing engines and fuel injection equipment (no modification required) without negative impacts to operating performance.
- Biodiesel has a nearly identical MPG rating to petro-diesel and it is the only alternative fuel for heavyweight vehicles requiring no special dispensing and storage equipment.
- Biodiesel readily blends and stays blended with petro-diesel so it can be stored and dispensed wherever diesel is stored or sold.
- Biodiesel has a very high flash point (300°F) making it one of the safest of all alternative fuels.
- It is claimed that biodiesel can extend engine life because of its superior lubricating properties.

Demand Growth Led By Transportation Sector

An international market for bioethanol and biodiesel was established in the first decade of this century and now both commodities are important constituents of the international commodities markets. Growth in consumption and production has been driven primarily by the transportation sector – especially road transportation – and by government policy. More than 60 countries have legislated for mandatory percentages of renewable fuel usage, or blending rates for biodiesel with petro-diesel. Biodiesel is the, cleanest, most energy-efficient and fastest-growing alternative liquid fuel worldwide. Biodiesel has grown tenfold in the last decade and now accounts for 31% of all biofuels and up to 50% of all biofuels in the large developing economies of Asia, Oceania, Latin America and Africa (Biocube Corporation). As the table immediately below makes clear, biofuels have developed a significant minority share of the market for road transportation fuel.

Ethanol & Biodiesel Used In Transportation	
As % Of Global Energy Use	0.80%
As % Of Global Primary Energy Derived From Biomass	8.00%
As % Of Global Road Transportation Fuels	3.40%
As % Of All Transport Fuels	2.50%
Source: Worldwatch Institute	

The United Nations Conference on Trade and Development (UNCTAD) in its 2014 published report, 'The State of The Biofuels Market', noted that "the large increases in production, use, and international trade of biofuels which were seen after 2006 have contributed to mature the industry, giving it a professional standing in line with other major tradable commodities". However, despite significant growth in output since the first decade of this century, with more than 22bn litres of biodiesel produced annually and the commodity traded daily in significant volumes across all continents, it is dwarfed by petroleum based products as the table below illustrates.

Global Biodiesel Production		Source
Billions of barrels of oil consumed 2012	31	International Energy Agency; BP, 2013
Biodiesel barrels equivalent produced in 2012 (m)	141.5	Worldwatch Institute
Biodiesel produced as % of oil consumed (all in barrels)	0.5%	Hardman Estimates
Global Biodiesel Output 2012 (litres billion)	22.5	Worldwatch Institute
Global Biodiesel Output 2011 (litres billion)	*22.4*	Worldwatch Institute

Growth in demand for biofuels, and especially for road transportation, has been strongly driven by blending mandates and supported by subsidies. Worldwatch reports that:

- 76 states, provinces, or countries had biofuels mandates in place in 2012
- Global subsidies for liquid biofuels were estimated to be well over US$20 billion for 2012
- Mandates or targets were established in 13 countries in the Americas, 12 in the Asia-Pacific region, and 8 in Africa
- In Europe, the EU-27 group of countries is subject to a Renewable Energy Directive (RED) that called for 5.75% biofuel content in transportation fuels in 2012.
- The United States and China have established—and Brazil has already achieved—targets of between 15 and 20% no later than 2022
- India has also mandated 20% ethanol by 2017
- Indonesia introduced a 10% blending mandate in 2013.

There is some scepticism however as to whether these targets will in all cases be met or adhered to. The EU's RED has been questioned over the effect that biofuel feedstock cultivation maybe having on food prices and changes in land use. In Indonesia it is doubted that the country's distribution infrastructure can facilitate the roll out of the mandate beyond the major metropolitan areas. Ultimately however it is market forces that will have the greatest influence on the sector's development. A recent media report on the biodiesel market in the USA reported the example of a small biodiesel producer in North Carolina, manufacturing biodiesel from used restaurant cooking oil, whose sales have fallen 40% since July 2014. The company had reduced its biodiesel to US$3.29/gallon from around US$4.15 in September, but this remains uncompetitive with conventional diesel at US$2.93/gallon.

Alongside the growth in demand for biofuels from the road transportation sector, other sectors including aviation, electricity, and shipping have begun to build biofuel usage into their fuel regimes. This pattern has reflected a more general 'greening' of energy policy across the international industrial spectrum in response to mounting social and political concern about climate change. It remains to be seen if the fragile international consensus to limit mankind's output of carbon dioxide will hold if energy prices remain depressed, but the data are sufficiently concerning to hope so.

Estimated 2012 carbon dioxide levels in atmosphere (parts per million)	394 ppm	International Energy Agency; 2012a
Estimated increase on highest level in last 400,000 years	31%	International Energy Agency; 2012a
PPM carbon dioxide required to stablise world climate at 2 degrees celsius increase by 2050	450 ppm	International Energy Agency; 2012a
Current projections for carbon dioxide levels in 2050 based on current patterns of consumption	950 ppm	International Energy Agency; 2012a

Biofuel Strategies For Developing Economies

The 2014 UNCTAD report ('The State of The Biofuels Market'), observed that the basket of producing countries had not changed substantially since 2006. As the table below reveals, the largest producer nations are for the most part developed economies, yet the greatest potential for the sustainable production of 1st Generation biofuels is widely accepted to exist in the developing economies.

Biodiesel Producer Analysis (2012)	Billions of Litres Produced
USA	3.6
Argentina	2.8
Germany	2.7
Brazil	2.7
China	0.2
Other EU (excluding Germany)	6.5
Other	4.0
Total	**22.5**
Source: Worldwatch Institute	

Developing economies in Africa and Asia in particular, have a favourable combination of climate, land availability and cheap abundant agricultural labour, to support the development of a sustainable biofuel economy. Bio-energy is regionally or locally important in many places around the world. Traditional biomass (typically wood, charcoal and animal dung) is still used for cooking by 38% of people worldwide, and this rises to 90% for large swathes of Africa and some parts of Asia with significant negative impact on forested areas. Consider the energy realities for Sub-Saharan Africa:

- 68% of the population lacks access to clean modern energy sources
- 60% of all energy is imported (BP June 2012 Energy Review)
- Progressive chronic deforestation is taking place as forest and scrub is used for charcoal production
- 76% of the population of Sub-Saharan Africa was thought to rely on wood, charcoal and dung for cooking (IEA 2006)
- In 2010 Africa was estimated to account for only 3% of world biomass fuelled electricity generation
- Africa is thought to have up to 120m ha of under-utilised arable land.

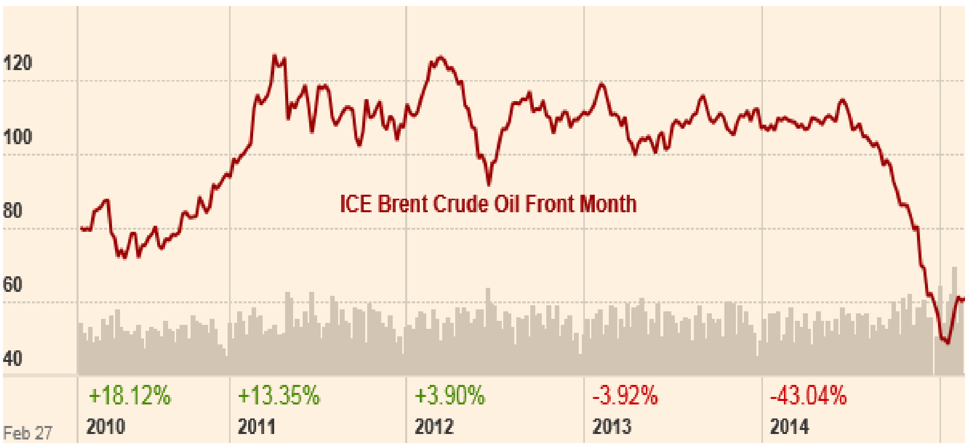
Socially and environmentally, large swathes of Sub-Saharan Africa are in urgent need of locally provided sustainable energy. A biofuel strategy based on cultivated feedstock could provide at least part of the solution. It is in this context that Jatropha has been proposed as a possibly valuable crop for African agriculture.

The establishment of a sustainable biofuel sector in a developing economy is typically driven by the need to substitute imported and expensive fossil fuels with local energy sources. This is likely to be driver both at a local or regional level as well as at the national level, especially if logistics are sub-standard. The NGO, New Partnership For African Development (NEPAD) argues that a vital condition for the development of a successful biofuels sector is "a predictable, consistent, realistic, sustainable, transparent and coherent regulatory framework". It is also the case that feedstock production should enhance the rural economy and not compete with food production for land, labour and water; 1st Generation Biofuels are typically land hungry.

The Challenge of Shale Oil

At its peak in February 2006, Nigeria exported some 1.3m b/d to the USA; that trade has now quite literally, 'dried up'. In July 2005, US crude oil imports reached a high of 10.8m b/d, but by July 2014 this had reduced to 7.6m b/d as domestic production of shale oil has ballooned. This was forewarned by Nigeria's oil minister Diezani Alison-Madueke who noted in 2013 that the development of the US shale oil sector was "one of the most serious threats for African producers".

It is a warning which the biofuel sector should heed also, since there is no escaping the hard economic reality that despite concerns about climate change and carbon footprint, a stuttering global economy is drawing relief from cheap crude oil. Theories abound as to why OPEC, led by Saudi Arabia, did not slash quotas in November 2014. Perhaps the decision was a mix of both geo-political rivalries and a tilt at the US shale producers, but reportedly shale producers are able to make profits at $50 to $70 a barrel. The International Energy Agency was cited by Bloomberg (14th October 2014) as observing that "only about 4% of U.S. shale oil production needs prices above $80 for drillers to break even". Wall Street analysts are somewhat sceptical about this claim, and suggest that perhaps 30% of the drilling community requires pricing at $80+ per barrel; published data suggest that the US sector would be more comfortable with per barrel values well above $60.



Source: Financial Times

With the advent of a plentiful supply of shale oil in the US (and perhaps now in other countries also), the prospects for a return to $100/barrel oil are uncertain. The current price of $62 per barrel (Brent Crude) translates to approximately $446/mt, while $80 per barrel out turns at $576/mt approximately. These values present a significant challenge to the biodiesel sector and its most important feedstock suppliers, the producers of vegetable oils. The halving in value of crude oil since mid 2014 has been reflected also in the price of the vegetable oil complex with palm oil trading down between $600-$700/mt since August 2014.

Source: World Bank

The current price for crude palm oil (CPO) compares with more than $1,000/mt achieved during Q1 2014. In West Africa however, producers are still receiving between $800-1000/mt for CPO as the region and the continent are net importers of the commodity.

Palm oil enjoys the lowest cost of production within the vegetable oil complex – efficient producers are able to deliver crude palm oil to refiners at circa $400/mt, but there is a wide range within the industry and at a market price from $468/mt -$576/mt, many would struggle to achieve acceptable returns. This then is the new reality for the biodiesel sector, a very different scenario from the first decade of this century when concerns about the rising costs of fossil fuels (especially crude oil trading at or over $110/barrel) and sensitivity around climate change had produced an unprecedented interest in biofuels and green energy. It was against this background that the first wave of serious interest in Jatropha was expressed in farming and refinery start-ups and in the formation of new, Jatropha focused crop science companies.

Jatropha – A Highly Suitable Feedstock For Biodiesel

The leading US bio-energy research company Synthetic Genomics Inc (SGI), founded by J. Craig Venter and Nobel Laureate Hamilton Smith, working with the Asiatic Centre for Genome Technology (ACGT), and owned by Malaysian palm oil conglomerate Genting Berhad ($9.0bn market capitalisation), announced completion of a first draft, 10x assembly of the Jatropha genome in August 2010. The partners noted that they had focused on Jatropha because:

- it is a tropical tree
- it is one of the highest yielding oilseed plants in the world
- it can be grown on marginal, non-food producing land

- it has a very short generation time
- it can be productive for 30 to 40 years
- its seed oil and biomass are ideal for biofuel production
- it is an ideal subject for genetically engineered improvements.

"Having the sequenced genome of Jatropha will enable us to develop new, sustainable energy feedstock that grows on marginal land or in more arid climates and that does not compete with agriculture for food production," said J. Craig Venter, Ph.D., founder and CEO of SGI. Even in the five years since this announcement, the development of the plant has been significant and in contrast with the implied expectation in the SGI / ACGT announcement of tropical plantation lives of up to 40 years, crop scientists are now postulating that it may be possible to develop Jatropha cultivars suited for annual high density cultivation in temperate climates. With confidence increasing amongst the crop science companies who are developing Jatropha, that the crop can deliver from 4 mt - 7 mt of dry seed per ha (depending on environment and agronomic regime), it may be possible to produce up to 2mt of CJO/ha.

Jatropha oil is a moderately unsaturated oil and liquid at room temperature. Depending on different factors including contamination with particles, CJO should be fluid at around 10 degrees Celsius. Its structure comprises a triglyceride containing mostly linoleic and oleic fatty acids and under correct circumstances Jatropha oil will make high quality biodiesel. The high triglyceride content of the oil is highly suitable for trans esterification so that Jatropha oil lends itself well to conversion into biodiesel and aviation fuel. Like rapeseed oil it has a low solidifying temperature and has lower levels of gum & resin than many of the vegetable oils, which means that it can be used as straight vegetable oil (SVO) in simple agricultural equipment.

Advantages over mineral-oil derived diesel include:

- lower particulates
- very low sulphur levels
- lower smoke emissions
    - an important requirement for coastal shipping
- a high cetane rating as biodiesel
    - a measurement of the combustion quality of diesel fuel during compression ignition
- 4% more efficient than conventional aviation fuel [Boeing 2009].

Table: General properties of Jatropha oil

Specifications	Value
Triglyceride (%)	80-95
FFA (%)	3-19
Moisture (%)	0.5-3
Diglyceride (%)	2-5

Source: Biocube Corporation

Before processing into biodiesel, crude Jatropha oil (CJO) must first be refined to remove gums, waxes and any impurities, and free fatty acids must be removed. This is a 3 stage process:

1. Degumming – by addition of phosphoric or citric acid and separating

2. Bleaching & filtering
3. Removal of free fatty acids by passing through a de-acidification column. JATROPOWER advises Hardman that in its experience of properly harvested dried and stored Jatropha seeds, the free fatty content is always less than 2%.

A small group of companies is now able to refine pure vegetable oil (PVO) into biodiesel using modular, containerised plants that can be set up anywhere. These have particular relevance for the production of biodiesel from Jatropha oil at this point in the commercial evolution of the crop. Local need for, and the required price for biofuel will both be better satisfied by the cultivation of Jatropha oil at point of use and its conversion to biodiesel also at point of use. These modular, transportable plants can range from 1,500 tonnes processed pa to 12,500 tonnes; being dry wash they require no water, hence their site flexibility. The capital cost for such equipment may start from $350,000, for a unit producing between 1,500mt-2,000mt pa and may rise to $1m plus for larger scale units.

Cost of production of biodiesel at point of use/source of feedstock, will vary depending on the market price of methanol, other chemicals and labour rates. One producer has advised Hardman that its costs are typically in the range of US 23-27c per litre before the cost of feedstock oil At between 1,000 and 1,100 litres/mt (depending on the specific gravity measure for the CJO used) this equates to between $230-$250/mt and compares with industrially scaled refinery costs estimated in the range $90/mt-$123/mt. Plant With A Bad Name (March 2011) cited a World Bank report of the same year [Biofuels In Africa, Donald Mitchell] which put the cost of converting CJO to biodiesel at between $90/mt- $123/mt (8 cents to 11 cents per litre) excluding cost of feedstock and depending on the scale of the production unit.
One 'at source' refining unit that Hardman has reviewed is The BioCube™, a transportable biodiesel refinery design-engineered and available in a modified 20' sea container. It can operate on or off-grid and produces commercial quantities of high quality biodiesel from a wide range of waste and renewable feedstock oils, including Jatropha. Biodiesel from the BioCube can be used directly to fuel generators, trucks, agricultural equipment or any modern diesel engine without modification.

Designed for ease of use and robustness, reportedly the BioCube can be operated by a semi-skilled technician after a short training programme. It combines hi-tech semi-automated touch screen systems, with components that are easy-to-operate and maintain. BioCube units can be 'daisy-chained' in multiple units to create a BioCube Plant to meet larger volume needs and can grow incrementally as demand increases.

By operating close to the point of harvest and consumption, the BioCube eliminates the carbon footprint associated with centralised, bricks and mortar refineries. The manufacturer proposes the equipment as "an elegant solution to the problem of making distributed biodiesel processing commercially viable for communities and commercial enterprises". With a capital cost per unit starting at circa $350,000 and a setup time of only days, The BioCube™ is a low cost and relatively immediate answer to the need for refining capacity and contrasts with capital costs ranging from $2m (for mini-refineries) to $100m+ for large scale refineries.

Source: BioCube Corporation

Sustainability

Jatropha has been seen as a more ethical choice as a feedstock for fuel production, based on the argument that the crop does not compete with food crops for arable grade agricultural land. Moreover Jatropha can demonstrate a Green House Gas (GHG) saving of around 60%. RE Bailis and JE Baka of the Yale School of Forestry & Environmental Studies have presented analysis of a comparison of life-cycle GHG emissions from synthetic paraffinic kerosene (SPK) produced as jet fuel substitute from *Jatropha curcas* feedstock cultivated in Brazil, against a reference scenario of conventional jet fuel. Life cycle inventory data were derived from surveys of Jatropha growers and processors. Results indicate that a baseline scenario, which assumes a medium yield of 4 tonnes of dry seed per hectare under drip irrigation with existing logistical conditions using energy-based co-product allocation methodology, and assumes a 20-year plantation lifetime with no direct land use change, results in the emissions of 40 kg CO2 per GJ of fuel produced, a 55% reduction relative to conventional jet fuel. However, direct land use change can lead to widely varying changes in carbon stocks ranging from losses in excess of 50 tonnes of carbon / ha when Jatropha is planted in native cerrado woodlands to gains of 10-15 tonnes of carbon / ha when Jatropha is planted in former agro-pastoral land. (Environ Sci Technol. 2010 Nov 15;44(22):8684-91. Epub 2010 Oct 26). Independent life-cycle analysis by Ecofys (a specialist advisory firm in energy saving and renewable energy), shows Jatropha-based biodiesel provides a nearly 70% reduction in GHG emissions over petroleum-based diesel.

Proof that Jatropha oil has not compromised food production enables the product to fulfil the certification issues related to EC Directive 2009/28 EC. The Directive stipulates that the proportion of renewable energies is to be increased to a mandatory 20% in the EU by the year 2020. In the transport sector, the proportion of renewable energies is to rise to 10% of total fuel consumption over the same period. This mandatory target blending rate applies not only to biofuels, but to all renewable energies used in the transport sector, including electric power and hydrogen produced from renewable sources for instance. A significant share of these biofuels, but not all, can be brought onto the market by low level blending of biodiesel in diesel and of bioethanol in petrol.

Current fuel standards allow up to 7 volume% FAME (the most common type of biodiesel, B7) and 10 vol% ethanol (E10).

In particular the Directive seeks to avoid a negative impact on food production, requiring reference to the FAO Hunger Map. The Directive promotes the use of degraded land, which favours the production of Jatropha oil, because this brings more land into production. Only Sustainable Biofuels will count towards the EU's Renewable Energy Directive (RED) targets and the 'National Biofuels Obligations' of EU countries. Basic EU sustainability criteria for the production of sustainable biofuels include:

- GHG emission reduction performance compared to fossil fuels
- Avoidance of deforestation, negative impacts on biodiversity and land use change
- Cross border transfers of renewable products, guarantee of origin, traceability must be demonstrated
- Promotion of opportunities for employment and regional development especially in rural areas (EU Directive Sustainability Criteria)

There are as yet no sustainability criteria specifically for Jatropha and those under development, such as Roundtable Sustainable Biomaterials (RSB), are in their infancy. Industry practitioners have proposed that:

- Policies should synergise with the needs of the local environment and communities
- Jatropha related enterprises should make a positive social and environmental impact
- Jatropha business should implement best practice across all areas of production including cultivation, harvesting, processing.

In the context of the sustainability requirements detailed above, it is interesting to note the decision of JOil to develop its demonstration farm in Burkina Faso; the first 100 acres were planted in 2014. The JOil site was selected in the southern part of Burkina Faso because the aridity increases towards the northern part, thereby increasing the demand for water exponentially. It is to be noted that no cultivation is happening in these regions and chances of these lands succumbing to desertification is high due to progressive climate change. The development of Jatropha plantations in these regions will it is hoped reverse or hold in check this pattern. Jatropha plantations can also be useful in preventing run-off and consequential erosion during the wet season, allowing more water to percolate in to the ground thereby increasing the water table. In this region, where the day rate for agricultural labour is circa $3, there is high unemployment and a shortage of training for the acquisition of skills. The JOil project offers both positive socio-economic and environmental benefits for the region.

Source: JOil (S) Pte Ltd

Renewable Jet Fuel

Biofuels have the potential to reduce the impact of the airline sector on Greenhouse Gas (GHG) emissions and to form a component in the fuel cost management strategies of passenger and freight transporters. The revision to the ASTM International standard, D7566 (Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbon), approved the use of synthetic jet fuels in 50/50 blends for commercial airline service. It “now includes an annex with requirements for synthetic fuel components manufactured from hydro processed esters and fatty acids, produced from various renewable sources,” (Enright 2011 Aviation Fuel Standard Takes Flight. ASTM International.) including Jatropha. Biofuels that have ASTM standards for aviation use include fuels based on the Fischer-Tropsch process and the hydro-processed esters and fatty acids process (HEFA).

The aviation industry is committed to achieving carbon-neutral growth by 2020 and the use of sustainable aviation biofuels, to decrease overall carbon emissions, will form a critical component in meeting this target. At the core of the industry’s sustainability objective is the vision of a jet engine fuelled with sustainable biofuel and thus releasing only the carbon dioxide originally absorbed by the feedstock plants. Similarly, sustainable jet biofuel can also be made from waste products such waste cooking oil, industrial by-products, or even municipal solid waste. Fuels from these sources use carbon that would otherwise be directly released into the atmosphere and can thus result in lower lifecycle carbon impact. The Sustainable Aviation Fuel Users Group (SAFUG - http://www.safug.org/biofuel-use/), contrasts sustainable jet biofuel with petroleum based fuels which do not recycle atmospheric carbon dioxide, but instead release additional carbon dioxide into the atmosphere.

Sustainable aviation biofuels are defined by SAFUG as those that:

- Meet or exceed jet fuel standards
- Have significantly lower carbon emissions over their lifecycle compared to fossil fuel sources
- Do not displace food crops or jeopardize drinking water supplies

- Minimize impacts on biodiversity and do not contribute to the clearing or conversion of natural ecosystems and areas of high conservation value
- Have a positive socioeconomic impact where feedstocks are grown.

The International Air Transport Association (IATA), the trade association for the world's airlines, representing some 250 airlines or 84% of total air traffic is active in the formulation of industry policy on critical aviation issues. In respect of alternative fuels to conventional petroleum based jet fuel, it confirms that:

- The industry is exploring reliable alternatives to conventional jet fuel that are sustainable and have a smaller carbon footprint
    - Biofuels should only be made from sustainable, non-food biomass sources.
    - Jatropha can be grown on degraded lands and is resistant to drought
- Main requirements for sustainable alternative jet fuels:
    - Can be mixed with conventional jet fuel, can use the same supply infrastructure and do not require adaptation of aircraft or engines (drop-in fuel)
    - Meet the same specifications as conventional jet fuel, in particular resistance to cold (Jet A: -40˚C, Jet A-1: -47˚C), and high energy content (min 42.8 MJ/kg)
    - Meet sustainability criteria such as lifecycle carbon reductions, limited fresh water requirements, no competition with food production and no deforestation
- Sustainable aviation biofuels ("biojet fuels") are one of the most promising solutions to meet the industry's ambitious carbon emissions reduction goals
    - Lifecycle greenhouse gas emissions from biofuels can be up to 80% lower than traditional fossil jet fuel emissions
- Sustainable biojet fuels allow airlines to reduce their carbon footprint, ease their dependence on fossil fuels, and offset the risks associated with the high volatility of oil and fuel prices.

IATA reports that in the period between 2008 and 2011, at least ten airlines and several aircraft manufacturers performed flight tests with various blends containing up to 50% biojet fuel. These tests demonstrated that biojet fuel was technically sound. A number of conclusions were drawn from the experience of these test flights:

- No modifications to the aircraft were required
- Biojet fuel could be blended with conventional fuel
- The engine powered on the biojet mix even showed an improvement in fuel efficiency in some cases.

Since the certification of hydro-processed esters and fatty acids (HEFA) fuels in 2011, 21 airlines have performed over 1,600 commercial passenger flights with blends of up to 50% biojet fuel from used cooking oil, Jatropha, Camelina and algae. Airlines performing these flights have included:

- KLM*, Lufthansa*, Finnair, Interjet, Aeroméxico, Iberia, Thomson Airways*, Air France, United Airlines, Alaska Airlines*, Thai Airways, LAN, Qantas, Jetstar, Porter, Gol, Air Canada, bmi, NextJet, SAS and Norwegian (* indicates longer series of regular biojet flights).

According to the SAFUG website test flights began in 2008, and culminated in the approval of fuel as part of the ASTM and Def-Stan fuel standards. To date, more than 1,500 passenger flights have been flown using sustainable biofuel. SAFUG claims that its members (representing 28 of the world's leading airlines) utilize sustainable aviation biofuels on a regular basis in their commercial operations. Lufthansa successfully completed a six-month series of commercial flights to study the long-term effect of biojet fuel on engines, noting no adverse effects. Additionally, KLM conducted 26 long-haul flights in 2013 demonstrating it is possible to organize and coordinate a complex supply chain and fly regular scheduled flights on biojet fuel.

Biojet fuel derived from Jatropha oil has been successfully tested by Air New Zealand and Boeing on a 3 hour test flight in 4 Boeing 747 engines in 2008. Scientific findings released by Air NZ following the test flight which utilised a 48% blend of Jatropha oil and traditional jet fuel, showed a 60% to 65% reduction in GHG emissions. In 2009 United Airlines became the first North American carrier to perform a two-engine aircraft flight demonstration using sustainable biofuels derived from algae and Jatropha. Mission NewEnergy, reported that the Jatropha oil used in one Boeing trial was blended with regular aviation spirit at 20% to achieve required fuel characteristics for jet engines. Separate test results show that a blend of Jatropha and algae oil biofuel, used in Continental Airlines' test / demonstration flight was some 1.1% more efficient than traditional jet fuel and also reduced life cycle GHG emissions by an estimated 60%-80%.

IATA reports that around the world multi-stakeholder groups (airlines, airports, aircraft manufacturers, governments, biomass and biofuel producers and suppliers) are working together on initiatives for the deployment of biojet fuels. Some examples include CAAFI (US), ABRABA (Brazil), aireg (Germany), Bioqueroseno (Spain), Plan de Vuelo (Mexico), AISAF (Australia) and further projects are taking place in China, Canada, the UAE, Qatar, and Scandinavia.

Certification

IATA states that it is working with ASTM International and other certification bodies on new alternative jet fuel standards (e.g. ASTM D7566). Since 2011, biojet fuel blends of up to 50% have been certified for commercial passenger flights.

Current Status of Biojet Fuel

Former IATA CEO Giovanni Bisignani has been reported as saying that aviation biofuel is a US$100bn opportunity, but unsurprisingly, the main challenges to the wide deployment of biojet fuels are not technical (noting the positive results reported above from testing so far), but commercial and political. Currently, biojet fuels are more expensive than conventional fuel, therefore demand is low and risk is high for investment in production infrastructure. The jet fuel price index shown below has been drawn from the IATA website. It provides the latest price data from the leading energy information provider Platts. The index and price data shows the global average price paid at the refinery for aviation jet fuel on the reported date. With some 1.9bn barrels of fuel consumed annually the global market for jet fuel is currently worth circa $140bn pa. Readers should note that 12 months ago this would have been closer to $234bn. The European goal of achieving 3%-4% substitution by biofuels by 2020, if applied globally, would suggest a potential market of $5bn-6bn annually for Renewable Jet Fuels.

06-Feb-15	Share in World Index	cts/gal	$/bbl	$/mt	Index Value 2000= 100	vs. 1 week ago	vs. 1 month ago	vs.1 yr ago
Jet Fuel Price	**100%**	**176.1**	**74**	**582.9**	**202.2**	**12.50%**	**11.40%**	**-39.90%**

Source: Platts

The European Advanced Biofuels Flight Path is an initiative by the European Commission in close coordination with Airbus, leading European airlines (Lufthansa, AirFrance/KLM and British Airways) and European biofuel producers (Neste Oils, Biomass Technology Group, UPM, Chemtex Italia and UOP) to define a roadmap in order to achieve a target of 2m mt of sustainable biofuels used in European civil aviation by 2020 – circa 3%-4% of total jet fuel in use in Europe. The initiative is a shared commitment by its members to support and promote the production, storage and distribution of sustainably produced 'drop-in' biofuels for use in aviation. It also targets establishing appropriate financial mechanisms to support the construction of industrial "first of a kind" advanced biofuel production plants. Current targets amongst airlines for alternative aviation fuel usage include:

- Aireg in Germany has set a target of 10% of alternative aviation fuel for 2025.
- Indonesia has introduced a biojet fuel mandate of 2% commencing in 2016, rising to 5% by 2025.

A 3% volume blend-in of sustainable second generation (fuels derived from biomass sources not competing with food production) biojet fuel yearly worldwide would reduce aviation CO2 emissions by about 2% which would be a reduction of over 10 million tonnes of CO2. This would require investment of around $10-15 billion in production and distribution facilities (all according to IATA). IATA believes a share of sustainable second generation biojet fuel of roughly 3%, similar to the EU's Biofuels Flightpath target, is achievable by 2020, contingent on a fair political and legislative framework that makes biofuel use for aviation competitive with the road transport sector.

Jatropha Oil As An Economic Feedstock

Can Jatropha oil be produced at a cost which supports the commercial manufacture of biodiesel? As illustrated in the table below, our estimate for biofuel yield per ha places Jatropha 4th in terms of productivity behind maize and ahead of rapeseed, but significantly trailing both sugarcane and oil palm. Our estimates are however based on only 4mt seed/ha; the group of Jatropha crop science companies are targeting to increase the productivity profile of the crop with 6mt-7mt/ha now being indicated on experimental stations, and with favourable agronomic conditions. At 6mt/seed/ha, Jatropha would be yielding 1.65mt/biofuel/ha, bringing it closer into line with maize. These data suggest that the productivity profile of the crop is supportive of it being considered as a potentially important new feedstock for the biodiesel sector.

Crop	Biofuel	Conversion Efficiency (litre/mt feedstock)	Global Average Crop Yield (mt/ha)	Biofuel Yield mt/ha
Maize	Ethanol	419	4.9	1.9
Sugarcane	Ethanol	86	70.6	5.7
Oil Palm	Biodiesel	234	14.8	3.3
Rapeseed	Biodiesel	414	1.9	0.7
Soyabean	Biodiesel	183	2.3	0.4
Jatropha (H)	**Biodiesel**	**283**	**4.0**	**1.1**
Sources: Understanding Biofuels in Africa, Donald Mitchell, 2011; FAOSTAT 2012				
(H) Hardman estimate				

Whereas we have identified from the published accounts data of more than 50 agro-industrial palm oil companies around the world, that palm oil can be produced for as little as $400/mt delivered to a refinery or port, cost of production data for Jatropha on an industrial scale do not exist. One of the larger operators of the out grower model estimated per tonne CJO production costs at circa $700 but with scope for this to reduce to $500-$400 with better efficiencies, mostly around harvesting. The cocoa sector, in which 90% of global supply is small holder produced, confirms that out grower production of a major commodity can form the basis of economic supply. As for the processors of cocoa, the attraction for the Jatropha processors would lie in avoiding the cost of supplying and managing labour. Generally however, and cocoa has been an exception to this rule, efficient plantation models are expected to achieve better economies than out grower schemes. Hardman's analysis suggests that CJO could potentially be produced for approximately $580/mt under a traditional (manual labour versus mechanisation) model of production assuming:

- 4mt/ha dry seed
- 95% crop harvest efficiency
- $4/day labour
- $407/mt variable cost.

In production zones with the agronomic and labour cost features assumed in this model, the oil would compete successfully with imported palm oil even at today's low prices for CPO. With a transport premium added, CJO would also just about compete with imported crude oil at current prices.

As a direct substitute for mineral oil derived diesel, the price of biodiesel can be expected to track conventional diesel, with or without a 'green' premium. Until the production costs of CJO have become settled in a sustainable production methodology, the biofuels industry will reserve judgement on the crop's suitability as a long term high volume feedstock. In the meantime, the commodity can be expected to meet the needs of energy poor, import dependent economies.

Alongside professional commercial farming of the crop, with innovation in mechanisation of field work and harvesting, and improved genetics aimed at improving yield and oil content, there is much that can be done, and that is being done, to improve the economics of plantation production.

Commodity Price Drivers For Return per Hectare

There are a variety of views about the price drivers for CJO. In respect of non-food crude vegetable oils like Jatropha, received opinion is that pricing will be determined by fossil fuel prices in the first instance, and then by the willingness of the market to pay a premium for sustainable alternative energy sources. CJO pricing is likely to be a function of a number of influences including:

- International traded price of competing feedstock including:
  - crude mineral oil – current market rates are $447/mt
  - crude palm oil (CPO) – current market rates are $650/mt (FOB)
- Compliance: the US or EU blending penalty
- Green premium: for sustainability, carbon profile.

In many of its countries of origin, CJO can be expected to trade in tandem with heavy fuel oil for which it may become a part replacement in local economies. Some producers argue that CJO can trade at a premium to crude oil because it can be used as a feedstock for middle distillate replacements, and as a direct replacement for middle and heavy distillates, without conversion. (Middle distillates include a range of refined products situated between lighter fractions, such as LPG or gasoline, and heavier products such as fuel oil. Typically they include jet fuel, heating kerosene, and gas and diesel oils, such as marine bunker fuels). Also CJO has use within speciality chemical products.

A true understanding of the market potential for the commodity will only emerge once there is a reasonably scaled and consistent supply of product for use. Until that happens, we think that CJO will be priced by reference to the local / market price of diesel or fuel oil, and to crude palm oil (CPO), or such other high volume vegetable oil as maybe a feature of the local market.

Jatropha Seed Kernel Meal

The traditional description of Jatropha as a fuel crop has relegated the significant utility of Jatropha kernel meal (JKM). With as much as 1.5x more protein than soya meal and with a superior amino acid pattern, JKM represents an attractive new ingredient for animal feed including fish on which it has been trialled with excellent results. As detailed herein, Jatropha varieties may be either toxic or non-toxic. Meal produced by the more commonly cultivated toxic varieties would need to be processed for the complete removal of the toxic phorbol ester fraction prior to incorporation in animal feed. While a commercially scaled methodology for this process has not yet been established, a number of technologies have been developed to support such a process including at least one patented methodology that has been used to produce small industrial sized quantities of meal. For a commercial process to become a reality, first there must be an adequate supply of Jatropha seed. The oilseed meal sector has a value of some $100bn pa globally and this is dominated by soya meal. With the appropriate certifications from national and international standards bodies, JKM has the potential to compete well with soya meal. In the first instance however the primary market for JKM is likely to be in markets contiguous to source, which in many cases will not be well supplied with high quality protein mixes for animal feed. Based on international prices Hardman estimates that a professional Jatropha farm producing some 6mt of dry seed per ha could expect to generate revenues in excess of $730/ha from JKM.

More Protein Than Soya Meal

For some time there has been significant interest in Jatropha kernel meal as a potentially valuable animal feed. Meal produced from toxic varieties of Jatropha must first be stripped of anti-nutritional compounds, but in principle, the meal from edible Jatropha varieties could be fed to animals once heat treated.

The kernel meal left over from oil extraction has a protein score of around 65% of dry matter. Due to its high protein content, high protein digestibility and good amino acid composition, Jatropha kernel meal has considerable potential as a supplemental source in the diets of ruminant and monogastric animals including fish. Rakshit Devappa Kodekalra described Jatropha proteins as being "at least comparable to, if not better than soybean proteins". *Isolation, characterization and potential agropharmaceutical applications of phorbol esters from Jatropha curcas oil. Ph.D Dissertation, by Rakshit Devappa Kodekalra, Hohenheim University, 2012.*

The high nutritional quality of heat treated non-toxic Jatropha kernel meal has been demonstrated in feeding experiments with fish and rats. Data extracted from N. Richter (Richter, N., 2012. Evaluation of suitability of non-toxic and detoxified *Jatropha curcas* L. meal as feed for fingerling common carp, Cyprinus carpio L.: with reference to phytase application. Ph.D. Thesis, University of Hohenheim, Stuttgart, Germany) showed equal body weight development of common carp fed on a fish meal based control diet (45% by weight fish meal) as on a diet where 87% of the fish meal was replaced by heat treated non-toxic Jatropha kernel meal. To date however the presence of antinutritional factors/toxic components (and in particular phorbol esters) in the meal of common toxic Jatropha has prevented use of Jatropha kernel meal in animal nutrition.

The values shown in the table below are for non-toxic (NT) Jatropha.

Proximate composition (%Dry Matter)		
	Non Toxic Jatropha kernel meal	Soybean meal
Crude protein	63-71	41-50
Crude lipid	<0.75	<0.75
Ash	9-11	4-7
Non-Starch Polysaccharides	13-14	13-14

Aminoacids	Jatropha kernel meal	Soybean meal
Methionine	1.76	1.22
Cystine	1.58	1.70
Valine	5.30	4.59
Isoleucine	4.85	4.62
Leucine	7.50	7.72
Phenylalanine	4.89	4.84
Tyrosine	3.78	3.39
Histidine	3.08	2.50
Lysine	3.40	6.08
Arginine	12.9	7.13
Threonine	3.59	3.76
Tryptophan	1.31	1.24

Source: *Values* from analyses at University of Hohenheim, Institute 480b.
Soymeal Data except amino acid :
http://www.fao.org/ag/AGA/AGAP/FRG/AFRIS/Data/736.HTM
http://pdf.gaalliance.org/pdf/GAA-Swick-Apr02.pdf

The toxicity of Jatropha seeds is due to the presence of phorbol esters and other anti-nutrients including trypsin inhibitor, lectin (curcin) and phytate. Although curcin can readily be neutralised by heat treatment, phorbol esters present more of a processing challenge. Phorbol esters are generally known for their tumour promoting activity and irritation of the epidermal cells. They occur naturally in many plants of the family Euphorbiacaeae, of which *Jatropha curcas* is a member. For Jatropha kernel meal to be safe for animal feed, the phorbol ester fraction has to be almost entirely removed.

The phorbol ester contents in Jatropha kernels vary depending on the genotype, but are mostly in the range of 2-6 mg phorobol esters/gm kernel. The kernel meal remaining after oil extraction has slightly lower toxicity profile, as part of the phorbol esters are extracted with the oil. To our current knowledge, the values are as follows:

- Phorbol ester (PE) content in kernels: 0-10 mg PE/gm kernel
- Phorbol ester content in kernel meal: 0-8 mg PE/gm kernel meal
- Critical value for animal feed has been indicated at 0.02 mg PE/gm animal feed. However it is reportedly very difficult to reliably measure PE at this concentration. A method developed by University of Hohenheim results in lower than 0.1mg/g PE in full fat kernel meal. This was demonstrated not to be toxic as it did not cause feeding depression in animals, even at 87% replacement of fish meal.

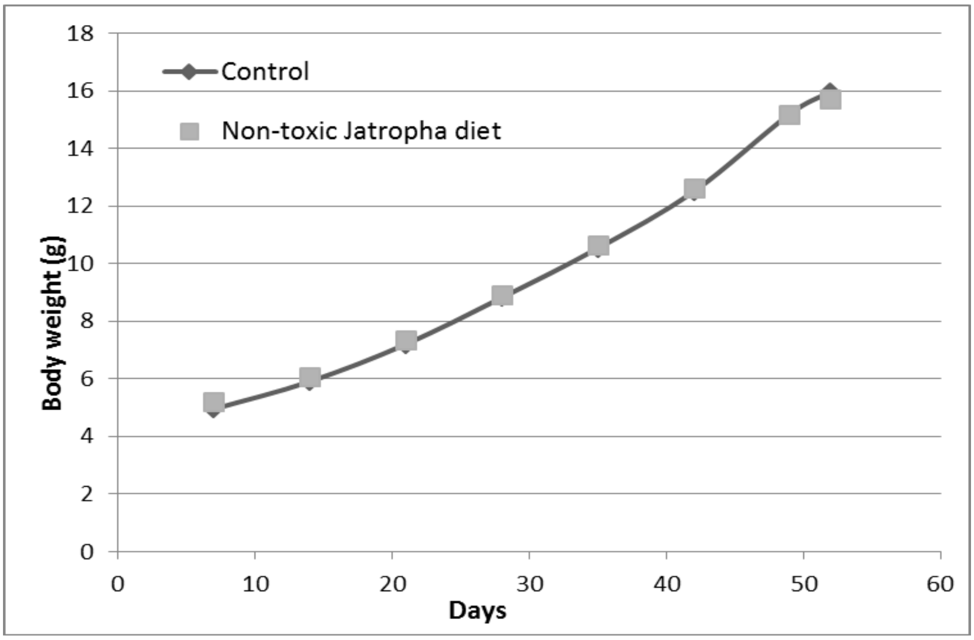
Toxicity of Jatropha seeds has been studied extensively in different animal models including goats, sheep, mice, rats and fish. Loss of appetite, reduced water intake, diarrhoea, dehydration and hemorrhagic effects were recorded.

(Goel, Makkor, Francis & Becker; 2007). Curcin, which is similar to highly toxic ricin (found in Castor Beans), is far less toxic and is found in low doses in many edible plants and is present in the kernels of both non-toxic and common toxic varieties. Many of the general classes of anti-nutritional compounds present in Jatropha kernel meal, (but not phorbol esters) can be found in the seeds of other plants, including soybean. For this reason most plant seed products undergo heat treatment before inclusion in animal feeds to destroy trypsin inhibitors and lectins and to improve carbohydrate digestibility. If Jatropha oil is extracted by screw press methodologies, using the whole seed, then the resultant seedcake will likely comprise 50-60% indigestible shell. For use as animal feed, the kernel must be processed without its outer shell. Typically this has been demonstrated using solvent extraction (methanol washing) methodologies which are also reported to give better oil recovery rates. Innovative alternative methodologies using steam and hot water are considered to have good application and to be preferable on environmental grounds to either methanol or hexane based methodologies. Hexanes (chiefly obtained by the refining of crude oil) are used to extract oils such as canola oil or soy oil from seeds. This methodology is commonly used in food based soybean oil extraction in the United States, and it is a recognised contaminant potentially present in all soy food products using the technique. The material is combustible and installations using hexane based processes must be secured against this risk.

Jatropha Kernel Meal For Aquaculture

The FAO provided data in 2010 to demonstrate that fish accounted for 17 % of globally consumed animal protein, providing more than 1.5 billion people with almost 20 % of their average per capita intake of animal protein. Total and per capita fish supplies have expanded significantly in the last five decades from 9.9 kg in the 1960s to 17.0 kg in 2007. According to 2013 data provided by FAO Fisheries and Aquaculture, world aquaculture production of fish for human consumption totalled 62.7 million tonnes in 2011 (for a growth rate of 6.2 %). Aquaculture contributed 40.1 % to the world total fish production. To meet growing demand and to ease pressure on wild stocks there will need to be an increase in the production of species such as carp and tilapia.

If production is to be economic, and reduce pressures on wild stock (mackerel are harvested for fish food), the industry will require the supply of low cost protein feeds. In fish farming, nutrition is critical because feed represents 40% – 50% of the production costs. The annual trade in fishmeal alone for use in aquaculture is estimated at circa $6bn. To produce a low cost protein rich feed for fish it is important to accurately determine the protein requirements for each species and size of cultured fish. Protein levels in aquaculture feed generally average 32-38 % for tilapia (and carp). Non-toxic or detoxified Jatropha kernel meal (JKM) represents a possible solution. The Johann Heinrich von Thünen Institut has been conducting feeding experiments (both laboratory and field-trials) with tilapia and carp, analysing growth and digestibility of different diets containing detoxified Jatropha kernel meal. JatroSolutions notes that working with Hohenheim University, it was able to scale up production beyond the laboratory to processed batches of 100 kg.



Source: JATROPOWER AG

Jatropha Protein For Packaging Applications

In August, 2014 a study was published providing new data on the potential of Jatropha protein based films for packaging applications: "Characterization of *Jatropha curcas* L. Protein Cast Films with respect to Packaging Relevant Properties"*. The aim of the study was to explore the potential for packaging applications of proteins from Jatropha and to compare the performance with literature data on cast films from whey protein isolate.

There is growing interest in the substitution of petrochemical based plastics by more sustainable raw materials, especially in the field of bioplastics. Proteins of different types such as whey, casein, gelatine, or zein have shown potential beyond the food and feed industry for application in packaging. Protein based coatings provide different packaging relevant properties including:

- barrier function against permanent gases
- barrier function against certain water vapour
- mechanical resistance.

As a by-product from oil extraction, significant amounts of Jatropha kernel meal are produced (some 25% -28% by weight of seed), of which some 63%-71% is protein. The study concluded that Jatropha protein cast films have suitability for barrier and mechanical resistance functionality and could be appropriate materials for use in food packaging applications.

**Characterization of Jatropha curcas L. Protein Cast Films with respect to Packaging Relevant Properties. August 2014*
Gabriele Gofferje, 1 Markus Schmid, 1, 2 and Andreas Stäbler 1
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Detoxification Technologies

There has been a significant amount of research devoted to developing methods to detoxify the kernel meal of common toxic Jatropha to enable its use as animal feed. There are a number of processes under development for the detoxification of jatropha kernel meal including treatment with ethanol, enzyme hydrolosis and washing with ethanol: Soxhlet extraction using 80% ethanol (Francis, Oliver, Sujatha; June 2012).

The different technologies can be broadly grouped into five strategies:

1) Solvent/chemical treatments, characterized by extractions or treatment of Jatropha material with alcohols, alkali, or other solvents or chemicals
    a. Anecdotally Hardman has been advised of a number of patents for this process. At its most basic the technologies are based on washing out the phorbol ester fraction with methanol.
    b. A commercial process would need assured scale to justify a significant investment in capital investment and would likely seek to include a methodology for recovering the phorbol ester fraction with its integrity intact.
2) Physical treatments, where the primary treatment is the application of radiation or a source of energy, generally independent of the use of chemicals.
3) Enzymatic treatments, where the removal or degradation of toxic compounds is accomplished through the use of purified enzymes or enzyme extracts.
4) Fermentation approaches, where Jatropha material is fermented with a microorganism capable of removing or degrading the toxic compounds.
5) Selection, breeding, or creation of non-toxic varieties, methods which are aimed at developing plant germplasm that is free of detectable toxic components.

The Singapore based crop science company JOil (S) Pte Ltd, has been working on developments for three of the five strategies listed above.

- The company has announced the development of a new *double solvents extraction system* that can achieve oil extraction from seed meal and partition phorbol esters away from the protein meal in a single process.
    - JOil reports that protein meal derived from this process contains non-detectable levels of phorbol esters.
- Based on its findings that phorbol esters in the soil are degraded by sunlight, JOil has developed a proprietary system to detoxify phorbol esters by short wave UV irradiation.
    - It is deemed to be an attractive approach due to assumptions made about:
        - Capital investment required
        - Ease of integration into an industrially scaled production system
- In collaboration with shareholder Temasek Lifesciences Laboratory (TLL) JOil has been researching the scope to 'silence the genes involved in the biosynthesis of phorbol esters.

TLL and JOil report that they identified a key gene involved in the biosynthesis of phorbol esters in Jatropha seeds. Furthermore their research indicates that they have developed techniques to 'silence' the expression of the gene. Unpublished research data indicates that phorbol ester content has been reduced by up to 90%. The technology needs to be further developed to produce plants yielding seeds with zero phorbol ester content and it needs regulatory clearance – but it may represent an important tool in the further development of commercial Jatropha kernel meal.

JatroSolutions GmbH, and Prof. Dr. Harinder Makkar have been granted patent protection (Patent 2 229 820 registered in Germany under No. 60 2009 016 789.8) for the 'Detoxification of *Jatropha curcas* meal for feeding to farm animal species and fish'. The detoxification process is based on alkali (sodium hydroxide) and short chain alcohol (methanol), resulting in the removal of the toxic phorbol esters (Method 1 detailed above). The research behind the successfully patented process was conducted under the leadership of Prof. Klaus Becker and Prof. Harinder Makkar at the University of Hohenheim. JatroSolutions based its detoxification-method on an innovative technology developed by GEA Westfalia. Instead of the traditional reliance on hexane-extraction it exploits a technique based on hot water and steam treatment which is reported to provide the same extraction-rates as can be achieved with the hexane based process. Hardman has been advised that oil recovery can be as high as 98%. The detoxification of kernel meal is currently based on methanol. The GEA process includes de-shelling of the seeds, and de-oiling of the kernels (which cannot be de-oiled by mechanical screw press once shelled). So after the de-oiling by the GEA process pure kernel meal is available for detoxification.

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JatroSolutions working with University of Hohenheim, has conducted very broad testing and experimentation with detoxified Jatropha meal and this research has formed the substance of a number of peer reviewed scientific papers. The conclusions drawn from this research support the use of the processed meal within the food chain and JatroSolutions confirms that the body mass gain in trial species was excellent. As stated above Jatropha meal fed to fingerling common carp, showed equal body weight development of common carp fed on a fish meal based control diet (45% by weight fish meal) as on a diet where 87% of the fish meal was replaced by heat treated non-toxic Jatropha kernel meal.

The detoxified products have been extensively evaluated on a number of animal species including highly sensitive fish species. Studies have been conducted into the growth, physiological, biochemical and histopathological consequences of feeding the detoxified products to trial species. The detoxified Jatropha products obtained by the patent process have been found suitable to substitute soybean meal and fish meal in monogastric, ruminant and aquaculture feeds including fish and shrimps. The studies have been peer reviewed and published in accredited international journals. JatroSolutions maintains that the use of a large scale detoxification process is feasible with immediate effect.

Agroils Technologies SPA is an Italian process engineering firm. It has a particular focus on innovation in the processes required to produce superior quality products and compounds from Jatropha. Amongst its areas of research and development, Agroils has focused on the separation of Jatropha phorbol esters from the proteins found in the kernel. In particular, Agroils is seeking to develop alternative methodologies to the use of solvents for the removal of phorbol esters including what it describes as a proprietary 'aqueous phase'. Agroils claims that the methodologies that it is working on have the potential:

- To produce phorbol esters concentrations with superior integrity to those recovered by solvent extraction
  - But its methodology will produce lower concentrations of phorbol esters
- To be cheaper than solvent extraction
- For a better impact on the environment.

Commercial, proven processes for rendering Jatropha kernel meal suitable for animal feed are not yet available, but as detailed above, a number of technologies have been demonstrated to be suitable for such processes. A single process for oil extraction and the removal or degradation of the phorbol ester fraction of the meal would represent the most economical solution. However if the phorbol esters within the meal were required for use in the manufacture of crop protection chemicals or other pharmaceutical uses, then a process that removed them from the kernel meal with their stability and activity preserved, would be required.

Processing Jatropha seeds for the production of meal as a component in animal nutrition will require the prior removal of the shell or husk (which is highly indigestible) and which would be recovered and sold for fuel. The calorific value of the shells is between 16-17 MJ/kg and is comparable to rice husks or moist wood, (Kratzeisen, Martin and Müller, Joachim; Energy from seed shells of *Jatropha curcas*; University of Hohenheim) and also comparable to the shells of kernels from oil palm fruits which have a calorific value of 16.9 MJ/kg. Typically palm kernel shells trade at between $40-$80/mt depending on location and local factors.

Non-toxic Jatropha

In 2012 Embrapa, (Brazilian Corporation of Agricultural Research) a state-owned company affiliated with the Brazilian Ministry of Agriculture, devoted to pure and applied research on agriculture, held a conference on 'Advances in the detoxification of Jatropha & Castor seed cake and their use as livestock feed'. Amongst the organisations present, the FAO discussed the opportunities and challenges (including toxicity) associated with Jatropha kernel meal as an ingredient in livestock feed. The Embrapa Conference also referred to non-toxic varieties of Jatropha, including an important Mexican variety, the seeds of which have been used for human consumption after roasting, and do not contain phorbol esters. The Conference concluded that "research on selecting better seed- and oil-yielding non-toxic Jatropha...will make these non-toxic Jatropha a good source of oil for human consumption... seed meal... could be used as good protein sources for ... for livestock feed."

The Swiss crop science company, JATROPOWER has focused on the research and development of non-toxic Jatropha varieties (found naturally in regions of

Mexico) for commercial cultivation. The company notes that the non-toxic edible varieties of Jatropha are naturally available and represent a lower investment risk and relatively immediate solution for cultivating Jatropha for both oil and kernel meal. Non-toxic varieties produce non-toxic harvests, even when pollinated by common toxic strains. The progeny of these pollinations may however produce toxic harvests. This provides inbuilt Intellectual Property Rights (IPR) into a business supplying seeds of non-toxic varieties.

Certification

In order for Jatropha kernel meal from common toxic Jatropha to become established as an acceptable commercial ingredient in animal feeds, especially for those entering the food chain, an economically viable process for commercial application must be developed and its output certified as of an acceptable standard by relevant official food standards agencies. An alternative strategy for the introduction of Jatropha kernel meal into the food chain would be to use the kernel meal of the non-toxic varieties of *Jatropha curcas*.

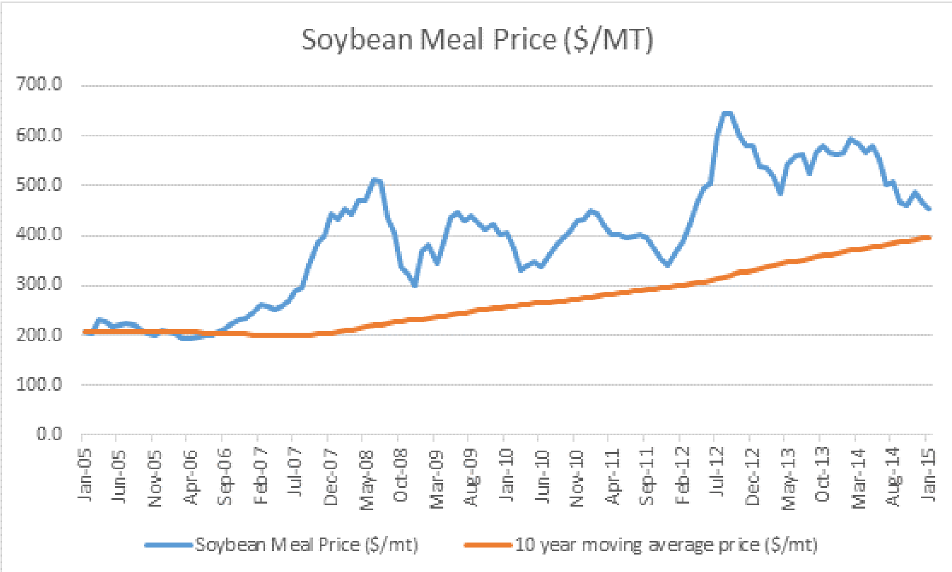
Whether the kernel meal entering the food chain is processed meal from the common toxic varieties or the meal from the non-toxic varieties, both will require certification, especially if the meal is to be traded internationally as a raw material like soya meal. We have been advised of one initiative by an EU agency to institute a certification process, but we have not seen any documentation as to whether the initiative is being actively pursued. It may require a producer to file for permission to use a certain process before official interest is translated into practice. Typically regulators take action to prescribe/mandate adequate testing procedures to detect any harmful substances only when they see the potential for the new material to enter the food chain. In 2007 for example the US FDA was in touch with Hohenheim University for information about the testing procedures for phorbol esters in animal feed – this being at a point of intense interest in Jatropha, during which aggressively optimistic assumptions were being made about the speed and scale of cultivation and the likely volumes of production.

The inclusion of a new material in animal feeds may take different and unofficial routes however. A product that producers find commercially attractive will typically find its way into formulations. In the first instance this is likely to be for private use, but if proven successful the pattern is for the formulation to gain adherents in the local market. Once larger volumes are produced the ultimate step is for the formulation to seek exports and all this might take place before any official certification. JATROPOWER reports to us that previously it has received enquiries for big volumes of non-toxic Jatropha kernel meal from animal feed producers in Africa and fish feed producers in Chile. Market activity tends to build for a particular product or formulation (provided the quality/price/suitability criteria are met) typically before it is officially certified.

Commercial Value Of Jatropha Kernel Meal

The global market for oil seed meal is dominated by soya meal. USDA February 2015 Oilseeds World Markets & Trade estimates 2014/15 global production of soya meal at 200.9m mt. Taking the 10 year average price of $400/mt this represents a global market of $80.36bn. Add in rapeseed meal of 39.9m mt and sunflower of 16m mt and the total market value pushes north of $100bn. Jatropha meal with its exceptional protein content and amino acid profile would be competitive with this complex.

In our financial models we have included Jatropha kernel meal at $450/mt, the 10 year moving average price of soya meal plus a $50/mt transport premium/protein premium. Readers will note from the commodity price chart below that the long term average price is trending upwards at a steepening rate. Similarly it will be noted that the commodity has traded regularly above the $400/mt level. Our expectation is that Jatropha will be grown for the most part in more remote regions with poor logistics and with relatively under-developed rural economies. In this context Jatropha kernel meal will, if it can be made available, have a ready local market amongst producers of animal protein who would otherwise have to import protein feeds with attendant and high logistics costs. In these circumstances the transport premium alone can be expected at $50-100/mt.



Source: Hardman & Co

The amino acid composition tables above, comparing Jatropha kernel meal with soya meal indicate that Jatropha kernel meal can include up to 1.5x as much protein per mt as is found in soya meal. This advantage could be expected to attract a premium, certainly if the commodity was competing with soya meal on the international market – but that is likely to be some way off. In local markets the price of Jatropha kernel meal is likely to be driven by the cost of whatever cheapest imported feedstock competes for local demand. However it is abundantly clear that with kernel meal representing some 27% of the seed crop, this represents a significant revenue opportunity for producers of Jatropha. On the basis of a 6mt/ha crop we would expect a revenue contribution of some $731/ha.

Jatropha Oil – Too Good To Burn?

Because CJO has an exceptional fatty acid profile and cold flow properties it is highly suitable for the manufacture of industrial lubricants, hydraulic fluids, dielectric coolants, surfactants, plastics and resins – in all a market valued in excess of $30bn annually. CJO has been noted for its potential as a lubricant in internal combustion engines – a market of some $8.5bn annually. The commodity has also been researched for its suitability as an oil for use in transformers. It was concluded that its use in the production of dielectric coolants could represent a significant market for CJO. Notably CJO also has potential as a bio-surfactant as environmental damage from the use of petroleum based surfactants ($30bn pa sector) drives manufacturers to make greater use of sustainable low impact commodities. These opportunities for CJO have challenged the traditional perception of the commodity as primarily a feedstock for biodiesel.

Industrial Lubricants

There have been a number of researches into the suitability of Jatropha oil for the production of clean, effective, renewable lubricant oil. Vegetable oil can be used as a bio-lubricant either by blending it with a commercial lubricant or by converting the vegetable oil into fatty acid methyl ester (FAME) for use as lubricant additive for internal combustion engines. Research conducted by the University of Malaya's Centre for Energy Sciences, Department of Mechanical Engineering by H.H. Masjuki and others (2011 IEEE First Conference on Clean Energy and Technology CET, concluded that Jatropha oil "had shown a high potential as an alternative lubricant in conventional internal combustion engines as an anti-wear lubricant additive, as well as the enhancer of lubricating performance".

A report by Transparency Market Research July 2014, projected tha the global independent lubricant manufacturers market would achieve an estimated value of nearly US$8.5 billion by the year 2019. The report states that factors such as the rising applications of lubricants in the automotive industry, the increasing demand for bio-based alternatives and the provision of value-added services and proper technical support by independent lubricant manufacturers could help the industry achieve significant growth during the forecast period.

Gunam Resul, M.F.M., and others of The Department of Chemical and Environmental Engineering, Faculty of Engineering, Universiti Putra Malaysia produced a paper entitled 'Synthesis of Biodegradable Lubricant From Jatropha Oil With High Content of Free Fatty Acids'. The paper considered Jatropha oil's potential application as a biodegradable lubricant. The study found that the lubricity characteristics of Jatropha based bio-lubricant, including pour point, viscosity and thermal oxidative stability, were comparable with other vegetable oil based lubricants. It concluded that after transesterfication with trimethylol propane (TMP), Jatropha oil derived lubricant "behaves as an excellent lubricant" and the paper postulated that "this could be a new way of development of Jatropha oil...".

The Italian process engineering company, Agroils Technologies SPA is investigating the opportunity to produce a Jatropha oil derived lubricant /

cutting fluid for metalworking. The company reports that it is in discussions with two European manufacturers of such lubricants. Tests conducted suggest that the Agroils' Jatropha oil product compares well with synthetic lubricants currently in use.

Dielectric Coolants

Dielectric liquids are used as electrical insulators in high voltage applications, e.g. transformers, capacitors, high voltage cables, and switchgear (namely high voltage switchgear). Their function is to provide electrical insulation, suppress corona and arcing, and to serve as a coolant. Transformer oil or insulating oil is usually a highly refined mineral oil that remains stable at high temperatures and that has excellent electrical insulation properties. These oils therefore form a critical part of the insulation system for transformers, providing insulation and coolant properties. In their paper, Production and Characterisation of Biobased Transformer Oil from *Jatropha curcas* Seed, (Journal of Physical Science, Vol.24(2),49-61 2013, Garba, Gimba and Emmanuel (from Department of Chemistry, Ahmadu Bello University, P.M.B. 1044, Zaira, Nigeria), explored the production of transformer oil from Jatropha that was non-toxic, non-flammable, bio-degradable and which was able to extend and enhance transformer functionality. The team from Ahmadu Bello University also examined whether the oil would enable the transformer to carry higher loads during peak demand periods without leading to premature insulation failure. The discussion below borrows extensively from the Ahmadu Bello University paper referenced above.
Viscosity is considered to be the most important property of transformer oil; it affects the operation of fuel injection systems, especially at low temperatures when an increase in viscosity impacts on the fluidity of the fuel. Jatropha seed oil has been measured with a viscosity of 8.2 cst which is close to that of diesel fuels. This level of viscosity is considered good for ease of pumping and atomising fuel. The Ahmadu Bello team also noted that the flash point of Jatropha oil is 150 degrees Celsius (oils with flash points above 66 degrees Celsius are considered safe oils; Makkar, H.P.S., Becker, K. & Schmook, B. (1998). Edible provenance of *Jatropha Curcas*. Plant Foods Human Nutr., 52, 31-36.). This indicates that Jatropha oil can prevent auto ignition and fire hazard at high temperatures during transportation and storage.

The cloud point for Jatropha oil is 14 degrees Celsius which indicates that Jatropha oil can perform satisfactorily even in cold climatic conditions. The oil also has a low pour point of 4 degrees Celsius, whereas higher pour points limit the use of oils in transformers in cold climatic conditions. The inquiry by the team at Ahmadu Bello University concluded that refined Jatropha oil is of good quality and that the values obtained for the oil by the team corresponded well with ASTM specifications*. As a bio-degradable oil suitable for use in transformers, the team concluded that there could be a significant market for Jatropha oil.

Characteristics of *Jatropha curcas* seed oil	
Property	**Value**
Saponification value	155 mg KOH g_{-1} oil
Peroxide value	7.20 meq g_{-1} oil
Iodine value	51.27 g 100 g_{-1} oil
Free fatty acids	0.0718 mg KOH g_{-1} oil
Acid value	0.1428 mg KOH g_{-1} oil
Viscosity	8.2 cst
Boiling point	124°C
Specific gravity	0.8480
Flash point	150°C
Cloud point	14°C
pH	5.2
Dielectric strength	22 kV
Pour point	4°C
Density at 27°C	0.725 g cm–3

Source: Production and Characterisation of Biobased Transformer Oil from Jatropha curcas Seed, Journal of Physical Science, Vol.24(2),49-61 2013, Garba, Gimba and Emmanuel. Department of Chemistry, Ahmadu Bello University, P.M.B. 1044, Zaira, Nigeria

** ASTM D6871 - 03(2008) - Standard Specification for Natural (Vegetable Oil) Ester Fluids Used in Electrical Apparatus: This specification covers a high fire point natural vegetable oil ester insulating fluid for use as a dielectric and cooling medium in new and existing power and distribution electrical apparatus such as transformers and attendant equipment. The physical property requirement including colour, fire point, flash point, pour point, relative density, and viscosity shall be tested to meet the requirements prescribed. The electrical property requirements including dielectric breakdown voltage, dissipation factor, and gassing tendency shall be tested to meet the requirements prescribed. The chemical requirements including corrosive sulphur, neutralization number, PCB content, and water shall be tested to meet the requirements prescribed.*

Surfactants

The annual global production of surfactants is estimated at some 15 million metric tons with a value of circa $30bn (Neil A Burns LLC). Industry references indicate that the global surfactant market will expand to exceed $40bn in value by 2020.Approximately 50% of total production is used in the manufacture of detergents, while the other 50% is utilised in a wide variety of industrial applications including amongst others, production of chemicals, textiles, cosmetics and healthcare items.

The largest proportion of surfactants has a petroleum base and is considered to be environmentally hazardous. The eco-toxicity, bio-accumulation and bio-degradability of surfactants are pressing issues for better management of our impact on the environment. In this context there is increasing interest in bio-surfactants including those produced from Jatropha oil. However it must compete in this segment with Palm Kernel Oil which has an estimated capacity of some 3.0m metric tonnes of fatty alcohol capacity annually.

Sophorolipids (SLs) are glycolipidic bio-surfactants that have been demonstrated to be suitable for replacement of petroleum based surfactants in detergents. SLs have been described as “a kind of microbial extracellular bio-surfactants produced by non-pathogenic yeasts” Jatropha Oil Derived Sophorolipids: Production & Characterization as Laundry Detergent Additive; Kasturi Joshi-Navare, Poonam Khanvilkar and Asmita Prabhune; Biochemistry Research International Volume 2013 (13) Article ID 169797. Bio-surfactants have to compete with petroleum based compounds in terms of cost, functionality and production capacity (Makkar and Cameotra 2002). With raw materials representing 10%-30% of overall cost of production, there is considerable interest in finding economical and renewable sources.

Kasturi Joshi-Navare, Poonam Khanvilkar and Asmita Prabhune have explored the utility of Jatropha oil as a raw material for the synthesis of SLs. Jatropha oil is largely composed (80%-95%) of saturated and unsaturated fatty acids with chain lengths of 16 or 18 carbon atoms, which Joshi-Navare et al confirm is ideal for production of SLs. SLs are synthesised using C.bombicola, a robust strain of yeast which is able to survive and produce SLs in the presence of Jatropha alkaloids. Joshi-Navare et al confirmed also that Jatropha oil derived SLs were recognised as having desirable (for surfactants) wetting properties, contact angle reduction and antibacterial action. Jatropha SLs demonstrated efficiency in stain removal and when used as detergent, showed improved performance and yet were bio-degradable and non-toxic.

Plastics and Resins

Odetoye et al (2012)* reported the suitability of Jatropha oil for alkyd resin production. Alkyd resins are one of the major raw materials in the formulation of surface coatings. They are polyester products formed of the polymeric condensation of polyhydric alcohol, polybasic acid and monobasic fatty acids. Surface coatings such as alkyd paints and varnishes are used as decorative and protective finishes in industrial coatings and diverse manufactured goods. Binders or film-forming substances, solvents and pigments are the three basic constituents of surface coatings. Alkyd resin is a common binder for surface coatings and paint formulations. Fatty acids derived from vegetable oils represent the monobasic constituents of alkyd resins, and influence the drying properties and hardiness of the films formed through their action on flexibility.
*Review of Utilization of Non-Conventional Seed Oils for Alkyd Production in Nigerian Paints Industries; T.E. Odetoye, D.S. Ogunniyi and G.A. Olantunji, Department of Chemical Engineering, University of IIorin, PMB 1515, IIorin, Nigeria).

Jatropha Components For Use in Bio-pesticides

Hardman's review of the sector has found a widespread interest in the potential for Jatropha phorbol esters for use in the formulation of bio-pesticides, but this has been accompanied by an understanding that considerable scientific, technical and regulatory issues must be resolved prior to commercialisation including:

- Development of a commercial process for extraction of stable, high integrity phorbol esters
- chemical stabilization
    - once extracted Jatropha phorbol esters rapidly lose activity at room temperature and if exposed to strong light
- method of storage
- formal application trials.

While Jatropha derived phorbol esters appear to have considerable promise as the active agent in bio-pesticides due to their toxicity for many agricultural pests and disease carriers, including snails, the compounds are reportedly too easily broken down in nature. This instability of the isolated compound represents an as yet unresolved problem for commercialisation. Suitable technologies need to be identified to preserve the compound's stability and which yet allow it to biodegrade quickly in the environment.

Utility in Toxicity

Mankind has learned to exploit the toxicity of common toxic Jatropha in a variety of ways. The plant is used for hedging and animal enclosures in many parts of the developing world because of its rapid growth and toxicity/repugnance to grazing animals. Similarly a search of the internet will find numerable references to the use of Jatropha compounds for controlling insecticidal and other pests of humans, their crops and their livestock. Jatropha oil has been used reportedly to control infections, bedbugs and intestinal worms (Burkill, H.M. 1985. The useful plants of West Tropical Africa Vol. 2) and its oil and aqueous extracts from the oil have been used in the control of cotton bollworm and the control of pests on pulses, potatoes and corn (Kaushik and Kumar, 2004).

Diverse studies have provided evidence of bio-pesticidal activity of Jatropha phorbol esters. In the paragraph below we detail the findings of Ratnadass, A and Togola, M and Cisse, B and Vassal, J (2009) *Potential of sorghum and physic nut (Jatropha curcas) for management of plant bugs (Hemiptera: Miridae) and cotton bollworm (Helicoverpa armigera) on cotton in an assisted trap-cropping strategy.* Journal of SAT Agricultural Research,7. pp. 1-7. ISSN 0973-3094.

The cotton bollworm (CBW) Helicoverpa armigera and plant bugs (PB) (Hemiptera: Miridae) are important pests of cotton in Africa. For sustainability reasons, it is considered necessary to reduce the use of chemical control measures for these pests. Ratnadass et al reviewed studies conducted from 1995-1998 on the potential of Jatropha extracts, and in particular the phorbol ester fraction of the oil, for sorghum protection from PB damage, and on the insecticidal activity of Jatropha extracts on CBW. Jatropha oil application on sorghum panicles showed some effect on PB when the damage level was high, but it did not compete with pyrethroid protection levels. Ingestion insecticidal activity of phorbol esters was found on all tested larvae. Development of larvae and the reproductive ability of adults derived from new-laid eggs treated with solutions of 0.35g ml-1 phorbol ester and above were reported to be considerably affected.

It should be noted that this paper refers to applications of Jatropha oil; Ratnadass and Wink (see below) concluded that phorbol esters are most stable in oil, in which they are relatively heat resistant and enjoy good shelf life. Interestingly the Italian process engineering company, Agroils Technologies SPA , which has been working on the detoxification of Jatropha kernel meal, amongst other Jatropha related processes, reports that it has recently begun "to focus on the biological activity of phorbol esters for the production of biopesticides". Agroils indicates that is researching the potential to 'harvest' phorbol esters in the company's proprietary 'aqueous phase' detoxification process. Agroils advises that its experience has been that phorbol esters captured in the dried product obtained from the company's 'aqueous phase' remain relatively stable with good biological activity, which is surprising noting the previous reference to recorded stability in oil. JatroSolutions also reports that it has upscaled a method of phorbolester isolation from Jatropha oil.

In a 2012 publication (The Phorbol Ester Fraction from *Jatropha curcas* Seed Oil: Potential and Limits for Crop Protection against Insect Pests. Alain Ratnadass and Michael Wink; Int J Mol Sci 2012; 13(12): 16157-16171.,), Ratnadass et al reviewed a wide body of reported work on the insecticidal effect of Jatropha and its extracts – and in particular the effect of the phorbol ester fraction on crop pests. Jatropha contains a variety of toxic compounds including curcin (found in seed meal) and hydrogen cyanide (found in seed oil), but the primary focus for biocidal action has been directed at the phorbol ester fraction. Despite the fact that the phorbol ester fraction from the seed oil of Jatropha has been reported as a promising component in bio-pesticides for crop protection, both pre and post harvest, the paper noted that commercialisation of Jatropha based bio-pesticides has yet to occur. Ratnadass et al advance the following possible reasons why commercialisation of Jatropha based technologies has not taken place:

- Use of phorbol esters on stored post harvest food ingredients could leave toxic residues
- Unknown impact of decomposing phorbol esters on field environment
- Biodegradability and low persistence in soil conflict with requirement for long action against pests
- High variability of phorbol ester content
- Standardisation of chemically complex extracts
- Potential phyto-toxicity
- Cost of development & registration / regulatory approval costs which involve very much the same costs as a registration and approval of a synthetic pesticide
- Difficulty of obtaining patents for phorbol ester extracts

After reviewing more than 100 peer reveiwed studies, Ratnadass et al concluded that extracts of Jatropha (in particular *Jatropha curcas*) leaves, seeds and oil are repellent, deterrent or toxic, either by contact or ingestion, to several agricultural pests. The most effective extracts were noted to be toxic diterpenes and in particular, phorbol esters. It was further noted that while it was unlikely that Jatropha would be cultivated simply for its insecticidal properties, compounds such as phorbol esters represented valuable co-products alongside the plant's primary products, (which includes seed oil and kernel meal). The study proposed that where the crop was grown in isolated or land-locked countries – for example in the Sahelian countries – where Jatropha oil produced for fuel was competitive with imported fuels – then the phorbol ester extracts could be seen as a cheap crop protection product for farming communities priced out of the market for synthetic chemical based crop protection. Ratnadass et al concluded that "the study of the insecticidal effects of (Jatropha) seed oil, particularly phorbol esters, and their evaluation in real conditions, should be given priority, rather than screening of novel bioactive substances."

Medicinal Uses of Jatropha

Folk medicine throughout the Jatropha growing regions includes diverse uses for Jatropha leaves, oil and sap. The references are mostly anecdotal but as the article below indicates, the plant has properties that may usefully be researched for their utility in managing health issues in humans and animals.

Application of *Jatropha curcas* L. seed oil (Euphorbiaceae) and microcurrent on the healing of experimental wounds in Wistar rats. José Roberto Passarini Junior; Fernanda Oliveira de Gaspari de Gaspi; Lia Mara Grosso Neves; Marcelo Augusto Marreto Esquisatto; Gláucia Maria Tech dos Santos; Fernanda Aparecida Sampaio Mendonça. Acta Cir. Bras. vol.27 no.7 São Paulo July 2012

"The latex derived from J. curcas has medicinal, pesticidal and antimicrobial properties and is widely used as a healing agent (9). Villegas et al.(10), studying the wound healing activity of the latex in rats, found that this property is due to the presence of a proteolytic enzyme. The roots, stems, bark, leaves, seeds and fruits, fresh or cooked, are widely used in traditional folk medicine in many parts of Western Africa (11),(12). Esimone et al.(13) obtained promising results with an ointment containing fresh J. curcas leaf extract applied to excision wounds created in the back skin of albino rats. In a study using albino mice, Shetty et al.(14) showed that crude J. curcas bark extract was effective in accelerating the healing process of experimentally induced skin wounds. Direct application of crushed leaves of the plant to cuts and wounds has been shown to promote coagulation. The seeds of J. curcas are used as anthelminthic agent and for the treatment of gout, paralysis, ascites, and skin disease. The seed oil of the plant has been to shown to be effective in treating rheumatic diseases, parasitic skin diseases, itching, jaundice and fever, as well as a diuretic agent (14-17)".

Biomass – A Potential Revenue Stream

Some plantation businesses are anticipating developing a revenue opportunity from the supply of biomass. This may refer to fruit husk (pericarp surrounding the seeds), seed shell, and prunings from the trees themselves. Depending on the customer's needs, the biomass may require some degree of drying (naturally or through artificial heating) and/or cutting to a size suitable for the intended customer. It can be used as fuel for steam boilers to produce electricity or for cooking and heating or as an input for higher value products as detailed below.

SGB has calculated the potential to produce 46mt/ha of green biomass from year 2, using its early maturing varieties. The company is projecting this level of output for the productive life of the plantation. The price of biomass produced and processed up to point of sale from the plantation will need to compensate for the additional costs of fertilisers, and their application, which will be required to replace this significant output if compared to a practice of using the prunings as a form of organic fertilizer to be returned to the plantation soil. This will clearly be a dynamic relationship depending on input and output pricing and will need careful management by the plantation operator.

The model will work best in energy poor environments where local pricing can offset the cost of production and provide an acceptable margin. SGB advises that it is developing a business model based on locations in Central America and elsewhere in the world where KWH are priced at or above a minimum level of US$0.10 kWh. Logistics too will play a part in the economic equation; distance and cost to market will be important economic factors.

In higher labour rate environments the pruning and collection of prunings would need to be undertaken mechanically and SGB reports that it has developed an equipment to mechanise the harvest of plantation prunings in 5x25x40mm chip size – direct from field to processing facility.

We referred to the Biomass Energy Centre for price guidance in respect of wood chip and pellets. Typical prices for pellets are between US$0.06 and US$ 0.075 per kWh ($279-$393 per tonne), whereas wood chip at a 30% moisture content is between US$0.03 and US$0.045 per kWh ($139.5-$236 per tonne). The SGB assumption of 46mt/ha includes 35mt prunings, 7.5mt pericarp and 3.5mt shell. SGB is anticipating delivering its Jatropha biomass to potential customers at a moisture content of between 45% - 50%. The company advises that it is anticipating targeting the local steam boilers in Central America, and its preliminary research indicates that sales values of $35 - $40/mt of green biomass (~50% moisture content) can be achieved.

Biomass provides an alternative for fossil energy, which can be imported by high energy consuming regions such as the EU wherein domestic resources may be limited. This requirement creates economic opportunities for feedstock suppliers in resource rich countries, and in countries of origin the supply of biomass can be synergistic with the development of the local wood processing, the agricultural products sector and local electricity supply.

OSB/Woodchip Export

Wood chip material is sourced globally for OSB/particle board manufacturing plants. Depending on the source, certain fumigation requirements are mandated to ensure that bugs and other diseases do not migrate from country to country, but otherwise, the requirements for this grade of material are reasonably broad.

Densified Biomass Fuel (DBF)

Better known as pellet fuel, this product is now widely consumed in more than 1,000,000 homes in the US for space heating and in 4,000,000 homes and businesses throughout Europe. In addition, a parallel market has arisen for 'industrial' pellet fuel that is defined separately as a partial or full replacement for coal in existing steam boilers at electricity generating stations.

Advanced DBF Options

The most frequently referenced new forms of pellet fuel manufacturing include torrefaction and briquetting. Briquetting of biomass is a low-cost, low-volume method used to transport biomass more efficiently that has been a staple of third-world countries for decades. Modern high-speed briquette machines are largely produced for waste recycled metals, not for soft materials like biomass that require significant compression to create heat that converts the lignin into a binder.

Diesel Fuel Production

There are a small number of emerging processes worldwide that have demonstrated the conversion of biomass into various forms of fuel. Moreover, there are a number of private research firms that have already or are in the process of updating technical assessments of these various systems. The combination of on-site fibre and local/regional consumption has the potential to yield significant value for biomass material.

Economics of Agro-industrial Production of Jatropha Products

Wheat, soya, palm oil are important commercial crops which have proven cultivation models and well documented records for economic production. Cocoa is also an important commercial crop with annual trade in beans of some $12bn pa, but unlike other tropical tree crops such as oil palm or natural rubber, there is no library of documented records for its economic production under plantation cultivation – it is a crop almost entirely produced by small holders. Jatropha is not yet an important commercial crop and its production, like cocoa's, is today largely at the instance of small holders; there are no records and there are no precedents for its economic production under plantation agriculture. Since 2011 Hardman has been attempting to piece together jigsaw fragments of information to construct a set of rational economic scenarios for the plant's commercial cultivation. Any analysis of the economics of Jatropha cultivation must begin by defining the setting for such cultivation. We outline below two contrasting settings and offer estimated economic outcomes. As within any farming model the twin drivers are revenues per ha and cost of production. Management of the crop is largely non-mechanized, so labour costs and labour efficiencies matter greatly. Efficient and economic harvesting is perhaps the greatest challenge. Jatropha, in its natural environment, will produce flowers almost continuously; a dry season which induces dormancy in the plant helps to concentrate the flowering and fruiting periods. Breeding strategies are also focused on this issue. With the fruits ripening over an extended period, harvesting like flowering can be a continuous activity – and this racks up man days and costs. Careful and innovative management is required to harvest both efficiently, (our models below anticipate a high 95% recovery rate of harvestable fruits), and economically.

The crop science companies focused on the development of Jatropha as a commercial crop recognize the importance of mechanization in terms of efficiencies and cost control, especially in higher labour rate environments. Not surprisingly SGB, whose demonstration farm is to be based in Guatemala where agricultural labour commands a day rate of $12, is introducing mechanization where ever possible. The company advises that mechanized solutions for direct seeding, pruning, and pest control have been implemented. SGB also advises that it is at an advanced stage for the mechanization of harvesting. Harvesting technologies will be influenced by a number of factors, including the morphology of the plant, plantation design, ground conditions and topography. From the farmer's perspective cost of equipment, annual maintenance costs, speed of operation and fuel consumption will be major considerations. For large scale production of Jatropha, mechanization will be a necessary co-development along with the plant itself.

What is not in question, when we consider the economic viability of Jatropha cultivation, is the value of its seeds. The shell of the seed comprising 35% of its weight has high calorific value, very similar to the shells of oil palm kernels which typically sell in the range $40-80/mt. The oil which accounts for another 38% of the seed will produce a value (linked most probably to crude palm oil) of $650/mt at today's internationally traded price for CPO, to $1,000/mt which CPO is attracting in Africa. The remaining 27% of the seed is meal with higher protein content than market leader soya, and based on soya meal prices it is likely to trade in a range of $350/mt-$550/mt. Jatropha seeds have proven and significant economic utility – what must be demonstrated is that they can be produced in sufficient quantities and at an economic cost. The illustrations provided by Hardman below are the results of intensive discussions with industry players over the past 5 years. They are neither unduly optimistic nor strenuously conservative – they offer a reasonable perspective on how the production of the crop can be managed for profit. A number of the leading crop science companies developing Jatropha are now planning to establish suitably scaled demonstration farms to prove this economic model.

Our calculations below are linked to estimates for the cost of producing biodiesel at source. In some production environments this may be the route to achieving optimal returns on the oil crop. Our estimates suggest that based on cost at source (energy poor depressed rural economies), CJO based biodiesel could be produced from US$0.87-$1.00/litre.

Traditional Model – Cultivation on Degraded Land in Semi-Arid Environments

One vision for the plant's cultivation is as an oil crop produced on marginal or degraded lands in semi-arid environments. This is a traditional setting for the crop, but this setting for cultivation naturally limits the volume of harvests possible. There are offsets: these are regions which are typically dependent on imported energy and characterized by rural poverty and high unemployment. Such employment as is available, which is largely informal, will be in the agricultural sector. Jatropha projects in these regions offer the prospect of significant economic, social and environmental benefits. Both JOil (Burkina Faso) and JatroSolutions (Ghana) are developing or proposing to develop, demonstration Jatropha farms in these traditional Jatropha regions. Labour rates in these environments typically start from circa US$2-$3/day. In these settings, logistics are likely to be basic to fragile, and they are settings largely inappropriate for significant capital investment in processing technologies. These factors will limit the opportunities to optimize the value of all the components of a Jatropha crop; oil will be the primary product of interest and greatest value, especially if it can be converted to biodiesel within the source region. Under these agronomic conditions, which may include rainfall no higher than 600mm/pa, seed yields per ha will be in a range of 2mt-4mt/ha with effective agronomic management. The upper end of the yield range will need rainfall of 800mm even with drought resistant materials.

We would anticipate that the greatest value attaches to CJO which will likely trade above international prices, inflated for a transport premium of up to $100 mt and possibly more. West African palm oil can trade at a premium of 10% above CIF Rotterdam and also capture a transport premium of $50-100/mt. Meal, high in protein, would however be most likely to be sold for fertilizer or fuel and this would not be expected to exceed the prices paid by local buyers of domestic or industrial fuel.

CJO Price ($/MT)	1000	$/MT
Meal Price ($/MT)	50	$/MT
Shell Price ($/MT)	50	$/MT

Revenues in our model are driven by a harvest recovery rate of 95% (all manual) and an oil recovery rate of 80% to give OER of 28%.

Revenue		
CJO Rev	798.0	$/ha
Meal cake Rev	40.6	$/ha
Shell Revenues	47.4	$/ha
Total Revenue per hectare	**$886.0**	

Agricultural cost to maturity is assumed at 50% of what we would expect for cultivation on arable land where in more favourable climates where we would expect a total investment of circa $1,600/ha to maturity at year 3. Labour is assumed at $3/day and all activity on the farms is manual. We also assume a lower cost of capital (10%) on the basis that debt finance would make up only 20% of the capital structure and that it would be provided on favourable terms, perhaps under a development finance initiative.

Maintenance	135	$/ha
Harvesting	120.0	$/ha
Fertiliser	45	$/ha
Diesel	55	$/ha
Decortication	5	$/MT of fruit
Decortication	23.1	$/ha
Crushing cost per MT of seeds	10.8	$/MT of seeds
Crushing	32.4	$/ha
Others	10	$/ha
Total Variable Costs	**$420.5**	**$/ha**

Cash cost per MT of CJO	787.7	$/MT
Cash cost per MT of Meal Cake	39.4	$/MT
Cash cost per MT of Shell	39.4	$/MT
Cash cost per Litre CJO	0.72	$/L
EBIT per hectare	**$188.1**	
EBIT margin	*21.2%*	

The example above is based on a harvest of 3mt/ha. If instead we assume a harvest of 4mt/ha, then the economics are transformed.

Cash cost per MT of CJO	653.0	$/MT
Cash cost per MT of Meal Cake	32.6	$/MT
Cash cost per MT of Shell	32.6	$/MT
Cash cost per Litre CJO	0.60	$/L
EBIT per hectare	**$410.0**	
EBIT margin	*34.7%*	

Cultivation In Favourable Agronomic Setting

If we assume that Jatropha is cultivated in an environment of adequate rainfall in the range 1,000-1,500mm/pa and with suitable sunlight and temperature range, which might include large swathes of Africa, Asia and the Americas, then with appropriate agronomic management it may be possible to harvest dry seeds up 6mt/ha or more annually. In this setting labour rates are likely to be higher and for the purposes of discussion we have used a day rate of $12 – consistent with parts of Central and South America.

In a more prosperous environment with adequate logistics we would assume that the products of Jatropha cultivation would attract internationally competitive prices as indicated below, but note that we have pitched CJO lower than in the model above to reflect a reduction in transport premium. Importantly however we assume that the high protein meal will achieve a price guided by global leader, soya meal.

CJO Price ($/MT)	850	$/MT
Meal Price ($/MT)	450	$/MT
Shell Price ($/MT)	50	$/MT

The assumption that meal would achieve full value provides a significant boost to revenues more than offsetting the lower assumed value for CJO.

CJO Rev	1356.6	$/ha
Meal cake Rev	731.0	$/ha
Shell Revenues	94.8	$/ha
Total Revenue per hectare	**2182.4**	$/ha

An important driver of our calculations for profitability is daily harvest (kg) rate. In the first model we have assumed 75 kg seed picked per day. This approximates to circa 115 kg of fruit per day. This requires a harvester to pick 240gm of fruits (circa 20 fruits) per minute for each of 8 working hours – this is a 'big ask'. Within the coffee sector 90 kg of coffee picked per day is considered good. Much will depend on the harvesting methodology. An economic harvester technology holds out the prospect of transforming the economics and management complexity of large scale Jatropha cultivation. This is an area of intense enquiry by the sector participants and by at least one of the international equipment manufacturers, Oxbo International (Oxbo Ploeger Group). SGB is itself working on the development of a proprietary prototype equipment. In advance of its own technology being available, or until a compelling agro-industry solution is introduced, SGB has developed a method based on having teams of two workers using a modified wheelbarrow (see photograph below) which the company reports has significantly improved manual harvesting efficiencies. The model developed assumes only 6.5 hours of actual harvesting but crucially instead of the harvesters picking selected ripened fruit, they pick the entire bunch. This approach requires a degree of uniformity with ripening which is an issue with Jatropha, especially in wetter climates where the plant will flower continuously. In more arid environments however flowering is more concentrated and the method could have good application.

The four crop science companies detailed herein are all seeking to concentrate flowering and ripening patterns in commercial Jatropha species and SGB reports that it has been able to use the methodology illustrated below with good effect on varieties with more concentrated ripening patterns.

Source: SGB Inc

SGB reports that using the wheelbarrow, 2 man team methodology illustrated above, per worker daily harvest rates outturn at between 237 kg and 283 kg per day. There might be a downside in terms of oil quality and volume, with a mix of fruits of mixed maturity. SGB reports that seed oil content was 38.31% when only mature fruit were collected from one of its hybrid as compared with 37.34% when a mixture of fruits of varying maturities was analyzed for the same hybrid.

In our model (based on manual labour only) we assumed 100kg of dry seed picked per day or 154kg of fruit allowing for higher productivity per worker and the use of innovative harvesting techniques. This produced a broadly acceptable result as demonstrated below. Readers will note however that harvesting related expense represents the largest of the cost classes below. This underlines the importance for the sector of the development of an economic mechanized solution – especially for large scale to very large scale production and in higher labour cost zones. In the calculation below harvesting accounts for 47% of the variable cost; in the palm oil sector where harvesting is only partially mechanized, but the total system is well practiced, harvesting typically represents no more than 15-16% of total cash costs of production (p/hectare basis).

Maintenance	540	$/ha
Harvesting	720	$/ha
Fertiliser	90	$/ha
Diesel	55	$/ha
Decortication	*5*	*$/MT of fruit*
Decortication	46.2	$/ha
Crushing cost per MT of seeds	*10.8*	*$/MT of seeds*
Crushing	64.8	$/ha
Others	10	$/ha
Total Variable Costs	**1526.0**	**$/ha**

Total variable costs are higher for the more productive cultivation, based on higher labour costs ($12/day) and higher fertilizer expense. We have also assumed a higher cost of debt at 12% and debt at 40% of the capital structure.

Cash cost per MT of CJO	751.5	$/MT
Cash cost per MT of Meal Cake	397.9	$/MT
Cash cost per MT of Shell	44.2	$/MT
Cash cost per Litre CJO	0.69	$/L
EBIT per hectare	**$252.8**	
EBIT margin	*11.6%*	

If however we raised the harvest productivity to the level reported by SGB, which would produce circa 165kg of dried seeds per worker/day, then the EBIT outcome is greatly enhanced.

Cash cost per MT of CJO	641.1	$/MT
Cash cost per MT of Meal Cake	339.4	$/MT
Cash cost per MT of Shell	37.7	$/MT
Cash cost per Litre CJO	0.59	$/L
EBIT per hectare	**$536.5**	
EBIT margin	*24.6%*	

In particular the cash cost per litre of CJO evolves at a level that would be highly competitive with diesel. The illustrations below reflect the cost of CJO production (used in 3 of the examples above) in the total production cost of biodiesel in region of origin for CJO using a mini-transportable refinery system. The illustrations are based on operative labour for the refinery at 15x the day rate of agricultural labour – in the lowest cost environment. Technical workers are likely to earn a high multiple of the agricultural day wage; we have assumed $12,000 pa. For more affluent settings we chose to inflate the cost for operative labour at say 6.5x the higher rate of agricultural labour ($12/day) with an operative receiving $20,000pa (a little under 60% of the North American rate), the labour cost per litre increases by $0.047. Today in Burkina Faso, diesel is selling at approximately $1.20/litre. A producer of CJO with capacity to refine for biodiesel on the plantation, using the lowest cost economic production model below, would achieve a gross margin of 40%.

Biodiesel Production Costs	**$/litre**	
CJO (at cost of production)	**0.59**	
Potassium Methylate	0.09	
Methanol	0.06	
Other	0.04	
Total Inputs	**0.78**	
Labour	0.07	
Fuel, Insurance, Consumables	0.01	
Total Cost per litre biodiesel	**0.86**	
		$/litre biodiesel
$ Cash Cost CJO/mt: $788	0.72	0.99
$ Cash Cost CJO/mt: $752	0.69	0.96
$ Cash Cost CJO/mt: $641	0.59	0.86

Source: Hardman Estimates/Biocube Corporation Ltd

Who Is Who of 21st Century Jatropha

Jatropha is not a well known species or crop. Most consumers will have seen an image of a tea bush or a banana 'palm' (actually it is a lily), most would struggle however to describe a cacao tree and very few indeed would have heard of Jatropha. This is not surprising, Jatropha is not yet an important crop, it is not a cornerstone of agriculture in any country or region today. What is surprising however is the attention this largely unheard of plant has attracted from some of the most eminent crop scientists of our times, and the investment it has drawn from a number of the world's best known corporate names. The 'Plant With A Bad Name' described in Hardman's first publication on the Jatropha sector, March 2011, has been able to secure an impressive class of student and some very large industrial and financial investors.

Heavy Weight Shareholders

Four life science investors including a national research laboratory, one of Europe's largest energy utilities, a leading US petro-chemicals company, one of the world's leading names in automotive manufacture and a global name in chemicals, makes for an impressive roll call. That these names are all longstanding investors in the leading crop science companies that are committed to developing and or transforming Jatropha into an important 21st century crop, invites our interest. Each name listed below has had the relevant experience to make an informed judgement about the strength of the investment case for the crop's development. Whether we approach Jatropha without any prior knowledge or with an acute awareness of the cynicism that grew out of the failure of earlier ill-conceived refinery ventures, the commitment made to the crop's development by the roll call of names below must challenge any existing pre-conceptions and encourage greater interest in the crop.

Energie Baden Wuerttemberg AG

The investment division of Energie Baden Wuerttemberg AG (EnBW) has owned 51% of JatroSolutions since 2013 (49% from 2009). EnBW, with a market capitalisation of Euro 6.9bn, is the 3rd largest of Germany's energy utilities. EnBW has 3 core business areas: Electricity, Gas, and Energy & Environmental Services. The Company has sales offices and subsidiaries in Germany and throughout central and eastern Europe.

Temasek Life Sciences Laboratory (TLL)

TLL is a non-profit organization established in 2002 to undertake frontier research in molecular biology and genetics utilizing a broad range of model organisms. It is a shareholder in and partner with JOil (S) PTE Ltd. Affiliated to both the National University of Singapore and Nanyang Technological University, TLL has some 220 researchers and is working to develop the biotechnology industry in Singapore through collaborations and joint research ventures with local & international partners.

Tata Chemicals Limited (TCL)

TCL with a market capitalisation of $1.5bn, is one of the world's largest producers of soda ash. It is one of the principal shareholders in JOil (S) PTE Ltd. Tata's industry essentials product range provides key ingredients to some of the world's largest manufacturers of glass, detergents and other industrial products. TCL is a leading manufacturer of urea and phosphatic fertilisers.

Toyota Tsusho Corporation

Toyota Tsusho Corporation brings together Toyota's automotive business with Tomen's wide range of businesses and customers outside the automotive sector. TheToyota Tsusho group combines a global network and trading activity underpinned by a world class manufacturing business. Listed on the Tokyo Stock Exchange it has a market capitalisation of some $7.6bn and is a shareholder in JOil (S) PTE Ltd.

Thomas McNerney & Partners

Thomas McNerney is a USA venture capital firm with approximately $600m under management. It is an investor in SGB, Inc. TMP targets investments in the pharmaceutical, medical devices, biotechnology and diagnostic sectors. Companies raising growth capital for product commercialization are of particular interest.

Flint Hills Resources (FHR)

FHR is a wholly owned subsidiary of Koch Industries, Inc ($115bn in sales). It is an independent refining, chemicals, biofuels and ingredients company based in Wichita, Kansas. FHR has expanded its operations through capital projects and acquisitions worth more than $11 billion since 2002. It is a leading investor in SGB, Inc. Its refineries produce fuels that power much of Texas and the Midwest. The company's ethanol plants produce fuels that are used across the United States. Its petrochemicals are used to manufacture goods from plastics to building products to packaging materials. The base oils it markets are the principal raw material used to produce premium motor oil, commercial lubricants and sealants and coatings. FHR operates ethanol plants with a combined annual capacity of 820m gallons of ethanol. It is a leading producer of transportation fuels in the Upper Midwest, is the largest purchaser of ethanol in Minnesota, where it has utilized ethanol and other biofuels in its fuel distribution system since the mid-'90s.

Finistere Ventures

Finistere Ventures is a life science venture capital firm based in San Diego with a longstanding shareholding in SGB, Inc. The fund's investment strategy is focused on "Food, Energy and Health" related technologies. These include technologies related to agricultural innovation. The fund seeks for early stage, innovative, disruptive technologies, with clear Intellectual Property protection, large and addressable markets, and with the potential for significant exit value.

Life Technologies

Life Technologies is a brand of Thermo Fisher Scientific Inc. (NYSE: TMO), and an investor in SGB, Inc. TMO claims to be the world leader in serving science. It has revenues of $17bn annually, some 50,000 employees in 50 countries, and a market capitalisation of $50bn. It seeks to accelerate life sciences research, solve complex analytical challenges and increase laboratory productivity.

Senior Scientists

Detailed briefly below are the senior scientists who have shaped the research and development of Jatropha, both for their respective companies and also for the academic and research establishments across 3 continents. Their careers have all embraced senior roles in academic and research science with applied practice in the field.

Professor Dr. Klaus Becker, Emeritus Senior Scientist – JatroSolutions GmbH

Identified to be one of the world's most influential agricultural scientists by Thomson Reuters, Professor Becker founded and led JatroSolutions until his retirement from the day to day management of the company. He has held the position of Professor and Head of the Aquacultural Systems and Animal Nutrition Department in the Tropics & Subtropics, at the University of Hohenheim, Germany, since 1986. His specific scientific interests have been focused on basic and applied fish energetics and nutrition, as well as research on the use of low quality forages and by-products feed for ruminants. Dr. Becker has authored or co-authored over 200 peer reviewed research papers, 9 book chapters and more than 250 abstracts and proceeding papers. He is member of several professional societies and editorial boards. Dr. Becker has conducted research projects in over 20 developing countries in Africa, Asia, Central America as well as in Europe and supervises senior scientists in advanced laboratory techniques encompassing in vitro and in vivo studies of rumen bacteria as influenced by feed quality and secondary plant compounds.

Dr. George Francis – CEO JATROPOWER Group

Dr George Francis holds a PhD from the Faculty of Agriculture, University of Hohenheim, and has more than a decade of experience with international bio-energy projects, many of which have been inter-cultural projects, and an even longer experience of Jatropha. Specifically Dr Francis undertook 6 years of post-doctoral research on Jatropha under the auspices of Hohenheim University. Dr. Francis played a key role in the DaimlerChrysler-DEG Jatropha project titled "Biofuels from Eroded Soils in India", during his time at Hohenheim. This was the first comprehensive project to investigate the many aspects of Jatropha cultivation on wasteland, extraction of oil from its seeds, biodiesel production and the potential uses of the by-products remaining after oil extraction. On conclusion of this project, Dr Francis's company, Live Energies GmbH was awarded the follow-up activity titled "Microcredit supported Jatropha cultivation on wastelands in India" sponsored by a consortium consisting of Daimler AG, Bayer CropScience AG and Bayer CropScience India, again with the support of DEG, Cologne. This project investigates the feasibility of Jatropha farms established on wastelands to increase income of small farmers who owns such un-utilizable land. Dr Francis has acted as a consultant on Jatropha and other bio-energy projects to national governments, multinational financial institutions and private companies world-wide. He has been an invited reviewer for EU funded sustainable energy projects under FP6 and FP7 since 2001. Dr. Francis has authored or co-authored 13 peer-reviewed scientific publications on Jatropha since 2005 in addition to several popular science articles and articles in scientific conference proceedings. When JATROPOWER was formed in 2007 Dr Francis took up the position of CEO of group.

Dr. HONG Yan, Chief Scientific Officer – JOil (S) PTE, Ltd

Dr Hong joined JOil in 2008. He has a background in biological science and received his PhD from the Chinese Academy of Medical Sciences in 1989. In 2001 he was awarded an MBA from the National University of Singapore. He has led an independent research group within the Institute of Molecular Agrobiology, University of Singapore since 1998, investigating biotech crop development, forestry biotechnology, herbal medicine, bio-energy plants and new technology development. He has 8 patents and many peer reviewed publications to his credit. Dr Hong Yan is also an adjunct Associate Professor with Nanyang Technological University (NTU).

Dr. Srinivasan Ramachandran, Chief Technology Officer – JOil (S) PTE, Ltd

Dr. Srinivasan Ramachandran, Chief Technology Officer, obtained his PhD in Biochemistry with Plant Molecular Biology as specialization from University of Idaho, USA. In 1993, he joined Prof Nam Hai Chua's group at the Institute of Molecular and Cell Biology, later at the Institute of Molecular Agrobiology, Singapore. He headed the group of Rice Functional Genomics at Institute of Molecular Biology since 2001 and since 2002 at Temasek Life Sciences Laboratory. Also since 2007 leading a group at the Center for Bioenergy Plants, at Institute of Botany, Chinese Academy of Sciences, Beijing, China. He has several peer reviewed publications and patents to his credit.

Robert Schmidt, Ph.D. Chief Scientist – SGB, Inc.

Dr. Robert Schmidt has more than 30 years of research in plant molecular genetics, specializing in developmental genetics of seeds, flowers and inflorescence and whole plant architecture. He holds a B.A in Biology from Harvard, and a Ph.D. in Cell and Molecular Biology/Botany from Duke University. He spent 3 years as a Postdoctoral Fellow at Brookhaven National Laboratory before accepting a faculty position with University of California, San Diego in 1987. As a Professor of Biological Sciences at UCSD, he taught and conducted research for 24 years where he held the Paul D. Saltman Endowed Chair in Science Education. Dr. Schmidt has produced contributions to corn genome projects and has published over 60 peer-reviewed articles in highly respected journals. In 2010 he was elected a Fellow of the American Association for the Advancement of Science. After several years of serving as a consultant to SGB's R&D activities, he retired from UCSD in 2012 to take on the full time position as Chief Scientist at SGB.

JATROPOWER AG

JATROPOWER AG (JATROPOWER) combines 14 years of corporate research into Jatropha with over 20 years of experience of the crop of its scientists led by its group CEO and Chief Scientist, Dr George Francis. Managed and owned by a small group of former Swiss industrialists with relevant life sciences sector experience, together with Dr Francis, JATROPOWER's proprietary planting material (which incorporates all the breeding material of the former Quinvita NV) is now being cultivated over some 8,000ha of client farms. Within the sector the company is renowned for its focus on edible or non-toxic Jatropha and for a concentration on development of plants able to produce commercially acceptable harvests in degraded soils in semi-arid climates where the crop does not compete with food production. Already the company has demonstrated the efficacy of the high protein kernel meal from edible Jatropha as an animal feed thus strengthening the Jatropha business model. Aside from a well resourced technical division which drives the company's ongoing R&D programme, JATROPOWER represents itself as a commercial partner for businesses seeking to farm Jatropha, able to supply a number of proven lines of both edible and common toxic varieties and to support a new Jatropha project from conception to post implementation.

Company & Management

Founded in 2007, JATROPOWER is a privately held Swiss company located in Baar, Canton of Zug. The company owns and is developing a collection of elite edible and common toxic *Jatropha curcas* varieties from a highly diverse germplasm base of 650 accessions. Since 2012 the company's seeds have been planted with customers on more than 8,000ha. By 2016 JATROPOWER plans to make available to the market lines of second generation hybrid varieties with enhanced yield potential.

The Board of Directors comprises three Swiss nationals all of whom have had experience of management at the most senior levels of significant Swiss and international businesses, including life science companies. While Mr. Peter Gmür as active Chairman of JATROPOWER is mostly involved in Strategy and Supervision, Mr René Garo and Dr Peter Bollmann are following the management of the business and its activities. For this they work in close partnership with Group CEO, Mr George Francis. Mr Garo has a background in the successful development of plant based life science businesses and Dr Bollmann in corporate affairs, business development, finance and controlling. JATROPOWER is wholly owned by its three directors, Peter Gmür, Peter Bollmann and René Garo, and by the Group CEO, Dr George Francis, an alumnus of Hohenheim University in Stuttgart where Dr Francis has been a central figure in the university's 30 year Jatropha research programme.

Development Team

Dr George Francis – A Leading Jatropha Crop Scientist

A review of the history of JATROPOWER must begin with Dr George Francis. Dr George Francis holds a PhD from the Faculty of Agriculture, University of Hohenheim, and has more than a decade of experience with international bio-energy projects, many of which have been inter-cultural projects, and an even longer experience of Jatropha. Specifically Dr Francis undertook 6 years of post-doctoral research on Jatropha under the auspices of Hohenheim University. Dr. Francis played a key role in the DaimlerChrysler-DEG Jatropha project titled "Biofuels from Eroded Soils in India", during his time at Hohenheim. This was the first comprehensive project to investigate the many aspects of Jatropha cultivation on wasteland, extraction of oil from its seeds, biodiesel production and the potential uses of the by-products remaining after oil extraction. On conclusion of this project, Dr Francis's company, Live Energies GmbH was awarded the follow-up activity titled "Microcredit supported Jatropha cultivation on wastelands in India" sponsored by a consortium consisting of Daimler AG, Bayer CropScience AG and Bayer CropScience India, again with the support of DEG, Cologne. This project investigates the feasibility of Jatropha farms established on wastelands to increase income of small farmers who owns such un-utilizable land. Dr Francis has acted as a consultant on Jatropha and other bio-energy projects to national governments, multinational financial institutions and private companies world-wide. He has been an invited reviewer for EU funded sustainable energy projects under FP6 and FP7 since 2001. Dr. Francis has authored or co-authored 13 peer-reviewed scientific publications on Jatropha since 2005 in addition to several popular science articles and articles in scientific conference proceedings. When JATROPOWER was formed in 2007 Dr Francis took up the position of CEO of group.

Chief Executive Officer, JATROPOWER India - Professor J. Oliver

Professor Oliver's professional career spans some 38 years, during which time his focus has been mostly devoted to the agricultural extension services. Professor Oliver has a PhD in agricultural extension, a subject on which he has written some 35 research papers and 100 articles in various farm journals. Professor Oliver has worked for both the Department of Agriculture, of the Government of Tamil Nadu, and with the Tamil Nadu Agricultural University, in Coimbatore. Before joining JATROPOWER, he was involved in the introduction of Jatropha cultivation over large numbers of small holder farms.

Managing Director, JATROPOWER Kenya – Mr Charles Barnabas Gasston

Barney Gasston has decades long experience in the implementation and management of agricultural projects in Africa dealing with bio-energy production, medicinal plant production on contract with European companies as well as cattle ranging techniques. Barney was also among the pioneers of export oriented rose farming in Kenya, has initiated several other agricultural projects in several African countries on his own and has worked in the past for Global Agricultural majors such as Monsanto.

Research & Development Programme

The company commenced its research and development programme for *Jatropha curcas* in 2008 with a strategy of continuous genetic improvement by way of conventional breeding supported by marker assisted selection at its research farms. Then in early 2014, JATROPOWER took over the selected elite genotypes and certain technologies and intellectual property rights of Quinvita BV, Belgium which had been active in Jatropha genetic improvement since 2006. Until it went into administration in 2013, Quinvita had been one of the leading crop science companies within the sector. The combination of two significant selections of proven, elite Jatropha breeding material has confirmed JATROPOWER's position as one of the international leading crop science companies in the Jatropha sector. Today JATROPOWER is able to boast a germplasm collection of 650 accessions of *Jatropha curcas* selected from global provenances, including all the major Jatropha 'hot-spots' extending from Central America and including Mexico, SE Asia and India, Africa and Madagascar. The company is seeking to achieve significant synergies from the acquisition of the Quinvita IP. The transaction combines over 7 years of JATROPOWER's proprietary research with 7 years of R&D by Quinvita.

Edible or Non-toxic Jatropha

From its inception in 2007 and in addition to the pursuit of a traditional breeding and development program for the conventional toxic Jatropha varieties, JATROPOWER had a strategic focus on the development of non-toxic or edible Jatropha using state-of-the-art agronomic and genetic analysis techniques for the development of non-toxic varieties.

Edible or non-toxic Jatropha varieties are distinguished from common toxic varieties by the virtual absence of phorbol esters in their seeds. The oil and kernel meal of these non-toxic varieties have the same characteristics of common Jatropha except for phorbol ester fraction. Consequently, the detoxification process involving additional cost is not required if the kernel meal is to be used as an animal feed ingredient.
(see e.g. http://www.jatropower.ch/partnering/non-toxic-Jatropha.php)

The high nutritional quality of heat treated non-toxic Jatropha kernel meal has been demonstrated in feeding experiments with fish and rats. Data extracted from N. Richter (Richter, N., 2012. Evaluation of suitability of non-toxic and detoxified *Jatropha curcas* L. meal as feed for fingerling common carp, Cyprinus carpio L.: with reference to phytase application. Ph.D. Thesis, University of Hohenheim, Stuttgart, Germany) showed equal body weight development of common carp fed on a fish meal based control diet (45% by weight fish meal) as on a diet where 50% of the fish meal was replaced by heat treated non-toxic Jatropha kernel meal. In other experiments up to 87% by weight of fish meal could be replaced by Jatropha kernel meal without causing feeding depression in fish and resulting in growth that was better than the case when a similar amount of fish meal was replaced by soybean meal.

JATROPOWER advises that non-toxic Jatropha plants always produce non-toxic seeds, irrespective of whether they are pollinated by toxic or non-toxic pollen. However, the company has observed that non-toxic seeds produced from non-toxic mother plants, if germinated, can develop into plants that produce toxic seeds. There is thus a significant risk that seeds produced from non-toxic plantations by open pollination will give rise to toxic offspring. This pattern provides inbuilt IPR protection for suppliers of non-toxic elite or hybrid planting material.

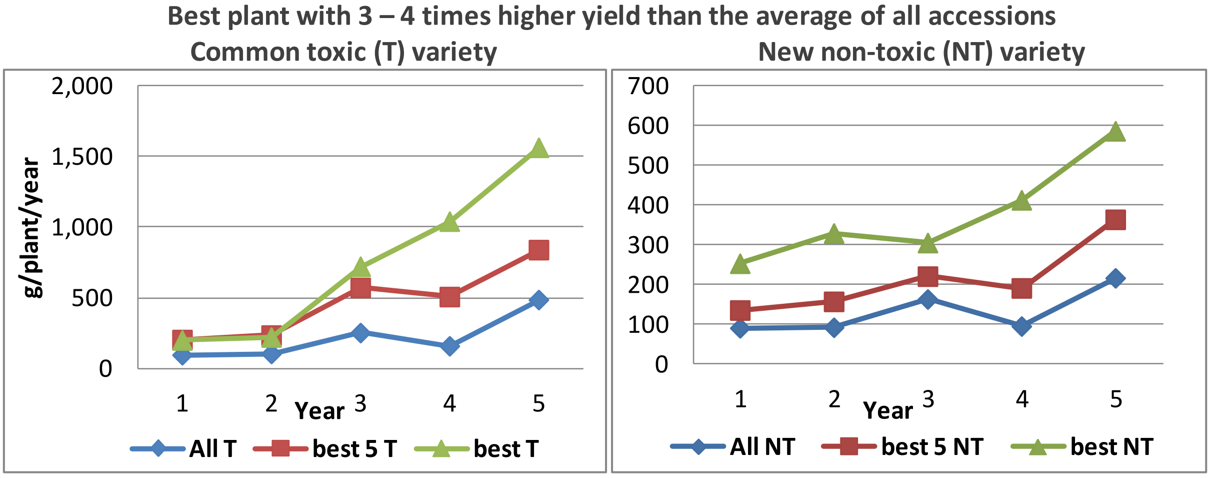
Based on feeding trial results at the University of Hohenheim, a value of 0.1mg phorbolester/g full-fat kernel meal (measurement according to the Hohenheim method) can be considered the limit above which seeds can be considered as toxic. This limit compares to an average of above 2.5mg phorbolester/g in the kernels of the common toxic varieties. Jatropower expects to be able to supply larger quantities of non-toxic seeds of its non-toxic elite parent plants by 2015 and of its second generation, non-toxic derivative plants by around 2017.

Employing DNA analysis techniques the company has been able to identify suitable markers that can reliably distinguish between common toxic and non-toxic parent plants. These markers will help in the early differentiation of non-toxic and toxic plants, in further enumerating the inheritance pattern of the non-toxic trait and its homozygosity. The non-toxic markers identified in JATROPOWER's research have been made available to the Jatropha community via a research publication (Plant Science 207 (2013) 117– 127). JATROPOWER has continued to make good progress with the determination of the inheritance patterns of the non-toxic trait with further research publications with new results expected in the near future. The company expects to identify further markers that are closer to the non-toxicity allele, which would also help evaluate the homozygosity of the trait. Jatropower has a history of and an ongoing programme of intensive study into the inheritance pattern of the non-toxic trait, with the aim of developing non-toxic Jatropha accessions with greater vigour than their naturally occurring ancestors.

Hybridisation & Breeding Strategies

In 2010 JATROPOWER commenced a hybridization programme. This was commenced with 15 elite parent pairs from which F1 and F2 plants were produced. The hybrid nature of the F1 plants is routinely confirmed through marker analysis. From the first results, several crosses produced very promising F1 plants (series JP 286, JP 682, JP1511, JP6830, JP3068 etc) in terms of seed productivity. Series JP286 showed a hybrid vigour of almost 100% compared to the most productive parent based on dry seed yield during years 1 and 2. Favourable characters of the best toxic F1 hybrid observed were robust growth under drought conditions at the farm in 2013 (only 170mm rainfall, life-saving irrigation of 15liters every 15 days during 8 completely dry months), early and thereafter continuous flowering and large sized fruit bunches.

The company is seeking to demonstrate that its best performing plants can sustainably achieve yields 3-4x higher than wild stock growing in degraded soils in semi-arid climates. Additionally JATROPOWER is working (across multiple locations) to show that the F1 hybrids of its elite plants can further increase yields by factor of 2.



Note: year 4, 5 = drought years–annual rainfall below 200 mm

Semi-arid climate and degraded soil framework under which these yields have been obtained:

Rainfall:	average below 400 mm p.a.	Texture:	stony
pH:	8.2	Fertility:	deficient in N and P and
Soil depth:	30 cm		micronutrients such as B and Fe
Irrigation	14 litres every 14 days during rain-free months		

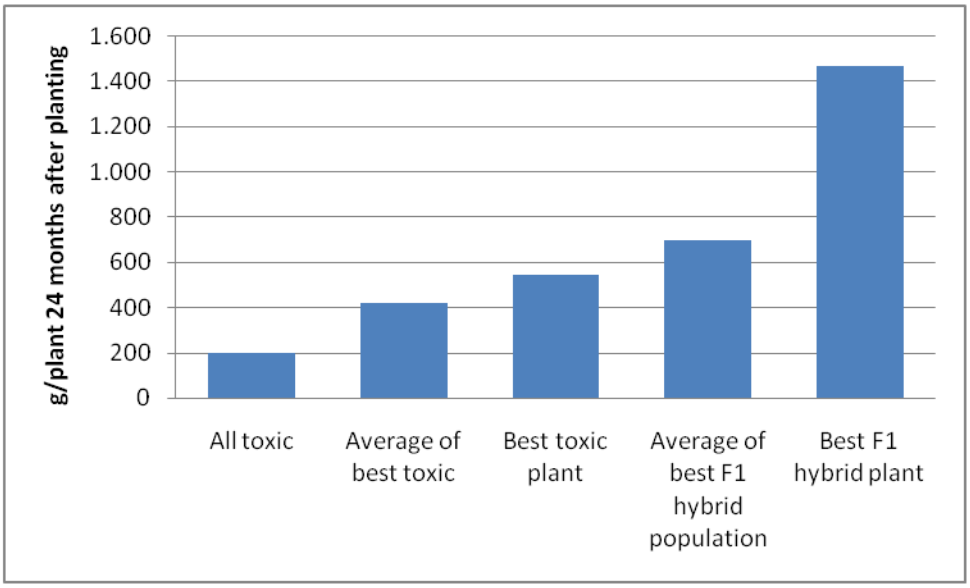
Note: planted on non-degraded deep soil under higher rainfall conditions (> 1200 mm/pa well distributed over 6-8 months) or under irrigated conditions yields higher by a factor of 2 or more can be expected.

JATROPOWER has identified non-toxic derivative plants, which it reports show early promise with regard to favourable characteristics such as large fruit bunches, heavy seeds and other similarities to the F1 hybrid. These elite derivative plants are currently under observation to identify the best performers on the basis of early indicators. Such selected elite derivative non-toxic plants will be cloned and transferred to the seed production orchards. The company is expecting hybrid vigour of 75% above the original parents for the elite non-toxic derivative selections.

The company's best performing non-toxic variety is described as significantly smaller in size as the picture below illustrates than its common toxic peers (spacing in this test plantation was 3m x 3m). JATROPOWER has observed that this non-toxic accession has a higher seed biomass per unit total biomass under its specific growing conditions. It is also reported to consistently produce large fruit bunches, most of which have above 20 fruits per bunch reducing harvesting effort. The smaller size of the non-toxic plant enables planting in a higher density, especially under rain fed conditions, which will offset the decreased seed production per plant, when seed yield per ha is considered. Trials at JATROPOWER's farm have shown that non-toxic varieties respond to pruning with about 10% increase in yield.

Figure: Size comparison of four year old selected elite non-toxic plant (left) and the selected elite toxic plant (right)

Figure: Seed yield pattern of elite cultivars compared to F1 hybrids



JATROPOWER has also been following the performance of a set of interspecific crosses between *Jatropha curcas* and other Jatropha species such as J. integerrima, J. glandulifera and J. gossypifolia. Further interspecific hybridisation trials are proposed in future.

Efforts are also on at JATROPOWER to develop a scalable model for commercial hybrid seed production in *Jatropha curcas*. JATROPOWER is scientifically monitoring a variety of characteristics of Jatropha including:

- Plant characteristics including:
    - male/female ratio in the flower bunches and the fruits of the accessions
    - general agronomy, effects of macro and micronutrients
    - parasite and pest management
    - Seed yields, physical characteristics, oil content, FFA content of oil
- Fatty acid composition of seed oil of selected accessions and its inheritance pattern
- Genetic improvement

- This is being continued through elite x elite crosses and inter-specific crosses.

- Evaluation of pistillate Jatropha plants to help increase productivity and their integration into the hybridization programme for cost-effective hybrid seed production
- Confirmation of hybridity of intraspecific hybrids before their evaluation
- Genetic diversity analysis using markers
- Development of DNA fingerprints for the selected elite accessions
- Association of markers to key characteristics such as non-toxicity.

JATROPOWER's technical team, based in India, has developed expertise in:

- plantation management
- plant genetics and breeding
- general agronomy
- organisation & management of contract farming with out-growers
- oil seed quality control
- oil seed commerce.

Additionally JATROPOWER has established:

- an international pool of experts with experience of Jatropha cultivation in Africa and Latin America
- access to state of the art technical expertise in Jatropha breeding and seed and oil biochemical analysis through co-operation with leading research institutes including:
    - ICAR laboratories in India
    - Tamil Nadu Agricultural University, Coimbatore, India
    - Hohenheim University, Germany
    - Humboldt University, Germany
    - San Carlos University, Paraguay.

Current Focus and Operations

The company has its main research and development activities and seed orchards spread over 12 farms in India operated by its wholly owned subsidiary Jatropower Bio-Trading Private Limited. Jatropower operations in India are led by Dr. J. Oliver, formerly Dean of the Faculty of Agricultural Extension at the Tamil Nadu Agricultural University, Coimbatore.

Additionally it has experimental farms in Kenya and Paraguay. In Kenya, JATROPOWER Kenya Ltd has been established in 2011 and this subsidiary owns the 20 acre experimental farm there. JATROPOWER has its own personnel in Kenya led by Mr Barney Gasston, who is well known in the industrial farming sector of the country. In Paraguay the company operates a Jatropha research farm in collaboration with University of San Carlos. The collaborative research activities are supervised by scientists at the University in co-ordination with JATROPOWER.

JATROPOWER's seed production orchards in India is producing and supplying commercial quantities of elite Jatropha seeds on order. These elite seeds have been assessed at client sites in Mali, Burkina Faso, Mozambique, Ghana and Panama and used to establish commercial plantations. The company has received repeat orders for its seeds from existing clients confirming the company's status a commercial producer of Jatropha planting materials. Up and until today, more than 8000 ha have been cultivated with planting material from Jatropower.

The company has available commercial quantities of 5 varieties and from the second half of 2015 it will be offering three additional cultivars including the first commercial non-toxic variety. The first commercial hybrid seeds are expected to be available in 2016. The current sales price of the company's elite plants is in the range of 30€/kg and depends on contract terms & conditions. The company points out that this is no more than 3% of the value of a single year harvest at maturity for a perennial crop with an economic life of 20 – 30 years.

Client Services

JATROPOWER is offering planting material from the above mentioned toxic and non-toxic lines for trials at the customer's site to identify the best performers under those conditions, along with a package of measures to ensure proper plantation management to enhance yield.

If larger areas are ready for plantation, the company can deliver required quantities of Jatropha seeds which have shown high yield potential in different areas of the world. Additionally JATROPOWER provides evaluations for, establishment of, and management of larger scale plantations, in particular preparation and review of business plans, due diligence on projects, plantation site evaluation up to establishment of Jatropha plantations, inspection, collection and trading of Jatropha seeds and oil as well as seed, seed kernel meal and oil quality evaluation.

For more details please refer to www.jatropower.ch.

JatroSolutions GmbH

JatroSolutions and its founder and Emeritus Senior Scientist, Professor Klaus Becker are amongst the earliest pioneers in the development of Jatropha as a sustainable and economically viable crop, in particular for cultivation on degraded soils across the semi-arid tropics. The company's origins and its present activities owe much to a rich endowment of knowledge and expertise from Hohenheim University in Stuttgart, where the company is based. Founded in 2005, the company was able to draw on the significant research into Jatropha that had been conducted already by Hohenheim University under the supervision of Professor Becker. A foundation asset has been the germplasm collection initiated by Professor Becker and his team and built up over a 10 year period. The collection comprises some 800 accessions from diverse countries including the species region of origin, Central America. Today JatroSolutions is able to offer an international customer base proven seeds from two common toxic and two non-toxic commercial cultivars. Central to all its activities is a chain of 18 research sites spread across Asia, the Americas and Africa where selected stock are rigorously tested under diverse climatic, soil and agronomic conditions. Scientific research represents the very bedrock of JatroSolutions and this is expressed in both its breeding programme and its approach to the commercialisation of Jatropha products. The company has patented a solvent based process for the detoxification of Jatropha kernel meal, which it has demonstrated in production quantities of up to 100kg. JatroSolutions is in a collaboration to utilize Jatropha kernel meal for boosting the production of farmed fish, and it has entered into a number of associations to promote the use of CJO in the aviation sector. Its management blends experience established in very large German corporations with science drawn from leading research institutions. As a subsidiary of Energie Baden Wuerttemberg AG (EnBW), one of Germany's top three energy utilities, JatroSolutions has strong financial and institutional support for its activities. Looking ahead the company is proposing to establish a significant demonstration farm in Ghana as a platform for its rich botanical material and the fully integrated services it is able to offer prospective developers of Jatropha plantations.

Company

Established at the Entrepreneurship Centre, University of Hohenheim, JatroSolutions GmbH (JatroSolutions) was founded by Professor, Dr. Klaus Becker in 2005 as a spinoff from the research into Jatropha that had been conducted by the University under his supervision. Mr Klaus Tropf, Managing Partner of JatroSolutions, was a co-founder. The company is formed of two subsidiaries: JatroSelect and JatroGreen and its mission is to breed and make available superior cultivars and innovative agronomic techniques to support the development of economically viable Jatropha cultivation.The company and its founder Professor Becker were amongst the earliest pioneers of Jatropha breeding and research.

Objectives

Today JatroSolutions has a network of scientific, technological and industrial partners who support its Jatropha related international breeding and development activities. JatroSolutions is seeking to develop products, technologies and concepts that will enable the commercial exploitation of the as yet untapped and diverse potential of Jatropha. Moreover the company is researching innovative and sustainable solutions to cope with some of the major challenges of our times including the production of food and energy on degraded land. The company boasts one of the most advanced and comprehensive Jatropha breeding programmes in the world with a chain of breeding and research stations in 18 separate worldwide. JatroSolutions aims to produce lines of superior Jatropha cultivars with desirable commercial traits and strong local adaptability using science based breeding strategies and drawing from a rich germplasm collection.

Shareholders

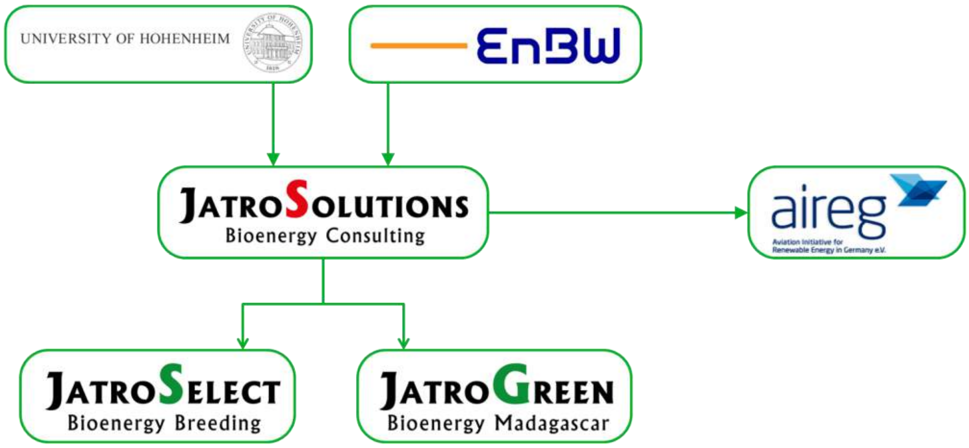
In 2009 Energie Baden Wuerttemberg AG (EnBW) acquired 49 % of JatroSolutions; in 2013 it increased the shareholding to 51%. EnBW, with a market capitalisation of Euro 6.9bn, is the 3rd largest of Germany's energy utilities. EnBW has 3 core business areas: Electricity, Gas, and Energy & Environmental Services. The Company has sales offices and subsidiaries in Germany and throughout central and eastern Europe. Originally held within EnBW's R&D division, the investment in JatroSolutions has been held within the Investments Division of EnBW since September 2014. JatroSolutions' management first reported to the Head of Research for EnBW, Prof. Dr. Wolfram Münch. In September 2014 JatroSolutions became a fully consolidated subsidiary of EnBW and in January 2015, EnBW appointed Mr Ralf Scholz-Pflug as Managing Director of JatroSolutions. The remaining 49% of JatroSolutions is owned by Professor Becker and Mr Klaus Tropf.

Structure

The company comprises two subsidiaries: JatroSelect and JatroGreen. JatroSelect GmbH (JatroSelect) is a wholly owned subsidiary of JatroSolutions focusing on the breeding of Jatropha varieties with valuable commercial traits. The company conducts performance tests of all origins in breeding stations in Asia (India), Africa (Madagascar and Cameroon) and Latin America (Argentina and Paraguay) and as a consequence JatroSelect is able to provide varieties suited to a diverse range of environmental conditions.

JatroGreen S.A.R.L. (JatroGreen) – was founded in 2007 as a German-Malagasy joint venture by JatroSolutions and Green Island Association, a NGO. This followed from the establishment of a project set up in 2004 following a request by the Government of Madagascar to Hohenheim University to establish small pilot Jatropha plantations on waste land in different regions across Madagascar. Some 300 ha of plantations were subsequently developed in the regions of Analamanga, Bongolava and Haute Matsiatra. In cooperation with EnBW, JatroGreen has been running a large research and demonstration project in Madagascar. In 2007 EnBW and JatroGreen began researching opportunities for the reduction of greenhouse gases.

The chart below details both the structure of JatroSolutions and its important relationships and partnerships.



Source: http://www.jatrosolutions.com/vision.html

Management Structure

- Professor, Dr Wolfram Münch, Head of Research & Development for EnBW, also heads the JatroSolutions Advisory Board. From this vantage point, Dr Münch has an important influence on the strategic planning and development of JatroSolutions and on the integration of the company's activities within EnBW's strategic approach to the development of renewable energies and the environmental impact of energy production on the environment. An alumnus of Heidelberg and Cambridge Universities, Dr Münch has led research programmes for diverse organizations include the Max-Planck Institute and Daimler Chrysler Group.
- Mr Ingo Peter Voigt, Senior Vice President, Head of Finance, M&A and Investor Relations for EnBW
    - Mr Voigt has ultimate responsibility and supervision of management and financial affairs of JatroSolutions on behalf of EnBW
- Mr Ralf Scholz-Pflug (EnBW appointee) - Managing Director of JatroSolutions
    - A supervisory, part-time role reporting to Mr Ingo Peter Voigt
- Mr Klaus Tropf as Managing Partner / Chief Operating Officer of JatroSolutions
- responsible for the strategic and operational leadership of the company's business development, international operations and day to day financial management
- Mr Sebastian Held – Prokurist
- Mr Held's role embraces the duties of financial controller, company secretary and general counsel.
- Dr. Juan M. Montes - director of the global breeding programme of JatroSolutions
- Professor Becker – Emeritus Senior Scientist.

Management Team

The company has a small management team under the day to day direction of Mr Klaus Tropf who combines deep experience of financial and legal responsibility within large scale corporations with a deep understanding of Jatropha research and development. He is supported by Sebastian Held with responsibility for both financial control and company secretarial functions and Dr Juan Montes as Director of the global Jatropha breeding programme. Additionally the breeding programme draws on the resources of a 5 person research & development group and the input of Emeritus Senior Scientist, Professor Klaus Becker.

Mr Klaus Tropf – Managing Partner

Mr Tropf, a co-founder of JatroSolutions, is currently managing partner of the company Mr. Tropf is responsible for the strategic and operational leadership of the company's business development, its global operations, finance, marketing and human resources management. After reading law at the University of Heidelberg, Mr Tropf first joined BW-Bank Mannheim, before commencing a near 30 year career with the Mercedes Benz group where he held a number of legal and finance related management positions.

Mr. Tropf is Treasurer to the "Aviation Initiative for Renewable Energy in Germany e. V." (aireg). He is also involved as an apiarist with a research project conducted by the University of Hohenheim, on the positive effects of beekeeping in Jatropha-cultivation. The practical phase of this project is being conducted at JatroSolutions 1000ha Jatropha farm in Madagascar.

Mr Sebastian Held – Prokurist

Mr Held's role embraces the duties of financial controller, company secretary and general counsel. His remit means that he has involvement with business strategy and the analysis and development of the Jatropha value chain. He joined JatroSolutions in 2011 after graduating with an M.A. in Finance.

Dr. Juan Manuel Montes- Director of Global Breeding

Dr. Montes studied agricultural sciences and specialized in corn breeding at the University of Buenos Aires, Argentina. After a period in a commercial corn breeding programme from the Limagrain Groupe in Spain, Dr. Montes continued his studies and obtained a M.Sc. and Ph.D. in plant breeding and applied genetics from the University of Hohenheim, Germany. As a post doctoral researcher, he researched strategies to breed corn hybrids for energy purposes. Dr. Montes has extensive experience in breeding strategy, cultivar development and optimization of breeding programmes. He has acquired the necessary skills to lead and manage the international scientific and technical teams of the global breeding programme. Re Montes has produced a number of scientific publications and has been responsible for a number of important cultivar developments.

Professor Dr. Klaus Becker- Emeritus Senior Scientist

Identified to be one of the world's most influential agricultural scientists by Thomson Reuters, Professor Becker was formerly CEO of JatroSolutions. He has now retired from the day to day management of the company, but he continues his involvement with it in the role of Emertius Senior Scientist, representing JatroSolutions at senior technical and scientific forums. Additionally he oversees worldwide desert projects designed by JatroSolutions to protect and upgrade the natural environment and to improve the quality of life of local populations. Professor Becker has been a distinguished pioneer of Jatropha related research and is widely regarded as one of the world's leading agricultural scientists. He has held the position of Professor and Head of the Aquacultural Systems and

Animal Nutrition Department in the Tropics and Subtropics, at the University of Hohenheim, Germany, since 1986.

Raised on a diversified livestock and grain farm in Central Germany, Dr. Becker earned his lower and diploma degree in Tropical Agriculture 1969 in Witzenhausen. After a 2 year period working with the German Development Aid Agency in Malawi, Dr Becker obtained a dual diploma degree in animal physiology and animal nutrition in 1974 and his PhD. in 1976 from the University of Göttingen. After a 2 year post-doctoral appointment, Dr. Becker became a Research Associate in the Department of Performance Physiology. His research focus during this time was on the energy metabolism of carp (Cyiprinus carpio L.) From 1983-1984 he was awarded the Max-Planck-Fellowship for studies in the Department of Zoology, Tel Aviv University, Israel. In 1985, Dr. Becker achieved the rank of Full Professor and Head of the Department of Animal Nutrition in the Tropics and Subtropics, University of Hohenheim. He held the position of Director of the Institute of Animal Production in the Tropics and Subtropics from 1991 to 2000. His specific scientific interests were focused on basic and applied fish energetics and nutrition as well as research on the use of low quality forages and by-products feeds for ruminants. From this area of focus, Dr Becker and his team developed an interest in secondary plant components in alternative feed and food resources from the tropics and subtropics.

Dr. Becker has authored or co-authored over 200 peer reviewed research papers, 9 book chapters and more than 250 abstracts and proceeding papers. He is member of several professional societies and editorial boards. Dr. Becker has conducted research projects in over 20 developing countries in Africa, Asia, Central America as well as in Europe and supervises senior scientists in advanced laboratory techniques encompassing in vitro and in vivo studies of rumen bacteria as influenced by feed quality and secondary plant compounds.

Research & Development Resource

A five person team of University of Hohenheim alumni supports the JatroSolutions research and development programme, spanning field data analysis, experimental research, project management and coordination and land acquisition.

The JatroSolutions breeding programme is also scientifically benefited from the deep reservoir of knowledge and expertise that has been established at the University of Hohenheim. Prof. Dr. Albrecht Melchingerm, a deeply respected name in the field of plant breeding science at University of Hohenheim, provides consultative advice to the programme. Professor Melchingerm collaborated with JatroSolutions on the company's initial breeding-concept, and helped to design the layout of the breeding programme itself. The company stresses that Professor Melchingerm is constantly available to provide an expert "second opinion" on all the critical decisions taken in respect of the programme.

Dr. Matthias Martin – Data Analysis

Dr. Matthias Martin holds a Ph.D in plant breeding and genetics from the University of Hohenheim, Germany. He investigated disease resistance of maize in field experiments and by use of molecular tools at the Institute for Plant Breeding, Seed Science and Population Genetics for three years, before joining JatroSolutions' breeding department, JatroSelect in 2011. His key responsibilities currently are coordination and data analysis of multi-location field experiments in the Jatropha breeding program.

Elisa Senger – Experimental Researcher

Elisa Senger M. Sc. Is a member of the breeding team located in Stuttgart, Germany. Her main tasks comprise the development of controlled pollination methodologies of *Jatropha curcas*, elucidation of the reproduction biology, and characterization of genotypes. She conducts scientific experiments in the field and greenhouses. She has a Master's degree in plant sciences of the University of Hohenheim. Elisa trained as an agricultural technical assistant at the plant breeding company KWS Saat AG (Einbeck, Germany) and as a researcher at the University of Hohenheim. She has published several scientific papers in the field of Jatropha breeding in high impact journals.

Dr. Brigitte Bohlinger – Project Management

Dr. Brigitte Bohlinger studied Agricultural Sciences at the TU München – Weihenstephan and at the University of Hohenheim, Germany. She obtained a Ph.D in plant production from the University of Hohenheim with focus on improving soil fertility in tropical areas of West-Africa by involving the indigenous fallow vegetation. After the research at the University she worked several years in Niger for a German development organization (DED), later as referent for 'Brot für die Welt' in Stuttgart responsible for projects in DRC. Her first association with JatroSolutions was in 2008, as coordinator for a research project on Jatropha cultivation in Madagascar, under the supervision of Prof. Dr. Klaus Becker. Since 2012 she has been a senior consultant to JatroSolutions with a primary focus on research services, feasibility studies, project establishment and management.

Lydia Probst - Project Coordinator

Lydia Probst Dipl-Agr. Biol. holds a diploma in Agricultural Biology from University of Hohenheim and has a practical agricultural background. Before her studies in Hohenheim, she worked as a farmer. Her interest in Jatropha developed while investigating the storability of Jatropha seeds in the course of writing her diploma thesis. Since 2011 Lydia Probst has been project coordinator at JatroSolutions. Besides activities in the field of Jatropha agronomy, she is also involved in cooperative research and development projects concerning the processing and use of Jatropha.

Gregor Heinrich – Land Acquisition

Gregor Heinrich M.Sc. was raised in Indonesia. He gained international experience in a research in in China and an internship in Indonesia. Gregor Heinrich majored in renewable raw materials and plant protection and joined JatroSolutions after finishing his studies at Universität Hohenheim. He is part of the JatroSolutions land acquisition team and the company's GIS-expert.

Jatropha Breeding and Research

The breeding programme has been established on a rich germplasm collection; some 800 provenances were collected by Dr Becker and his team. These accessions were collected over a period of 10 years from a very large number of countries including known centres of species origination in Central America. After genotyping each provenance, JatroSolutions took 150 common toxic accessions and 50 edible or non-toxic accessions into its core breeding programme. Each of these 200 accessions has been trialled in triple replications at all 18 of the company's experimental farm locations breeding stations in Asia (India), Africa (Madagascar and Cameroon) and Latin America (Argentina and Paraguay). The company stresses that the data collected from this in depth trialling under real agricultural conditions in diverse climatic and soil environments, provides the strong scientific underpinning of its development programme and commercial cultivars.

JatroSolutions addresses the market for common toxic cultivars and for edible, or non-toxic cultivars able to produce commercial harvests of feedstock for biofuels in degraded soils. For both classes of Jatropha cultivars the company's breeding objectives are set with its clients commercial requirements in mind. Objectives include to:

- Increase seed yield and yield stability across diverse climatic and soil environments and over the maturity period of the cultivar
- Increase the value of the seed
- Reduce the costs of:
    - crop production
    - harvest
        - by synchronizing flowering, increasing fruit retention and optimizing plant architecture.
    - post-harvest processes
- Increase value of the kernel meal by breeding high yielding cultivars that do not need to be detoxified for animal feeding.

Breeding for resistance against diseases and pests has reportedly acquired an ever greater significance within the company's main breeding objectives. Genetic improvement in the company's breeding lines is being continuously advanced to boost yield, improve quality and increase the tolerance and resistance of its cultivars to abiotic and biotic plant stresses and to strengthen water and nutrient use efficiency.

JatroSelect

JatroSelect is a plant breeding enterprise based in Stuttgart, Germany, and with breeding stations and testing sites in Argentina, Cameroon, India, Madagascar and Paraguay. JatroSelect's business is the domestication, breeding and seed production of Jatropha cultivars with improved traits to provide optimal economic outcomes for farmers. Molecular marker technology is applied to ensure that cultivars selected for commercialisation are genetically consistent with their performance specifications.

Source: JatroSolutions GmbH

The company supplies its Jatropha cultivars to an international client base, based on a cultivar range that has been bred for suitability in diverse climatic and soil conditions. All JatroSelect's materials have been tested in a large range of environments. Those selected for commercialisation are cultivars that have showed a consistent superiority in oil yield and stability under specific environmental and agronomic conditions.

Commercial Cultivars

All JatroSelect's commercial cultivars have been tested under diverse climatic, soil and agronomy regimes across the company's testing stations in Argentina, Paraguay, Cameroon, Madagascar and India. This has provided a wide range of field data to enable a thorough assessment of the potential productivity and commercial performance of these cultivars under different growing conditions.

JSPE101 – A common toxic variety, JSPE1010 is described as having a seed yield potential of 3 t/ha in well suited environments from its fourth growing season, thus giving up to 350% better productivity than wild stock. This cultivar has been developed for its broad adaptability and is superior drought tolerance. With an early flowering and fruit forming profile and good oil content at 34% plus, the plant is well suited for semi-arid environments.

JSPE102 – This common toxic variety has a recorded seed yield potential of 3 t/ha in well suited environments from its fourth growing season, and a relatively concentrated production period. Oil yields are indicated at up to 200% in excess of the performances of wild stock under the same conditions. Additionally the cultivar is described as being an early flowering and fruiting variety, with a robust constitution including superior resistance to leaf rust.

JSPE001 – Under good management this non-toxic cultivar is reported to have a seed yield potential of 1.5 t/ha in well suited environments from its fourth growing season. JatroSelect indicates that it can achieve 180% up to and above 250 % better yields than its wild peers. The variety is reported to have a shorter stature, a concentrated production period, a strong constitution and oil content in excess of 35%.

JSPE002 – Under good management this non-toxic cultivar is reported to have a seed yield potential of 1.5 t/ha in well suited environments from its fourth growing season. JatroSelect indicates that it can achieve 140% to 200% better yields than its wild peers. The variety is reported to have a shorter stature, a concentrated production period, a strong constitution and oil content approaching 36%.

Seed Production

Seeds are produced under what the company describes as "optimized agronomic management". The Jatropha fruits are hand harvested at the optimum stage of ripening and hand threshed immediately after harvest. The seeds are then dried to attain the most suitable moisture content for storage. The company's seed storage facility reportedly provides optimal conditions to maintain seed quality ahead of despatch to customers. Quality checks with molecular marker technology are performed to ensure the genetic purity of the material. Ahead of shipment to customers, the company checks the germination quality and early vigour of its seeds.

Services

JatroSolutions advises that it is technically equipped to translate concepts for integrated biofuel and animal feed production on wasteland into economic practice. As a leading breeding and technical services company in the Jatropha sector, JatroSolutions is well placed to provide a wide range of technical consultancy services including:

- Project feasibility studies
- Concept development
- Project establishment
- Project management
- Research services.

JatroGreen

JatroGreen has been operating a 1,000ha Jatropha demonstration and research plantation in Madagascar since 2007. The project serves as a platform for scientific research and development of management techniques. The socio-economic, ecological and economic aspects of Jatropha cultivation on wasteland are being studied on this project with the help of scientists from the University of Hohneheim.

The objectives of the project include:

- Production of plant oil and its use as substitute for fossil diesel and therefore to reduce greenhouse gas emissions
- Land reclamation: stabilisation of the soil against ongoing erosion and improvement of soil by establishment of Jatropha on degraded land
- Knowledge generation regarding Jatropha cultivation and commercialisation
- Generating labour and income in rural areas.

The Jatropha project in Madagascar has been a valuable source of agronomic know-how in Jatropha cultivation, processing and utilisation and has contributed to the technical competence of JatroSolutions.

Detoxification Technologies

JatroSolutions GmbH, and Prof. Dr. Harinder Makkar have been granted patent protection (Patent 2 229 820 registered in Germany under No. 60 2009 016 789.8) for the 'Detoxification of *Jatropha curcas* meal for feeding to farm animal species and fish'. The detoxification process is based on alkali (sodium hydroxide) and short chain alcohol (methanol), resulting in the removal of the toxic phorbol esters. The research behind the successfully patented process was conducted under the leadership of Prof. Klaus Becker and Prof. Harinder Makkar at the University of Hohenheim. The process has been demonstrated with the production of 100kg batches of detoxified meal.

The detoxified products have been extensively evaluated on a number of animal species including highly sensitive fish species. Studies have been conducted into the growth, physiological, biochemical and histopathological consequences of feeding the detoxified products to trial species. The detoxified Jatropha products obtained by the patent process have been found suitable to substitute soybean meal and fish meal in monogastric, ruminant and aquaculture feeds including fish and shrimps. The studies have been peer reviewed and published in accredited international journals. JatroSolutions maintains that the use of a large scale detoxification process is feasible with immediate effect.

The FAO provided data in 2010 to demonstrate that fish accounted for 17 % of globally consumed animal protein, providing more than 1.5 billion people with almost 20 % of their average per capita intake of animal protein. In 2013 the FAO reports that aquaculture contributed 40.1 % to the world total fish production. To meet growing demand and to ease pressure on wild stocks there will need to be an increase in the production of species such as carp and tilapia. JatroSolutions has been cooperating with the Johann Heinrich von Thünen Institut in feeding experiments (both laboratory and field trials) with tilapia and carp, analyzing growth and digestibility of different diets containing detoxified Jatropha kernel meal. JatroSolutions GmbH has provided the detoxified Jatropha kernel meal in quantities ranging from laboratory production up to industrial quantities. To meet growing demand for fish protein and to reduce pressures on wild stock the aquaculture industry will require the supply of low cost protein feeds; nutrition represents 40% – 50% of the production cost of farmed fish. Non-toxic or detoxified Jatropha kernel meal (JKM) represents a possible solution.

Partnerships & Collaborations

Greasonline GmbH

In 2014 JatroSolutions entered into a cooperation agreement with Greasonline GmbH. Greasoline is a spin-off from Fraunhofer UMSICHT in Oberhausen, Germany. It has developed an alternative technology for refining biokerosene (refinery) for use in the airline sector, in competition with Neste technology –

the current market leader. The Greasoline® process converts bio-based oil, fats and fatty acids, both unused and used, into fuels, fuel components and fuel gases. Unlike biodiesel and bio-ethanol, the liquid products contain no oxygen. Thus, they can be used for drop-in biofuels that act just like fossil fuels in handling, storage and application. JatroSolutions will be supplying Greasonline with CJO for refining as biokerosene.

aireg e.V

The "Aviation Initiative for Renewable Energy in Germany" (aireg e.V.), was founded in June 2011. The initiative to promote renewable energies in aviation, comprises 20 German research institutes, aviation businesses and bioenergy producers. The association sees itself as a platform for promoting science and research in the area of climate-friendly aviation fuels with the overriding emphasis on sustainability. The initiative aims to promote the use of regenerative energy sources in Germany and create a sound basis for political decision-making with regard to the introduction of climate-friendly aviation fuels.

JOil (S) Pte Ltd

JOil is a crop science company with an exclusive focus on Jatropha species and principally *Jatropha curcas*. Over a period of 9 years the company and its partner and shareholder, Temasek Life Sciences Laboratory have established a set of enabling technologies aimed at regenerating and transforming *Jatropha curcas* for commercial cultivation. JOil, backed by a group of powerful international industrial shareholders, is a science led organization. With the development of both breeding techniques and innovative enabling scientific techniques the company has produced a portfolio of Jatropha breeding materials and supporting technical services. The company boasts a seed bank with immediate availability to plant 20,000 ha and it has embarked on a pilot project in Burkina Faso to demonstrate the agricultural and economic feasibility of a commercial Jatropha plantation. JOil has built a reputation for leading edge Jatropha crop science centered on molecular biology, gene technologies and agronomy. With some 20 peer reviewed publications and 13 patents pending or granted, JOil and its partner TLL, have established a wide body of Jatropha related IPs.

Company & Management

JOil is a research & development organisation focused on the breeding & development of commercial varieties of Jatropha and the development of certain enabling technologies to breed & propagate the plant for large scale commercial cultivation. Headquartered within the National University of Singapore, JOil is a joint venture private limited company.

The initial phase of the Jatropha related R&D programme that is today at the heart of JOil's activities was commenced in May 2006 and involved 6 research groups within Temasek Life Sciences Laboratory (TLL) involving more than 25 researchers. When JOil was formed in 2008, the TLL technology developments were injected into the new company although TLL continued with Jatropha biotechnology research, supported by JOil. TLL is a JOil shareholder. JOil has an exclusive R&D collaboration with TLL to conduct upstream research on Jatropha plant biotechnology for production of Elite Jatropha, with JOil having an exclusive global license for the patents developed under this programme. For the first phase of its development [2008-2011], TLL operated with a team of 25 full time researchers, with 9 in the second phase [2011-2013], but the team has reduced to 4.5 FTEs in the current phase of its development [2013-2015] as several goals and milestones had been achieved sooner than expected.

Management

JOil is organised around its research & development focus with its management team reporting to a Board comprising representatives from JOil's shareholders. The management team comprising two senior scientists and a financial officer, and it controls a technical team of 7 doctorate level scientists. The combined scientific and management resource is supported by a Scientific Research Committee comprising senior research scientists, & industrial scientists. The senior management team includes:

- **Dr. Hong Yan, Chief Scientific Officer** – joined JOil in 2008. He has a background in biological science training (PhD, Chinese Academy of Medical Sciences, 1989) and business studies (MBA, National University of Singapore, 2001). He has led an independent research group in the Institute of Molecular Agrobiology since 1998 (later in Temasek Life Sciences Laboratory) on translational plant research areas like biotech crop development, forestry biotechnology, herbal medicine, bio-energy plants and new technology development. He has 8 patents and many peer reviewed publications to his credit. Dr Hong Yan is also an adjunct Associate Professor with Nanyang Technological University (NTU).

- **Dr. Srinivasan Ramachandran, Chief Technology Officer** - obtained his PhD in Biochemistry with Plant Molecular Biology as specialization from University of Idaho, USA. In 1993, he joined Prof Nam Hai Chua's group at the Institute of Molecular and Cell Biology, later at the Institute of Molecular Agrobiology, Singapore. He headed the group of Rice Functional Genomics at Institute of Molecular Biology since 2001 and since 2002 at Temasek Life Sciences Laboratory. Also since 2007 leading a group at the Center for Bioenergy Plants, at Institute of Botany, Chinese Academy of Sciences, Beijing, China. He has several peer reviewed publications and patents to his credit.
- **Srinivasan Sriram, Chief Financial Officer** - has an MBA in Finance and has worked with the Tata Group in India for more than 14 years before being seconded to JOil in September 2009, as GM (Strategy & Marketing). Before moving to JOil, Sriram was heading the biofuels division of Tata Chemicals Ltd., and was instrumental in setting up various agro-climatic research sites for Jatropha in India and Africa. His expertise is in finance, strategy and marketing.

Shareholders

JOil has an impressive shareholder list. Included amongst its largest and most influential shareholders are the three organizations detailed below.

Temasek Life Sciences Laboratory (TLL), a beneficiary of Temasek Trust, is a non-profit organization established in 2002 to undertake frontier research in molecular biology and genetics utilizing a broad range of model organisms. Affiliated to both the National University of Singapore and Nanyang Technological University, TLL has some 220 researchers and is working to develop the biotechnology industry in Singapore through collaborations and joint research ventures with local & international partners. Temasek Life Sciences Ventures Pte Ltd is an investment holding company whose mission is to commercialize life science technologies and intellectual property including those developed by Temasek Life Sciences Laboratory Ltd (TLL).

Tata Chemicals Limited is a global company which states that it has "interests in businesses that focus on LIFE: Living, Industry and Farm Essentials". The company is the world's second largest producer of soda ash with manufacturing facilities in Asia, Europe, Africa and North America. Tata's industry essentials product range provides key ingredients to some of the world's largest manufacturers of glass, detergents and other industrial products. With its farm essentials portfolio Tata Chemicals has emerged as a supplier of crop nutrients in India. It is a leading manufacturer of urea and phosphatic fertilisers and it is developing a business in crop protection. The Tata Chemicals Innovation Centre is focused on research & development in the fields of nanotechnology and biotechnology, and the company's Centre for Agri-Solutions & Technology provides advice on farming and crop nutrition practices. Tata Chemicals has a market capitalisation of $1.5bn.

Toyota Tsusho Corporation is the product of a merger, in April 2006, between the Toyota automotive business and Tomen, which had developed a wide range of business and customers outside the automotive sector. The new Toyota Tsusho group combines a global network and trading activity underpinned by a successful manufacturing culture. Listed on the Tokyo Stock Exchange it has a market capitalisation of some $7.6bn.

The Research & Development Programme

TLL had focused on 3 broad research platforms:

1. Development of enabling technologies
2. Identification of commercially valuable genes in Jatropha species
3. Development of gene modification technologies for developing commercially valuable Jatropha varieties.

Source: JOil (S) Pte Ltd

Enabling Technologies

Enabling technologies are defined as inventions or innovations that can be applied to drive radical changes. TLL developed a suite of technologies to "regenerate & transform" Jatropha species. These technologies were aimed at permitting the expression of target genes as required to underpin the commercial viability of the crop, several tissue and development stage specific promoters that will enable expressing of target genes in a specific area at a suitable time were also characterized and routinely used. For quick evaluation of commercial potential of genes, a cost effective and quick system for Jatropha gene function analysis was also developed. Together these technologies enable TLL/JOil to develop GM Jatropha varieties in an efficient manner.

Gene Identification

This entailed the development of gene function analysis to produce a cost effective & timely system for the evaluation of specific genes for their commercial usefulness. In particular there was a focus on those genes critical for the synthesis of Jatropha oil, toxins and those for flower development. These genes were targeted to generate commercially important traits in Jatropha. Examples include targeting genes critical to Jatropha oil synthesis and flower development to modify fatty acid composition and timing of flowering, tuning a transcription factor serving the role of a master switch toward more oil biosynthesis in seed. Seed toxins curcin and phorbol ester biosynthesis genes have also been cloned and their functions verified. Interception of these genes leads to development of low toxicity Jatropha. It should be noted that targeting its own gene and use Jatropha derived promoters not only fine tune gene expression with high level of precision in timing and location, but also alleviate concern of undesirable side effects (pleotropic effects) due to foreign gene expression in unnecessary parts of the plant.

Gene Technologies

TLL has developed a GM Jatropha variety that produces oil with high oleic acid content (up to 75% of oil content as compared with up to 45% found in non-GM varieties) in seed. This high oleic acid GM Jatropha was achieved by down regulating a *Jatropha curcas* desaturase gene in a seed specific manner. High oleic acid Jatropha oil is expected to yield higher quality biodiesel (high cetane number) with better oxidation stability. A single copy, homozygous transgenic line free of antibiotic marker gene was identified and JOil obtained permission from the government of Singapore for an open field trial of this GM Jatropha event, the first of its kind in the world. JOil expects to release its high oleic acid GM Jatropha for sale in 2016.

Other achievements include

Higher oil content

Through silencing of a triacylglycerol lipase. Based on the findings in the model plant Arabidopsis, that such genes are negatively correlated with accumulation of oils in seeds, a Jatropha gene with a similar function was characterized and targeted. GM Jatropha with this gene silenced, resulted in 13%-30% higher storage lipid in the seed with concurrent reduction of free fatty acid (FFA) content. This work is considered to be a breakthrough in breeding for higher oil content Jatropha. We understand that other two genes are also being modified for higher oil content with similar or better success. Such developments could have important benefits for the economic viability of Jatropha as a commercial oil seed crop. It should be noted that these data, first released in a peer reviewed journal publication, are only proof of concept work and are based on just a few plants managed under greenhouse conditions. It remains to be seen how these indications of significant seed oil content enhancement can be improved under actual commercial farming conditions.

Insect resistance in Jatropha

TLL also reported generating insect resistance by introducing a modified Bt gene, as an adaptation and extension of the successful technology of engineering Bt protein for controlling insects in many crops like rice, corn, canola and soybean. It is now well recognized that Jatropha is also susceptible to various insects. This Bt Jatropha is found to be effective against leaf rolling larvae of tortrix moths.

Virus resistance in Jatropha

Virus is among the most serious pathogen problems of Jatropha. A whole plantation can be devastated by a virus outbreak. Jatropha is susceptible to gemini viruses that are present in Jatropha relatives such as cassava and castor, making it difficult to control. TLL sequenced the Jatropha virus genome and successfully engineered virus resistance by silencing five viral genes. Such virus resistance was proven durable and inheritable. Moreover, such plants are cross protected against closely related virus species, probably due to multiple gene targeting. This is thought to be the first pathogen resistance Jatropha ever developed. We understand JOil is in discussions with other significant crop science companies for collaboration on the further development of this GM trait, with the objective of bringing virus tolerance from lab to field in soonest time possible.

Interception phorbol ester biosynthesis for non-toxic Jatropha

Jatropha meal value will be significantly boosted if phorbol ester (an epidermal cell irritating and tumour promoting compound present mostly in common toxic variety Jatropha seeds) can be eliminated from seeds. With much work on genomics and genetics, TLL/JOil identified a key gene involved in phorbol ester biosynthesis and managed to silence its expression in the seed. They then developed a few lines of Jatropha with significantly reduced phorbol ester fractions (up to 90%, non-published data). This could provide the basis for a new strategy to solve toxicity. The technology needs to be further improved to achieve Jatropha totally free of phorbol ester content in the seed and then regulatory approval will be required to certify the safety of this genetically engineered Jatropha meal for animal nutrition.

These developments suggest that the TLL/JOil group has established a set of valuable enabling technologies and a useful pipeline of gene technologies for commercial development. It is important to note that TLL/JOil are concentrating on cisgensis and intragenesis strategies – genetic modifications with a gene and regulatory fragments from the same species or related species, in contrast to transgenesis which deploys DNA sequences from any organism. Regulatory clearance for gene technologies based on intragenesis strategies are considered to face lower hurdles and this may be further eased by the fact that this is deemed a non-edible fuel crop. The challenges for JOil include finding mechanisms to:

- prioritize traits that have the greatest chance of gaining regulatory clearance in Singapore and in target international markets
- sustain funding for the possibly extended process of transitioning GM Jatropha from the laboratory field into a commercial application.
    - In pursuit of these goals we suspect that the company will be looking to explore a number of collaborative and risk/reward sharing structures.

Breeding Programme & Strategies

The JOil research & development team includes 8 fulltime members with PhDs in disciplines ranging from molecular biology, biochemistry, plant breeding techniques, agronomy and plant biotechnology. The technologies which are at the core of the company's endeavours include:

- Traditional breeding for development of elite varieties of Jatropha
- Development of propagation technology
- Hybrid seed technology
- GM field studies.

JOil operates a core breeding farm of some 1.2 ha in the Northwest of Singapore, also three breeding stations in Coimbatore State of Southern India and one station in central Java, Indonesia. These three geographic areas/ five stations together cover wet tropical and dry tropical climates, including sandy to clay soils.

Initial breeding materials are generated in Singapore and distributed to India and Indonesia for further breeding and development and in particular for better local adaptation, or special breeding projects. Examples include drought tolerance breeding that is conducted mainly in India and root rot resistance breeding which takes place in both India and Indonesia.

Once a good candidate is identified, field trialling is conducted in more than two areas. Once a candidate for commercialization has been confirmed, more extensive field trialling will be conducted in more regions/stations to confirm the specimen's superior traits before commercial launch. JOil also conducts field trials in target markets on short term leased land or through collaborations with its shareholders or other commercial partners. Over the years, JOil has conducted field trials of its new varieties in India, China, SE Asian countries, Egypt, Kenya and Mexico. The company's JO S1 and JO S2 are well tested seed derived varieties demonstrating a crop potential of >2mt/ha of dry seeds in the first year and 4-5mt/ha in the third/ fourth and onward years. Recently, JOil published a peer review paper detailing how it developed JO S2 through multiple generations of selection and its field trial in Southern India, complete with field agronomic data. The company currently has in its cold storage warehouses sufficient seeds of JO S1 and JO S2 to plant 20,000 ha, all for immediate delivery.

Breeding Strategies

JOil has employed two breeding strategies: intra-species breeding and inter-species breeding, with the latter methodology being more difficult as it typically results in sterile (mule) offspring.

Intra-species breeding involves the pollination of female *Jatropha curcas* flowers with pollen of the same species. The intra-species breeding programme aims to create better seed varieties with good field uniformity, higher seed productivity and better local adaptation. It starts from crossing desirable parental plants followed by a few rounds of field selection. One objective is to create plant varieties combining the higher productivity of the JOil commercial varieties with the location specific suitability of the native accession. Such crosses are likely also to enjoy the hybrid vigour that typically results from crossing two distinct accessions; the downside risk is that it takes multiple generations to generate a new variety with uniform field performance.

Inter- Species / Introgression Breeding - is the movement of genes from one species into the gene pool of another by generating F1 hybrid followed by a few rounds of backcrossing. Inter-specific breeding or introgression has the advantage of broadening the gene pool of *Jatropha curcas* and introducing possible new traits.

Managed introgression is a long-term project with no certainty of outcome. JOil has worked on this approach to develop a pipeline of promising hybrids. Two examples are its JO-H2 and JO-H3 lines. These are third generation back cross hybrids between *Jatropha curcas* and Jatropha Integerrima. The hybrids are compact in size with strong branches and a high female: male flower ratio. Clones of these hybrids have gone through multiple site field trials with good performance. JO-H2 and JO-H3 inter-specific hybrids are ready for launch and will be the first such plants to be commercially released.

Also in the pipeline are hybrids with good drought tolerance and those with good tolerance to root rot disease, two very desirable traits. JOil is especially excited by one compact hybrid with what it describes as "very profound fruiting" and good seed productivity in the first growth season. The company believes this hybrid could be a candidate for annual cropping at high density.

Marker Assisted Breeding

JOil together with TLL published the first Jatropha genetic map with 506 genetic markers after analysis of two backcrossing populations derived from fertile F1 interspecies hybrids (J. curcas x J. integerrima) [Wang et al. 2011. A First Generation Microsatellite- and SNP-Based Linkage Map of Jatropha. PLoS ONE 6(8): e23632)]. After that, they reported linkage of markers with some important traits like fatty acid profile, oil content and growth rate. JOil currently makes use of >1,500 genetic markers to map important traits, assist its breeding and track its breeding populations and new varieties developed.

Varietal Performance

From the breeding programme JOil has developed open pollinated varieties (OPVs) and intra- and inter-specific hybrids. Some of the varieties have been subjected to field trials in India, Indonesia, and ASEAN region and are now commercialized. Several of these varieties are under field trials in India and other locations for commercialization in due course. The open pollinated varieties JO-S1, JO-S2, JO-S3, and JO-S4 have been field tested and are ready for commercialization. Several intra- and inter-species hybrids including JO-H1, JO-H2 have been 'micro-propagated' using JOil's proprietary tissue culture technology and field trials of these varieties are now underway.

OPVs – JO-S1, JO-S2, JO-S3 and JO-S4

JOil is actively conducting performance trials of four OPVs: JO-S1 to JO-S4 in India and Indonesia. JO-S1 and JO-S2 are reported to have yielded an average of 2mt/ha dry seeds in year 1, 3mt/ha in the year 2 and 3.6mt in year 3. Fourth year yield indications suggest that 4mt/ha may be achievable. These two varieties have been released for commercial cultivation and are available for sale with sufficient seed to plant 20,000ha. The temperature range in the regions in India where these trials were conducted was 20^0 to 36^0C during the trial period and with mean average rainfall 750 mm. During the dry spell, plants were irrigated with water based on perceived need. Currently JO-S3 and JO-S4 are undergoing field trials in preparation for commercialisation. These two varieties are reportedly showing yield increases of up to 20% compared to the JO-S1 and JO-S2. Commercial seed orchards for these two pipeline varieties are being established and planting materials will be available for large scale plantation development from 2016.

Inter-specific and Intra-specific hybrids

JOil is constantly seeking to introduce variability into the breeding populations. Potential hybrids are put through field trials in Southern India. Among several intra- (*Jatropha curcas*) and Inter-specific hybrids (*Jatropha curcas* vs *Jatropha interigemma*), JO-H1, JO-H2, JO-H3, and JO-H4 were selected for field trials in India based on initial trial data from Singapore. The first year trials for these hybrids indicated overall seed yields better than that of seed derived varieties. The three hybrids (JO-H2, JO-H3 and JO-H4) with interspecific backgrounds, reportedly produced 1410 g to 1729 g on a per plant basis in the first year. These hybrids are also reported to have desirable agro-economic traits such as strong self-branching, early flowering, more female flowers per bunch, shorter inter-nodal length (less number of leaves between bunches), and shorter plant canopy compared to open-pollinated varieties. Since the seed derived offspring from these hybrid plants will be highly segregating in plant characteristics and seed yield, these varieties are being produced by tissue culture in Singapore and by 'OEM' partners for further trials and commercialization.

Desirable Traits

JOil is continuously seeking to strengthen its library of germplasm (gene pool) and to widening the genetic base for identification and selection of lines with tolerance/resistance to biotic and abiotic factors.

- A few *Jatropha curcas* lines that have proven resistant to powdery mildew disease (causal pathogen is fungus from Erysiphae family), are being used extensively as donors for transferring the mildew resistance trait into potentially high yielding varieties and hybrids.
- In addition, one more fungal disease which is more serious and can wipe off the entire plantations is root rot and several breeding populations were under screening for this disease in root rot hot spots and JOil has also identified a few lines showing tolerance to 'root rot' fungal disease. It is proposing to 'introgress' this trait into the high yielding field tested varieties of JOil.
- JOil is in the process of identification and selection of potential drought tolerant candidates for further screening and selection.
- To suit certain geographic locations with pronounced dry and rainy seasons, Jatropha varieties (similar to annual crops) have been developed. It is proposed that these can be grown during the rainy season and then during the dry season fruits can be harvested and the plants can be removed for biomass production. Since they are shorter statured plants with a small canopy, the number of plants can be increased for a planting density in excess of 5,000 plants/ha.

Propagation Technologies

For high value, inter-specific hybrid plants with complex genetic profiles (such as JO-H2 and JO-H3), planting with seeds will likely result in profound genotype segregation among progenies and hence poor uniformity in field performance. JOil/TLL has developed a proprietary tissue culture technology for commercial production of clonal varieties. This scalable and well tested technology has been internalized by its tissue culture subsidiary PT Monfori Nusantara (www.monfori.com). One business strategy for JOil is to license its tissue culture technology to OEM partners. The OEM partners are supplied with explants or young plants in culture, pre-formulated media and practical training. JOil will then buy back shoots suitable for rooting, or hardened seedlings ready for planting out. This model has been tested on small scale orders with OEM players in India, China, Thailand and the Philippines.

The value of tissue culture technology is that it allows for the speedy commercialization of high performing hybrid plants that cannot be duplicated by seeds. While costlier than seeds, it is promoted as an efficient means of delivering large volumes of plants with guaranteed performance profiles due to the nature of true-to-type cloning. The commercial viability of tissue culture Jatropha varieties will depend very much on being able to prove their additional value added over seed derived varieties. At the moment, smaller size with similar or higher single plant seed productivity within a short plantation season are best value adding traits of such hybrids. JOil is also working to lower production costs. Uncertainty regarding multiple year performance of such varieties is another issue. As we comment elsewhere in this report, for a perennial plantation, Jatropha cultivars need to be monitored from planting to maturity, perhaps a minimum period of 5-8 years, before the plant's lifetime yield curve can be accurately assessed. JOil, like many of its peers, only has 3-4 years of data for its most recently released and best performing cultivars. The absence of long term yield curve data might not be critical if high performing varieties are used instead for short rotation or even annual cropping.

Hybrid seed technology

Hybrid seed technology is widely utilized for commercial crops for 1) better productivity (heterosis, better performance than any of the parents) 2) tight technology control since seeds harvested from hybrids are not suitable for next season planting. It is also an efficient technology to produce uniform plantation materials. However, good hybrid seed technology takes time to develop with the following key components:

1. Developing distinct pure line elite varieties
2. Development of plants without male flowers or having male sterility and transferring male sterility to elite varieties, which will be used as a female parent for seed production
3. Test combining ability between parents
4. Field trialling for hybrid seed performance under various climatic environments.

In the process of Jatropha breeding, three male sterile lines were developed by the JOil breeding team. The most promising line has the male sterility characteristic controlled by a single recessive gene, as confirmed by genetic analysis in progenies. This was used to generate 20 F1 hybrid seed populations with other good accessions or pure Jatropha varieties as male parents. 10 of these hybrid populations went through one year random block design field trialling in 2013/2014. Two hybrid populations showed good growth, uniformity in field and better seed productivity (hybrid vigor) than both parents, also producing significantly higher results than seeded varieties. These promising hybrid populations are now under multiple field trials while JOil is in the process of producing commercial hybrid seeds. JOil targets to launch its first batch of hybrid seed varieties in 2016.

GM Jatropha and field studies

Based on the current regulatory framework, any GM variety must undergo field trialling for comprehensive data collection to address various concerns including:

- product safety
- field performance of GM plants
- stability of the transgene and encoded trait
- possible gene flow to non-GM Jatropha and related weeds
- possible environmental impact.

JOil is the first company to conduct a GM Jatropha field trial. It has established a purpose built 1.4 ha site in a well separated island, off the coast of Singapore. The intention is to collect comprehensive data on field performance and the genetics of GM Jatropha before applying for a commercial release of this GM Jatropha in Singapore. The company will then seek approval in other countries. This GM event with high oleic acid content per seed, involves tuning down an endogenous gene, but without the introduction of any exotic genetic information and without the use of antibiotic markers. This gene modulation will be enabled by using the intragenesis methodology. JOil reports that there has been intensive discussions regarding a more relaxed regulatory regime for new plant breeding techniques including intragenesis. The company will be hoping that its unique GM Jatropha will benefit from a more relaxed regulatory regime for intragenesis GM products.

In the event that intragenesis techniques are able to gain approvals under lighter regulatory regimes, a combination of GM and traditional breeding may lead to the 'stacking' of several important agronomical traits for the development of a superior Jatropha variety with high yields of oil/ha, better quality of oil characteristics, disease resistant and possibly drought resistant as well.

Processing technology to detoxify Jatropha meal for animal nutrition

JOil has been working on three strategies for the commercialization of Jatropha kernel meal as a component in animal nutrition.

- It has announced the development of a new *double solvents extraction system* that can reportedly achieve oil extraction from seed meal and partition phorbol esters away from the protein meal in a single process.
    - JOil reports that protein meal derived from this process contains non-detectable levels of phorbol esters.
- Based on its findings that phorbol esters in the soil are degraded by sunlight, JOil has developed a proprietary system to detoxify phorbol esters by short wave UV irradiation.
    - It is deemed to be an attractive approach due to assumptions made about:
        - Capital investment required

  - Ease of integration into an industrially scaled production system
- In collaboration with TLL, JOil has been researching the scope to 'silence the genes involved in the biosynthesis of phorbol esters.

TLL and JOil report that they have identified a key gene involved in the biosynthesis of phorbol esters in Jatropha seeds. Furthermore their research indicates that they have developed techniques to 'silence' the expression of the gene. Unpublished research data indicates that phorbol ester content has been reduced by up to 90%. The technology needs to be further developed to produce plants yielding seeds with zero phorbol ester content and it needs regulatory clearance – but it may represent an important tool in the development of commercial Jatropha.

Commercialization

JOil has established itself as a biotech company focusing on the scientific development of *Jatropha curcas* through breeding, GM, tissue culture and agronomy. The company has developed high quality Jatropha planting material for commercialization and it has established a set of 'best planting practices' to support the new agro-industrial plantation developers that it is targeting as clients.

The current product portfolio includes the following products & services:

A. Open Pollinated varieties: JO-S1 & JO-S2
B. Hybrid varieties: JO-H1
    i. These three varieties are offered with traits said to include early fruiting (for early project returns), and improved yields (on wild stock).
C. Consultancy & Services
    i. Including a customized agronomy practices manual.

JOil has developed a two-pronged approach for commercialization of its IP.

1. **Develop as a Planting material, Agronomy & Technology Player**: JOil will continuously develop and improve its current line of products & services including:
    a. Improved hybrid varieties
    b. GM Jatropha
    c. Technology development
    d. Build Plantation knowledge base.

The products and services under this option would include the following:

A. **Open Pollinated varieties**: JO-S3 & JO-S4 (20% more yield than S1 & S2)

B. **Hybrid varieties**: JO-H2, H3 etc. (Short stature, higher planting density – elite hybrid through TC); JO-HSB1, HSB2 etc. (elite hybrid through hybrid seeds technology)

C. **GM Jatropha**: With standalone or stacked traits including high oleic acid content, disease resistance, higher oil content and low toxicity

D. **Technology Licensing** including:

   i. tissue culture propagation technology, hybrid seeds technology, kernel meal detoxification technology

E. **Consultancy & Services**: Customized Agronomy Practices manual, pre-plantation consultancy & feasibility studies, plantation management consultancy, comprehensive lab analytical services.

2. **Operate as an Integrated Value Chain Player**: through participation, both direct and indirect, in the production of Jatropha Oil, Seed cake, Animal Feed, Briquettes, Biodiesel, Bio jetfuel, Glycerin and intercropping. JOil has developed what it describes as a robust modular agro-forestry model that would follow the nucleus plasma plantation model for implementation. Modules would be developed in partnership with local communities thereby serving to meet both their food and energy needs. A number of these models are planned to be implemented in regions including Africa, Indo-China and Brazil. Such modules could be developed either by:

   A. JOil itself, wherein JOil will fund and implement such projects

      a. To demonstrate the concept, JOil is establishing an initial plantation for potential scaled expansion in Burkina Faso.

   Or

   B. Participating in a consortium wherein JOil will contribute its expertise and know-how including planting material and agronomy practices. Other partners in the consortium might include:

      a. land owners with local knowledge
      b. plantation management companies
      c. refining technology players
      d. oil sector companies
      e. airlines
      f. financial investors.

Burkina Faso Project

JOil has been conducting trials on Jatropha varieties successfully in India, Singapore and Indonesia. To provide a scaled demonstration of the commercial cultivation of Jatropha, JOil is now working to develop a working demonstration model. Such projects are intended to form a platform for an entire Jatropha value chain with practical demonstration of commercialization of all Jatropha products including oil, kernel meal and biomass.

JOil has specified the following objectives:

1. Establish a 1000 ha working Jatropha plantation as a demonstration unit for potential Jatropha plantation developers and prospective customers for JOil's seed technologies, plantation and agronomy services
2. Validate the commercial use of products and by products of Jatropha

Criteria for selection of demonstration site / region

- Availability of contiguous patches of flat to gently undulating land
- Suitability of climate
- Internal market for Jatropha products
    - Import dependency for fuel and energy requirements

- Burkina Faso is a landlocked country with no oil reserves
- Availability of agricultural labour at economic rates
- History of Jatropha cultivation.

Source: JOil (S) Pte Ltd

Climate in Burkina Faso: Burkina has a dry tropical climate. It is under the seasonal alternation of moist air from the monsoon coming from oceanic high pressure and dry air from the Sahelian latitudes. The characteristics of climate include:

- Two marked seasons: rainy and dry
- A unimodal rainfall curve
- A dry season which is at least as long as the rainy one
- A total absence of a cool season (the annual minimum monthly temperature is > 18^0 C).

The JOil site was selected in the southern part of Burkina Faso because the aridity increases towards the northern part, thereby increasing the demand for water exponentially. It is to be noted that no cultivation is happening in these regions and chances of these lands succumbing to desertification is high due to progressive climate change. The development of Jatropha plantations in these regions will it is hoped reverse or hold in check this pattern. Jatropha plantations can also be useful in preventing run-off and consequential erosion during the wet season, allowing more water to percolate in to the ground thereby increasing the water table.

Site Selection: A total area of 354 ha has been leased from a local company of which some 200 ha have been identified as suitable for growing Jatropha (land assessment conducted by JOil teams from Indonesia and India). The site is located exactly 3.9 km from a main road.

- Site selection criteria included:
  - soil condition and depth
    - As the soils in the region are of average depth, any soil above 30 cm was considered suitable and others discarded

- climate
  - Burkina Faso has a suitable climate for Jatropha and Jatropha was found to be growing well in the area
- manpower availability.
  - The site location is 3 km from a population of more than 3,000 people ensuring all year labour availability.

Current Status of the project:

The planting of the first blocks was initiated in August 2014 and completed by November 2014. A total area of 40 ha has been completed at a spacing of 4 m between rows and 1.5 m between plants.

Source: JOil (S) Pte Ltd

The entire area of 40 ha is divided into 7 blocks, for ease of management and irrigation. The plants are growing well and they have begun to flower and produce fruit. To date there has been no recorded incidence of pests and diseases.

Irrigation is provided by way of tankers and tractors, once every 10 days with 5-7 litres of water per plant. Lake water is used to a small extent by local communities for domestic purposes (cattle and cleaning) only. Drawing water from this lake for the Jatropha plantation does not create any shortage for the communities as it is completely replenished by the rains. Further, this water is not used for irrigation by the communities as they practice rain fed agriculture. Moreover, JOil intends to do intercropping with food crops thereby helping the agricultural economy of the region hence making it sustainable.

General maintenance and supervision (including irrigation, cleaning, weeding and inspection for pests and diseases) is performed by a team comprising:

- 1 Manager
- 4 Supervisors
- 23 agricultural labourers.

Plantation JV

Another demonstration plantation for potential large scale development is being established in India along with CREDA – HPCL Biofuels Ltd. It is a joint venture company between Chhattisgarh Renewable Energy Development Agency (CREDA) and Hindustan Petroleum Corporation Limited (HPCL).HPCL is an Indian PSU engaged in the business of refining of crude oil, manufacturing, processing, and distribution and marketing of petroleum products. CHBL was formed to undertake Jatropha cultivation on marginal lands in Chhattisgarh, India and is interested in the production of bio diesel from Jatropha. The land and investment capital is being provided by CHBL, while JOil is contributing planting material, technical expertise and plantation development and maintenance services.

Successful Development of a Jatropha Technical Guideline (TG)

JOil reports that Singapore has become the first country in the world to accept an application for Jatropha Plant Breeding Rights after the development of a Jatropha Technical Guideline (TG) with JOil's assistance.

In 2013 the government of Singapore included *Jatropha curcas* under its 'protection list' and commenced to accept applications for Plant Breeder Rights for new Jatropha varieties (more details can be found at www.ipos.gov.sg). This marked the beginning of legal protection for new Jatropha varieties in Singapore, and addresses concerns about IP protection. According to JOil a number of countries include *Jatropha curcas* under their protection lists in principle but because they do not have a Jatropha TG including a *morphology chart* on how to describe a Jatropha variety, they are prevented from confirming new Jatropha varieties and granting their owners/developers, Plant Breeding Rights. With the collaboration of TLL and assistance of JOil, the Singapore Agri-Veterinary Authority (AVA), an USDA equivalent in Singapore, has developed a *Jatropha curcas* specific TG and now provides inspection services for the award of PVP certificates that gives an owner exclusive commercial rights for 25 years. Two of JOil's new varieties are now being inspected.

Plant Breeding Rights are intended to confirm ownership of IP and to ensure exclusivity of commercialization, in a similar way as a patent. WTO rules confirm that each member state needs to provide protection for new plant varieties either by:

- joining the International Union for the Protecting of New Varieties of Plants (UPOV)
- or creating a sui generis (new) system.

At December 2012, there were 71 members in the UPOV, including many of JOil's trading partners. JOil hopes that by taking the lead in the recognition of Jatropha breeding rights, more countries will follow Singapore's example, either by adopting or modifying Singapore's TG for Jatropha breeding rights. In the meantime Jatropha breeders can apply for plant breeder rights in Singapore. With IP protection thus ensured, Jatropha breeders can confirm legal ownership of IP and generate commercial returns through licensing.

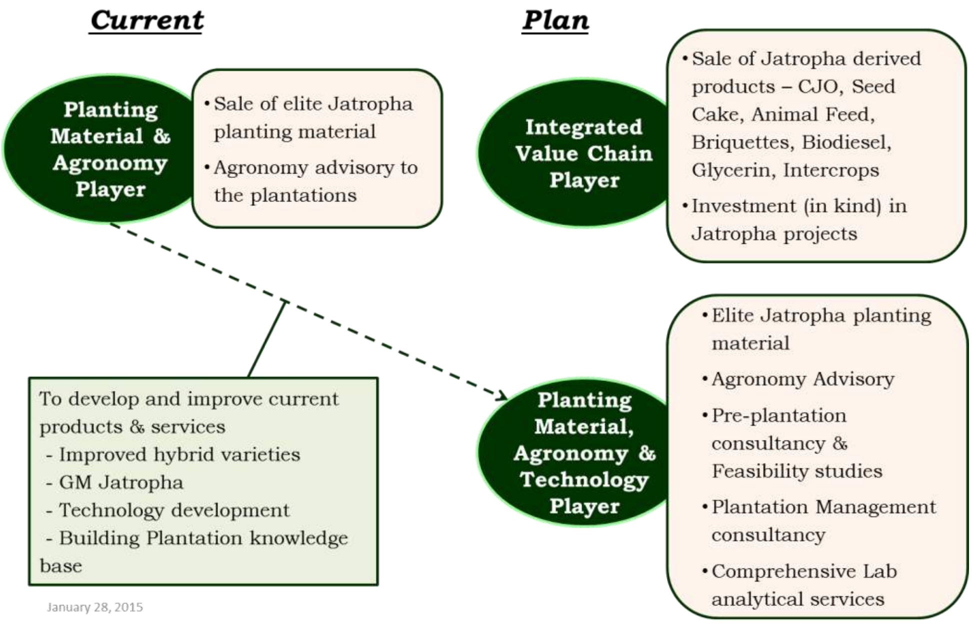
Jatropha Related Intellectual Property

JOil has built a reputation for leading edge Jatropha crop science, molecular biology, gene technologies and agronomy. With some 20 peer reviewed publications and 13 patents pending or granted, JOil and its partner TLL, have established a wide body of Jatropha related IPs. In house scientific knowledge and experience is typically supplemented with important alliances and affiliations. The collaborative relationship between JOil and TLL has been a central plank in the company's development of its enabling technologies, commercial products and services.

JOil lists commercial assets as including:

a. A portfolio of commercial varieties that have been tested and validated by multiple field trials, and now providing a seed bank with present capacity to supply 20,000 ha of new plantings.
b. Technical consultancy to support Jatropha plantation developments in diverse geographic regions and climates
c. A healthy pipeline of promising new varieties including:
    a. hybrid seeds
    b. interspecies hybrids
    c. clonal varieties
d. A proprietary tissue culture production technology led by its Indonesian subsidiary Monfori and several international OEM partners.
e. Multiple technology developments in the detoxification of Jatropha seed meal for animal nutrition
f. A Genetically Modified (GM) strain of Jatropha with 75% oleic acid content in seeds (normally < 45%).
g. The development of a 'whole value chain demonstration project' in Burkina Faso.

ANNEXURE 1: MOVE IN JOIL'S BUSINESS MODEL



ANNEXURE 2: JOIL'S PRODUCT & SERVICES PORTFOLIO

	Current	Short term pipeline	Long term pipeline
Open Pollinated Varieties	JO S1, S2 - Early fruiting/ returns - Yield better than wild types	JO S3, S4 - 20% more yield than S1 & S2	
Hybrid Varieties	JO H1 - Early fruiting/ returns - Yield better than wild types	JO H2 - Short stature - High planting density Elite hybrids through TC	JO H3, H4 Elite hybrids through hybrid seeds technology
GM Jatropha		GM Jatropha - High Oleic acid content - Disease resistance	GM Jatropha - High Oil Content - Low toxicity
Licensing Technology		TC Propagation technology Seed Cake detoxification technology	
Consultancy & Services	Customized Agronomy Practices manual	Pre-plantation consultancy & feasibility studies Plantation management consultancy	Comprehensive lab analytical services
Jatropha Value Chain		CJO Seed Cake Briquettes Intercrops	Biodiesel/ Bio jet fuel Seed Cake as Animal Feed

ANNEXURE 3: JOIL'S SCIENTIFIC COMPETENCY THROUGH MONFORI

In 2011, JOil acquired PT Monfori Nusantara, the largest independent tissue culture player in Indonesia and the only Indonesian company recognized by Australian quarantine (AQIS). It is an ISO 9002 and ISO 14001 certified company with a strong expertise in a wide range of TC protocols from grasses to teak plants and has a strong customer base. With this, JOil has its own commercial scale tissue culture facility with a production capacity of around 5 million Jatropha TC seedlings per year or 20 million ornamental TC plants per year. The current product line includes Ornamental grasses, Gerbera, Aglaonema, Cordyline and Aquatic plants. TC Jatropha production trials have also been conducted at the facility.

Since the acquisition, protocols have been developed for many plants including Vanilla Orchids, Amorphophallus Konjac, new varieties of Cordyline fruticosa, Aglaonema and aquatic plants; these plants are now in the production phase. Several other plants species such as Clove, Hoya carnosa, Dianthus (carnation), Euphorbia milii, Saintpaulia mini and Tea are in the protocol development phase.

Going forward, the strategy, in addition to scaling up Jatropha TC seedlings, is to add focus on food crops, plantation trees and crops, and commercial cash crops. Additionally, recent restrictions on import of horticulture products by the government may expand the local horticulture market for local players.

SGB Inc

SGB is a thoroughly American organisation, not simply because of the location of its headquarters, or because of the source of its funding, but by virtue of its scientific and commercial ambition and the support that it has won for this ambition from heavy weight US investors. At its core SGB is a crop science company, but by instinct it is a commercial multiproduct and services company seeking to valorise a range of products, services and business opportunities that are being developed around Jatropha. In common with its peers the company initiated its operations in the second half of the first decade of this century. Its research focus was Central America, the region of origin for Jatropha, where it developed an extensive germplasm library. With adequate funding from its industrial and life sciences investors, SGB recruited from the top of the US agri-science corporate and research spheres to establish a world class management team and a chain of 15 international research stations. The result of 7 years of applied investment and research is reflected in 15 commercial hybrids, a suite of enabling technologies and an ambition to transform Jatropha into a versatile crop for diverse agricultural and climatic environments.

Company & Management

Founded in 2007, San Diego, California based SGB Inc (SGB) is a commercial agricultural biotechnology and seed company with offices in San Diego, Guatemala and India. With a focus on Jatropha, SGB specialises in the development of plant oil, protein and biomass for use in global sectors providing industrial materials, transportation, energy and food chain components. Since 2007 SGB has been funded entirely with equity capital now totalling $40m.

Management

The senior management team combines very senior commercial experience within leading seeds companies including Seminis and Monsanto, with developmental crop science experience gained with global agri-science companies such as Monsanto, Seminis and Syngenta, and all this supplemented with the input of one of the leading figures in US plant molecular genetics. It is an impressive array of talent and it is further enhanced by a board of directors who also have highly relevant experience in the fields in which the company is active.

President & Chief Operating Officer - Miguel Motta

Miguel Motta is responsible for the strategic and operational leadership of the company's business development, global operations, marketing and human resources organization. Motta joined SGB in 2010 as Vice President of Marketing and Strategy following a career at Monsanto, and at Seminis, the largest developer, grower and marketer of vegetable and fruit seeds in the world.

At Monsanto, Motta was responsible for developing and executing the marketing and commercial strategy for Europe, Middle East and Africa, covering operations in more than 30 countries. Prior to that role, Miguel worked at Monsanto's headquarters leading merger and acquisitions efforts and the introduction of biotechnology products in the Americas.

During his time at Seminis, Motta served on the Executive Team that set the overall strategy and direction for the company while having direct responsibility for the global human resources function representing 3,000 employees in more than 50 countries. Prior to joining the Executive Team of Seminis, Motta was responsible for the finance organization in Europe, Middle East and Africa and was Managing Director for Spain and Portugal. Seminis was acquired by Monsanto in 2005.

Chief Scientist - Robert Schmidt, Ph.D.

Dr. Robert Schmidt has more than 30 years of research in plant molecular genetics, specializing in developmental genetics of seeds, flowers and inflorescence and whole plant architecture. He holds a B.A in Biology from Harvard, and a Ph.D. in Cell and Molecular Biology/Botany from Duke University. He spent 3 years as a Postdoctoral Fellow at Brookhaven National Laboratory before accepting a faculty position with University of California, San Diego in 1987. As a Professor of Biological Sciences at UCSD, he taught and conducted research for 24 years where he held the Paul D. Saltman Endowed Chair in Science Education. Dr. Schmidt has produced contributions to corn genome projects and has published over 60 peer-reviewed articles in highly respected journals. In 2010 he was elected a Fellow of the American Association for the Advancement of Science. After several years of serving as a consultant to SGB's R&D activities, he retired from UCSD in 2012 to take on the full time position as Chief Scientist at SGB.

Vice President, Agricultural Operations - Michael Pereira

Michael Pereira is responsible for supply chain management of seeds and Agronomic Practices for SGB. In this role, Pereira directs hybrid seed production, plantation research and agricultural operations.

Prior to joining SGB, Pereira worked at Mendel Biotechnology, where he successfully developed a commercially viable Miscanthus hybrid seed production system and directed seed physiology research that led to the first successful direct seeding of Miscanthus. Before joining Mendel, Pereira spent the majority of his career directing and managing global hybrid vegetable seed production for Syngenta and also Harris Moran Seed Company. At both these companies, he was directly involved in strategy and implementation of global production organizations.

Pereira has extensive international experience, having managed production activities in Asia, South Asia, South America and USA. Pereira holds a Masters in International Agricultural Development from UC Davis, and a Bachelor's Degree in Biology from the University of San Francisco.

Shareholders

The company's principal shareholders include:

Thomas McNerney & Partners

A USA venture capital firm with approximately $600m under management that is focused on investing in life science and medical technology companies. The firm targets investments in the pharmaceutical, medical device, biotechnology and diagnostic sectors. Companies raising growth capital for product commercialization are of particular interest.

Flint Hills Resources (FHR)

A wholly owned subsidiary of Koch Industries, Inc, that is an independent refining, chemicals, biofuels and ingredients company based in Wichita, Kansas. FHR has expanded its operations through capital projects and acquisitions worth more than $11 billion since 2002. Its refineries produce fuels that power much of Texas and the Midwest. The company's ethanol plants produce fuels that are used across the United States. Its petrochemicals are used to manufacture goods from plastics to building products to packaging materials. The base oils it markets are the principal raw material used to produce premium motor oil, commercial lubricants and sealants and coatings. FHR operates ethanol plants with a combined annual capacity of 820m gallons of ethanol. It is a leading producer of transportation fuels in the Upper Midwest, is the largest purchaser of ethanol in Minnesota, where it has utilized ethanol and other biofuels in its fuel distribution system since the mid-'90s. The company also has made equity investments in bioenergy companies, and is equipping a biodiesel plant in Beatrice, Nebraska to begin operations in 2015. FHR is a leading producer of chemicals and related products producing aromatics, intermediates and EPS, olefins and polymers. End uses for these chemicals include: synthetic fibres, agricultural chemicals, packaging, coatings, and appliance and automotive parts.

Kitano Capital LLC

A private investment firm based in Dallas, Texas with some $1bn under management.

Finistere Ventures

A leading life science venture capital firm based in San Diego. The fund's investment strategy is focused on "Food, Energy and Health" related technologies. These include technologies related to agricultural innovation. The fund seeks for early stage, innovative, disruptive technologies, with clear intellectual property protection, large and addressable markets, and the potential for significant exit value. Finistere Ventures has a focus on the agbio/renewable fuels sector as it believes that investments in the agbio / renewables sector provide opportunities for earlier exits than Life Sciences/ Pharmaceuticals, but still have meaningful intellectual property.

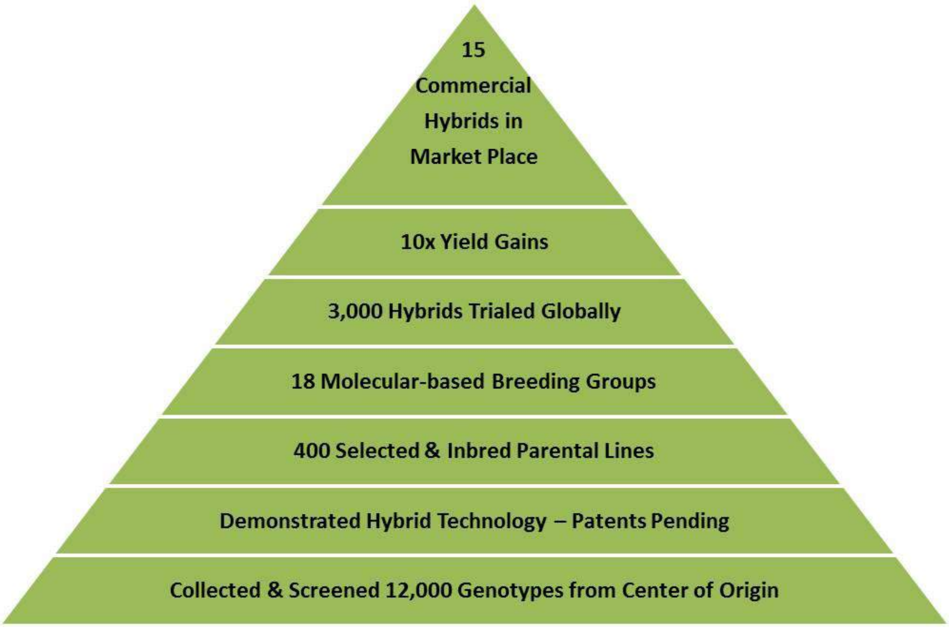
Life Technologies

A brand of Thermo Fisher Scientific Inc. (NYSE: TMO). TMO claims to be the world leader in serving science. The company has revenues of $17bn annually, some 50,000 employees in 50 countries, and a market capitalisation of $50bn. It seeks to accelerate life sciences research, solve complex analytical challenges, improve patient diagnostics and increase laboratory productivity. Thermo Fisher Scientific uses the Life Technologies brand name for a family of sub-brands of biotechnology products and services. The company provides genome sequencing products and services.

Breeding Programme & Strategies

Germplasm Collection

In 2007, SGB began developing an advanced molecular breeding and genomics biotechnology platform based on a rich germplasm portfolio. SGB focused on collecting the germplasm for its library from what has proven to be the richest pool, the species centre of origin in Central America. SGB currently possesses over 12,000 genotypes of Jatropha representing approximately 600 accession families. The company notes that its accessions exhibit "*an amazing degree of phenotypic & genetic diversity, facilitating selections for larger fruit clusters, larger fruit and seed size, oil content, variety in plant architecture, disease resistance and insect tolerance*". The diversity within SGB's Jatropha germplasm portfolio has provided its breeders with a deep pool of naturally occurring traits that are suitable for the development of a commercial crop. The company notes that because of Jatropha's rapid generation time, the ease of performing sexual crosses, and the depth of the germplasm portfolio, its breeders have been able to make very rapid progress in developing elite parental lines.



Source: SGB Inc

Figure 1 *– SGB corporate diagram highlighting its technical progress since its inception in 2007*

Enabling Technologies

Molecular Strategies

SGB reports that the development of, and use of proprietary molecular strategies to organize the company's diverse germplasm portfolio into groups reflecting their genetic relatedness (molecular clades), has been an invaluable tool for guiding the choice of parental lines that when crossed will provide the greatest degree of hybrid vigour.

Hybrid vigour is assumed to enhance crop profitability while eliminating variability and inconsistencies. Hybrids also provide a pathway for preservation and protection of a plant breeder's intellectual property. As with all hybrids, seeds saved from a field of hybrid plants will not breed true for the traits and trait benefits present in the hybrids themselves. This means that farmers must return to the original source of the hybrid seed for planting material that will be true for traits thus ensuring future income streams both for the farmer and SGB. SGB reports that it has trialled more than 3,000 unique hybrids through its global trialling network. Compared with a number of other commercially available stocks, the company reports that certain of its hybrids have demonstrated yield gains of up to 10x.

Hybrid Seed Production Methodology (Patent pending)

The company has developed a hybrid seed production method (which is awaiting patent award) employing the use of female only parental lines and insect pollinations. SGB reports that this methodology enables the cost efficient production of hybrid Jatropha seed. The ability to mass produce pre-screened hybrid seed has enabled SGB to rapidly produce seed at a low cost to respond to customer demand.

The company purports to provide customers with hybrid seed, only after having proven performance for the specific growing environment. The company also provides refined agronomic practices and locally-targeted agronomic solutions. SGB's express promise is that this combination of factors will ensure the farmer superior yields and consistency in performance even under known adverse site specific growing conditions, thus driving increased productivity and profitability.

DNA Barcodes

In support of its breeding activities, SGB advises Hardman that it has applied 'sophisticated genotyping and molecular breeding tools' designed to shorten breeding cycles and to accelerate the time to market of its elite planting material. SGB reports that its genotyping platform enables rapid and precise *DNA barcoding* with unique molecular identifiers of parental and hybrid lines. This not only provides intellectual property protection for its hybrids deployed commercially, but also enables quality control during seed production.

Agronomy Protocols

The company also reports that it has customized agronomic protocols, tailoring them for specific local cultivation conditions, including land preparation, irrigation, crop nutritional requirements, and management of disease, insects and weeds. The company is also addressing production practices and strategies for the optimization of plantation systems, including mechanized seeding, pruning and harvesting.

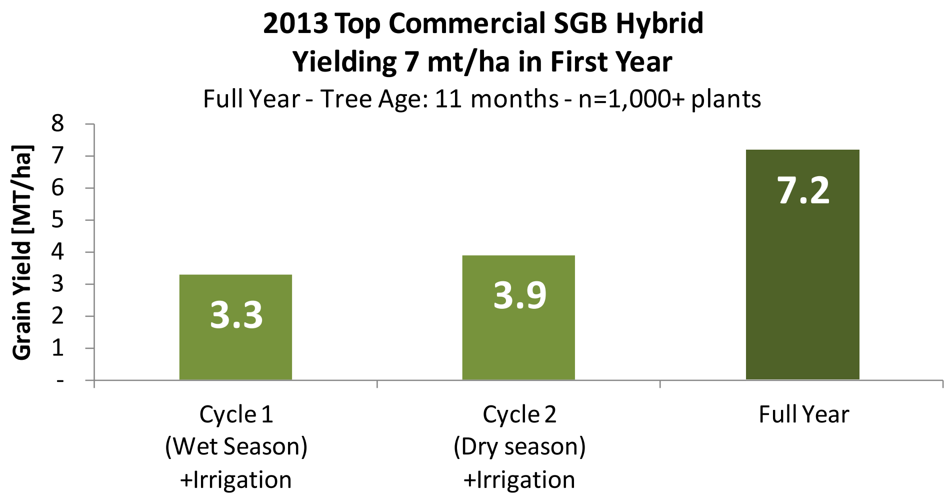
Commercial Hybrids

Superior Yields at 6 Months, 12 Months & Maturity

SGB reports that it has achieved grain yields of 7 MT/ha in its pre-commercial trialling for some of its top proprietary hybrids, as evidenced in Figures 2, 3 and 4 below. The company attributes the yield gains reported for its proprietary hybrids ("JMax Hybrids") to a combination of:

- SGB advanced genetics
- Shortened time to maturation
- SGB agronomic protocols

Figure 2 below reflects the extrapolated per hectare yield (at a planting density of 2,050 plants per hectare), based on actual yields achieved during the first year of growth from time of seeding, for the top JMax Hybrid planted in SGB's August 2013 trial at its Guatemala plantation research site. The number of hybrid plants in each plot in this particular plantation research trial ranged from 1,000 to 4,300. Plants were irrigated through a drip system as needed during the rainy season (800-900 mm/year of precipitation) and at frequent intervals during the dry season. This research site is described by SGB as incorporating previously underutilised lands consisting of semi-arid, sandy-loam soils with an undulating topography.



Source: SGB Inc

***Figure 2 –** Grain yield per hectare in Year-1 for SGB's top performing commercial hybrid in its 2013 pre-commercial trialling*

SGB's ability to achieve grain yields of 7MT/ha and greater in Year-1 have been ascribed to the confluence of several important traits influencing yield:

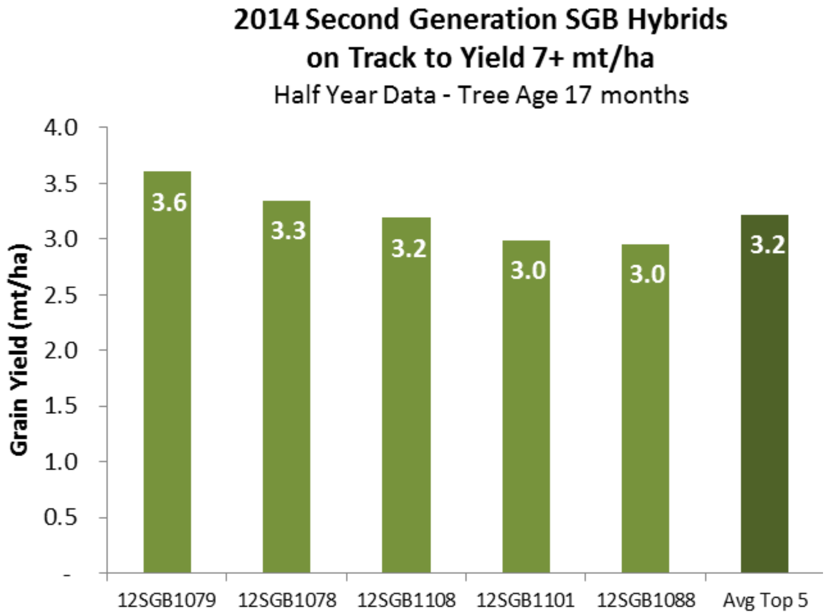
- high number of seeds per fruit (this hybrid produces a large percentage of 4-seeded fruits)
- the comparatively heavy seed weight (over 0.9 grams/seed vs an average of ~0.7 grams/seed)
- expressed early flowering trait (both after seeding and pruning) in comparison to the other hybrids.

For the second full year yield, SGB is projecting a further increase to 8.4mt dry seed per hectare for the referenced hybrid under similar growing conditions due to the plants having an established root system (growing back from the end of the season prune, not starting from seed) and being fully mature. Yields from the first cycle of Year-2 are reported to be trending on target to achieve the indicated extrapolations.

SGB has continued to experience further increases in yields with its 2014 suite of JMax Hybrids and anticipates being able to drive yields even higher by increasing the planting density from 2,050 plants per hectare to upwards of 3,300 without significantly reducing individual plant yield. Additional trials are underway to evaluate high density plantings of up to 6,600 plants per hectare under a perennial model. As part of ongoing agronomic research, SGB is also examining the impact of reducing irrigation on hybrid yields, with the goal of optimizing the trade-off between the savings from a reduction in irrigation and the lost revenue from the potential reduction in yield.

Product Pipeline

SGB has reported that it has increased the number of JMax Hybrids on track to realize yields of 7MT/ha or more per year to a suite of five for its 2014 pre-commercial hybrids. These JMax Hybrids are the result of crosses made from more genetically advanced parental lines, which exhibit a high degree of uniformity and improved yields over hybrid material of previous generations. These hybrids strengthen the genetic base of SGB's commercially available JMax Hybrids through the addition of novel crosses from parental lines which had not previously been evaluated.



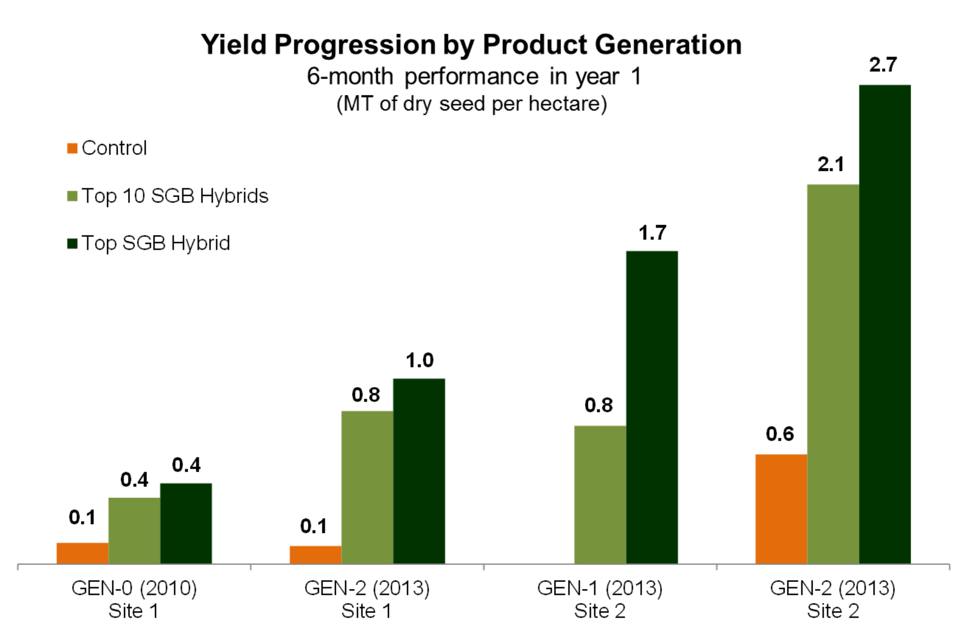
Source: SGB Inc

***Figure 3** – Six month per hectare grain yield for SGB's 2014 Top 5 pre-commercial JMax Hybrids, each of which is trending towards 7MT/ha per year.*

In keeping with its prior trialling experience, the company is projecting the second cycle semi-annual yield harvest data for the hybrids referenced in Figure 3 above to exceed the previous 6 month yield harvest data indicated above for a number of reasons primarily due to the increased maturity of the plants. As a result, all of the JMax Hybrids shown in Figure 3 above are on target to meet or exceed 7MT/ha per year.

Continuous Development

In common with its peers, SGB is continuously seeking to advance its breeding, agronomy and R&D efforts to further increase yields. Indeed it reports that it has experienced continuous yield gain with each successive new generation of JMax Hybrids as illustrated in the comparison between Figures 2 and 3 above, as well as in Figure 4 below. The company further sites this data as evidence of continued future yield gains that it believes it will achieve. SGB reports that as a result of its breeding and R&D efforts, it is continuously identifying new genetic lines which exhibit traits such as disease resistance, stress tolerance, increased flowering, increased seed size and number, as well as other favourable traits that facilitate its development of new and more productive hybrids.



Source: SGB Inc

***Figure 4** – SGB hybrid yield improvements between 2010 and 2013 during the first 6 months of each breeding evaluation*

The number above each coloured bar represents the extrapolated yield per hectare in metric tons of dry seed for the top performing JMax Hybrid (dark green bar), the average of the top 10 performing JMax Hybrids (light green bar) and the average of the Cabo Verde (the most common Jatropha genetic material commercially available) control (orange bar). The first early stage JMax Hybrids (GEN-0) were trialled in 2010. Although good uniformity was lacking, these first trials revealed a 300% yield increase over commercial material obtained from India, and the widely planted Cabo Verde (Control). With further selections (over 3,000 hybrids evaluated) and inbreeding of parental lines in combination with improvements in agronomic practices, the GEN-2 JMax Hybrids had more than doubled the 2010 yields when grown in the same location (Site 1), and achieved more than 6x the peak yields when grown at a more favourable site (Site 2) having deeper soils, a less humid climate and fewer overcast days.

Improved Uniformity

Through inbreeding of parental lines, the company seeks to achieve greater uniformity in hybrids, a pattern of development which increases the likelihood that the crop can be made suitable for mechanization of harvesting and plantation management.

SGB states that it has developed over 100 female and more than 1000 male inbred lines with uniformity ranging from 92-96% (F5-F6 level of inbreeding). The company estimates that this stock would enable the theoretical creation of more than 100,000 unique, highly uniform hybrids.

Detoxification

SGB in common with its peers is seeking to develop and/or utilise existing commercial technologies to enable detoxification of both its hybrid seeds and the harvested Jatropha products.

Breeding Strategies - Key Data for Achieved Milestones

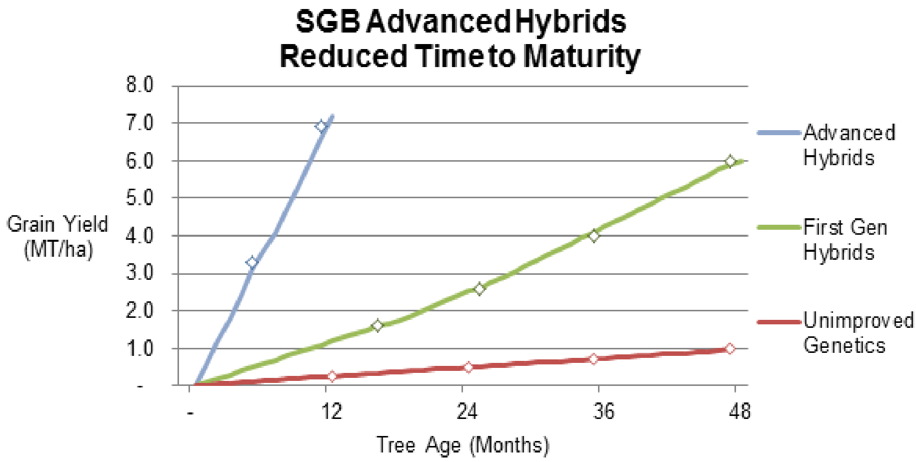
Direct Seeding

SGB reports an achieved rate of germination of between 90%-95% when direct seeding its JMax Hybrid seeds. There are a number of benefits associated with direct seeding:

- more rapid establishment of the tap and brace roots
- avoidance of root coil and J-root development
- shortened time elapse from planting to flowering
- avoidance of nursery costs
- reduction in planting costs

Reduced Time to Maturity

Wild varieties are assumed to take up to 8 years to achieve full productive maturity, although plantation managers typically work on a maturity period of 4-5 years (ex nursery) under professional farm management. SGB reports that its JMax Hybrids are able to realise something close to full assumed productivity between years 1 and 2 from germination. See chart below.



Source: SGB Inc

Figure 5 *– Comparison of grain yield over time of SGB's current advanced JMax Hybrids (blue line) in comparison to that of both its best performing first generation JMax Hybrids (green line) and the unimproved landrace variety (red line). Yields are reported on a per hectare basis and are extrapolated from the actual yields obtained in the plantation research trials of the advanced JMax Hybrids (Gen 1, planted in August of 2013) and the breeding evaluation of the first generation hybrids (Gen 0, planted in July of 2010). Note that the total yield at the end of year 1 for the advanced JMax Hybrids are nearly the same as that obtained in Year 4 for the best performing first generation JMax Hybrids. While both trial sites were located in Guatemala, the actual site locations and agro-climatic conditions were not identical. Irrigation was utilized in both trials.*

As shown in Figure 5 above, SGB's advanced JMax Hybrid produced first year yields on par with the yields of the previous generation JMax Hybrids (Gen 0) at Year-4 which indicates a possible acceleration to maturity in this hybrid. The significant improvements in yields and observed acceleration to maturity are also evident from the data in the yield progression charts above.

The company notes that a shortened maturity time provides a much more attractive value proposition to its farmers with the promise of revenue generation commencing in Year 1, as opposed to having to 'nurse' the plantation for 4 years or more to maturity.

Mechanization

As a result of its domestication and crop improvement programme, SGB reports that uniformity in its elite parental lines is now approaching 95%. The company expects that the JMax Hybrids produced from these parents will be sufficiently uniform as to be suitable for mechanization. Combined with direct (and mechanized) seeding, mechanisation of harvesting and pruning has the potential to increase operating efficiencies and to reduce costs. The company reports that it is currently optimizing a mechanical harvesting machine.

Planting Density / An Annual Crop

SGB believes that there is a pathway to annualizing Jatropha through high density planting coupled with breeding for specific plant morphology and traits along with the mechanization of the crop.

A successful annual model would open up the prospect of growing Jatropha in more temperate latitudes currently inhospitable to perennial Jatropha due to the species vulnerability to freezing. The company has conducted various high density trials of up to 30,000+ plants per hectare in Brazil, Guatemala and the southeastern United States to determine the impact on flowering and fruiting. Reportedly these trials have revealed a number of promising genetic lines within SGB's elite parental material that are tolerant to being planted in these higher densities. In addition SGB's trials suggest that yields per hectare in perennial Jatropha can likely be increased by not only increasing the intrinsic yield per plant, but by identifying genetics and morphology that can withstand the competition and stress that comes from higher plant densities to increase the overall yield per hectare.

Disease Resistance

SGB's initial selections from its germplasm collection emphasized apparent bacterial, fungal and pest tolerance and overall general vigour and productivity. Similar criteria for advancement are being applied during inbreeding of parental lines. The next step in SGB's breeding program is to initiate a concerted program directed at identifying specific disease and/or insect tolerant traits within its parental material. Global trialling of SGB hybrids exposes the company's hybrids to a diverse array of biotic and abiotic pressures, many of which are distinct from those encountered at its research sites in Guatemala. The company reports that this has provided valuable information to its breeders regarding potential sources of abiotic stress, disease and pest tolerance.

Male/Female Flower Ratio

Jatropha is monoecious species producing inflorescences with separate male and female flowers, but having a preponderance of male flowers (in the range of 10:1, male:female). From its germplasm collection SGB was able to identify and subsequently select and stabilize a trait referred to as "Female Only"; namely plants that produce inflorescences composed of only female flowers. The company now reports that it has over 100 inbred 'female only' lines coming from about 50 of the original 600 accession families in the germplasm collection, representing greater than 80% of the genetic diversity contained within SGB's germplasm.

Figure 6

Figure 7

***Figure 6** – shows an example of an inflorescence from a selected and stabilized inbred 'Female Only' SGB plant.*
***Figure 7** – above shows a typical monoecious Jatropha inflorescence manifesting both male and female flowers, but with a preponderance of male flowers.*

Plant Morphology

The company has collected data on the differences in plant architecture and the resulting effect on yields. The company uses this data to make selections based on the best plant architecture for traits favourable to increase light capture and/or facilitate mechanization of the crop. SGB has been able to identify the genetics that have the most influence on plant architecture and uses this information to make selections to influence future JMax Hybrid architecture and performance.

Crude Jatropha Oil ("CJO") Content and Profile

Current SGB hybrid seeds have a reported average oil content of 38% but the company's germplasm library contains genetic lines with up to 44% seed oil content. Since there is no inherent genetic restraint preventing oil content above 38%, the company views this as an opportunity to increase its hybrid seed oil yields in next generation JMax Hybrids.

Biomass

The company reports that its JMax Hybrids yield upwards of 46mt/ha annual green biomass (45-50% moisture content). The prunings and pericarp (fruit hulls) are high in cellulosic fermentables, which make them ideal for

- (i) burning for the production of energy
- (ii) refining for the production of ethanol or biodiesel or
- (iii) conversion into other high value products like OSB/particle board, densified biomass fuel, pellet fuels and protein meal.

Operations

SGB currently has offices in the U.S., Guatemala and India and employs approximately 50 individuals worldwide.

International Network of Research Sites

The company has established an international network of professionally-managed hybrid trials and agronomic research sites, known as JMax Knowledge Centers, where it reports it has evaluated more than 3,000 unique JMax Hybrids and optimized production and agronomic practices in a range of growing conditions. JMax Knowledge Centres offer SGB customers a well-established process to select, validate and scale elite JMax Hybrid planting material and to formulate agronomic best practices in furtherance of developing commercially successful Jatropha production businesses.

SGB has trialled its JMax Hybrids throughout its international network including more than 16 locations, with sites in:

- Brazil (6)
- India (8)
- Guatemala (5)
- United States (1)

The company is also currently in the process of establishing additional trial locations in Southeast Asia and Hawaii.
SGB also provides a customized offering of solutions and services to help customers design, plan, and manage commercial energy crop projects. The company has developed region and site specific local agronomic protocols including irrigation, crop nutritional requirements, and management of disease, insects and weeds to help ensure the success of each plantation. SGB provides the full array of these services from à la carte consulting engagements to provision of fully-integrated plantation project solutions. Currently, the company has on-going agricultural operations and/or trials in both Guatemala and India and has additional trial data from its recently concluded trials in Brazil. The Guatemalan sites include sites dedicated to seed production, breeding and plantation research for a total of approximately 50 ha.

In India, the sites consist of approximately 13 ha in three distinct locations: 1 ha in the north-west state of Gujarat, 4 ha in Maharastra and 8 ha in Andhra Pradesh. . SGB has also already begun the land identification and aggregation efforts for a 10,000ha Jatropha plantation project in Guatemala ("Verdeco").

Field Operations

SGB's most important field activities include:

(i) breeding
(ii) commercial seed production
(iii) commercial trials
(iv) plantation research.

The breeding activities evaluate the widest breadth of new genetic material with the goal of advancing a small percentage of the best performing genetics in any trial or evaluation. A critical objective of the breeding team is to advance selected parental lines towards homozygosity and to make selections among these inbred lines that will serve well in intra-specific hybrid combinations. JMax Hybrids are evaluated by the breeding team against the performance of checks and top yielding JMax Hybrids from prior evaluations. From these evaluations the most promising material is then passed on to the plantation research team for trialling with larger numbers of plants per hybrid.

Source: SGB Inc

The plantation research team trials a much smaller number of hybrids, but does so on a larger scale and under diverse agronomic conditions to determine the best agronomic parameters for deployment of those JMax Hybrids selected for advancement. Agronomic variables being investigated include plant density, water and fertilizer inputs, and pruning strategies.

The commercial trials involve the testing and evaluation of JMax Hybrids in new locations where the SGB team or a partner wishes to test a variety of material in order to identify those best suited for that particular agro-climatic condition. These commercial trials act as learning centres where 20-30 JMax Hybrids may be trialled in several replications to gather significant data on the best performers. The best performing lines are recommended for expansion to production on a commercial scale for the customer’s projects in the region.

When the top JMax Hybrids from these trials are identified, their parental lines are then passed on to the seed production team for commercial-scale production.

Business Model

SGB is a commercial, for-profit business. It offers a number of products and services to assist third parties in the successful deployment of commercial Jatropha plantation projects, including:

- the licensing of its elite JMax Hybrids
- the provision of agronomy and plantation consulting services
- project development/integration services
- proprietary molecular breeding technologies.

SGB deploys its services and technologies primarily through two commercial paths:

(i) direct licensing to parties interested in facilitating their own large scale commercial plantations, along with the provision of customized agronomy and plantation services as needed

(ii) structuring projects owned, operated and/or managed by SGB, in partnership with external investors and partners, which utilize SGB's various technologies .

SGB monetizes these products and services through collecting license fees, charging on a 'fee-for-service' basis, and/or through profit participation in the projects in which it participates.

SGB relies on proven off-the-shelf processing technologies to extract the oil from the Jatropha seeds as well as to dry and chip the biomass produced by the crop. The company is currently evaluating several protein meal detoxification technologies in order to determine which are best suited for deployment in its projects.

The decision as to whether the processing of the feedstock is to be handled by SGB, or contracted to a third party, is typically made on a case by case basis depending on the parties involved, economics of the project and desired end products. SGB has established working relationships with companies that provide the technology and services for each one of these steps.

Marketing, Distribution and Downstream Partnerships

SGB and Elite Hybrid Bioenergy ("EHB"), an entity incorporated out of Southeast Asia with expertise in commercialization and deployment of agricultural technologies, have entered into a distribution agreement whereby EHB has certain distribution rights for SGB's technology in Southeast Asia, China, and Australia. Under this collaboration, EHB is responsible for the marketing and distribution of SGB's technology in this region as well as for providing ground support for plantation development and management activities. EHB's primary focus is targeting the significant number of plantation companies in the region to deploy large scale Jatropha projects. EHB hopes to capitalize on favourable factors in the region that support the rapid expansion of Jatropha plantations, including climatic conditions that are well suited to the growth of Jatropha, the availability of a large pool of expertise in plantation establishment and operations, the availability of investment capital willing to invest in plantation projects, as well as an established market for similar plantation products.

In all other geographies, SGB handles the above-referenced activities directly. SGB has also partnered with shareholder Flint Hill Resources LP ("FHR"), a large independent refining, chemicals and grain processing company, to assist in downstream activities. In addition, SGB has developed relationships with strong off-take partners for the off- take of significant portions of the oil that it expects to produce on its commercial scale Verdeco project.

Project Verdeco

SGB is currently developing a fully-integrated, environmentally sustainable, off-balance sheet plantation project in Guatemala structured and managed by SGB, which will consist of a minimum of 10,000 hectares of its JMax Hybrid Jatropha.
The project is structured to utilize, and capitalize on, SGB's technology and regional strategy, including (i) use of its proprietary JMax Hybrid seed technology, which has been developed and tested within Guatemala for more than six years; and (ii) its intensive, project-based land and labour identification and procurement efforts achieved over the past six years of operations within the region.

Source: SGB Inc

A mandate letter has been signed with the Inter-American Development Bank ("IDB") to provide up to $46m in debt financing, and a letter of intent has been received from a European development bank to provide $10m-$15m in mezzanine financing for the project. The company reports that through its network of partnerships it has agreed to terms for one or more off-takes for significant portions of the CJO to be produced by the project. A land acquisition and aggregation process is underway and the company has initiated the environmental due diligence procedures required by the IDB and Roundtable on Sustainable Biomaterials ("RSB") for the certification of the project.

Besides being environmentally friendly, the Verdeco project is intended also to have a positive social and economic impact on the region in which it is located. Over 2,500 jobs will be created in the surrounding communities and land production will be improved through the utilization of underdeveloped or low yielding land. Furthermore, the project seeks to foster local entrepreneurship by helping to develop local contractors and resources as well as to institute health and educational programs throughout surrounding communities.

Finally, with greater than 100,000 ha of suitable land available in the region, the Verdeco project also offers the added benefit of the ability to scale up the project to a minimum aggregate total of 30,000 ha.

The project's operational model and modular expansion design allow it to tap into the available local labour pool to facilitate future expansion as needed. Through the integration of the plantation roll out, along with off-take agreements and centrally located processing platforms, SGB is seeking to demonstrate the commercial scale economic viability of its JMax Hybrid Jatropha where the company expects revenue from the sale of oil, biomass and protein to provide compelling returns to farmers and the different players across the entire value chain. Additionally, the company is developing the Verdeco model (for large scale Jatropha plantations), as a model for replication in other geographies.

Summary

Best In Class Technology

As a result of multiple years of performance data and a knowledge base gained through the evaluation and pre-screening of thousands of different genetics from SGB's germplasm library, the company states that it is now able to select and scale its top performing hybrids for commercial projects in numerous geographies around the world.

SGB claims that its molecular breeding and R&D efforts have enabled it to:

- Shorten the maturation period of its JMax Hybrids from the industry standard 4-5 years to only 1-2 years
- develop elite Jatropha hybrids with yield / productivity up to 10x greater than commercially available lines
- to identify numerous naturally occurring beneficial traits, which it has targeted and utilized in the development of region-specific JMax Hybrids to better respond to each customer's specific growing conditions thereby increasing the potential for superior yields and decreasing project risk
- provide localized agronomic and production protocols complementing and supporting the genetic potential of its JMax Hybrids.

Ability to Scale

SGB currently has over 15 commercially available hybrids; each one reportedly offers proven, high performance genetics. The company's commercial seed production programme is claimed to provide the necessary scaling and deployment capabilities to meet customers' needs. As previously stated, SGB also has a 10,000 ha commercial plantation project in early stage development in Guatemala.

Sustainability

SGB's JMax Hybrids have been developed to maximize an array of superior traits, including the ability to grow on under-utilised lands. The material can be cultivated on land that otherwise may simply lie barren, while eliminating the direct competition for land that may otherwise be utilized for food production. Jatropha plantations have already been shown to have a positive effect on greenhouse gas emissions as well as overall land value (Dehue and Hettinga 2008; Balis and Kavlak 2013).

SGB's commitment to industry-leading sustainable policies and project certification by the IDB and RSB are intended to ensure compliance with its customers' and partners' stringent social and environmental requirements as well as create opportunities for the potential incorporation of associated projects into various carbon credit trading schemes.

Logistics

SGB understands that success with commercial projects requires that the complete value chain is addressed – from crop science and project development and management to harvesting, processing and refining all the way through the ability to sell into existing commodities markets. CJO is able to use existing, proven supply chains for internationally traded oils.

Cost- Effectiveness

SGB understands that its JMax Hybrids must deliver sufficient volumes of high quality oils, protein and biomass as to ensure value creation along the entire supply chain.

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