The Jatropha System
An integrated approach of rural development

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The Jatropha System - An integrated approach of rural development
01. Introductory Remarks
All the photos in this book are taken by myself, the author, except if otherwise indicated. The drawings are from an end of study work of ..... in Bamako, Mali, in the year .

This book will be published in the internet, on the Jatropha website. Links are integrated, to show some small videos, which is not possible in a printed version.

A printed version will also be available on request to me (e-mail: henning@bagani.de), or in the e-shop at the Jatropha website. A .pdf-version will also be available for downloading.

This book will be subject to a permanent change, i. e. new information will be added at all time.

This book will try to underline information by pictures. So very often some different pictures are shown to illustrate an information.

02. Glossary
In this glossary some expressions are explained, many examples are cited from Madagascar, because the author was 2 times on the island and there are many good examples of Jatropha application there.

**Bielenberg Ram Press**: This is a hand oil press, which was invented by the American Carl Bielenberg in the years 1970 in Tanzania for edible oil extraction of sunflower and sesame. This press is easy to produce in simple work shops (only a welding equipment and some tools to cut flat iron bars are needed). This press has a
capacity of about 5 kg of seed per hour. It can be used by 1 person. The extraction rate is about 20\% (215 g of crude oil by kg of dry seeds, the sediment is about 20\% (test of the press in the workshop of ACAMECA in Antsirabe, Madagascar, by the ERI project in March 2006, see ANNEX)).

**C3** (Climate Change Corporation), this is a British company in the north of Madagascar, which wants to buy Jatropha seed in big quantity, extract the oil locally, and export the oil to Europe (via the ports of Vohemar and Antalaha to Toamasina). To produce the oil at a price fob (free on board) low enough (360 USD for 1 tonne), the company can only pay 140 Ar for 1 kg of seed. For this price, the farmers do not collect and sell seed.

**ERI** (Eco Régional Initiative), is a project of rural development of USAID in Fianarantsoa, in the south of Antananarivo. The project ERI works mainly on the production and use of Jatropha oil in collaboration with BAMEX and PLAE.

**Jatropha**: Jatropha is the name used in this book for the plant *Jatropha curcas* L., which is known in the French language as Pourghère or Pignon d’Inde, which is used as support for the vanilla plants in the north of Madagascar. The botanical family Jatropha is composed of about 175 different species.

Except for vanilla support, the plant is used as living fence to protect food crops in gardens and fields, and as an ornamental plant, because it is not eaten by animals.

The Jatropha plants which are used as support for vanilla, cannot produce many seeds, because their maintenance goes towards the support of the vanilla lianes (the lateral branches are cut off) to give 50\% of shade (the vanilla plant is an orchid and does not support full sunlight). So the Jatropha
support plant has only some branches with leaves for the shade at the highest part of the plant, which results in the production of only a relative small amount of Jatropha fruits at parts of the plant, where the harvest is very difficult. Also the vanilla plantations are very often very far away from the villages.

In Madagascar, an indigenous Jatropha species is known under the name of Jatropha mahafaliensis, which grows only in the south of the country on cacerique soil.

**Jatropha seeds**: These are the black seeds of the Jatropha plant, which are produced within a fruit, and which are ripe, when the fruit turns yellow. The dry fruits stay still longtime attached to the branches. The seeds contain between 30 et 35 % of a non edible oil. The kernel of these seeds contain about 45 to 50 % of oil. Traditionally these kernels are used to make torches for lighting or to start a fire (lighter, see photo at the right side). See torch.

**Kakute**

Kakute is a private company in Arusha, Tanzania, which is producing Jatropha soap and has a dissemination programme, financed by the McKnight Foundation from USA.

**KfW** *(Kreditanstalt für Wiederaufbau)*

This is the German bank for reconstruction, which serves as the bank for financial co-operation for the German government with the developing countries.

**PLAE** *(Projet Lutte Anti-érosive)*

This is a project of the German Co-operation *(KfW)*, which tries to reduce erosion in Madagascar. This project studied the feasibility to use Jatropha in its project activities against erosion.
**Polybags**
Small bags of black polyethylene-plastic film, which are filled with soil, to grow plants from seeds or from cuttings in a nursery.

**Price of seed (Purchase price for seeds)** is a key element for the economic rentability of oil production (see the sensitivity of the calculation of the oil price with the EXEL software (just change the purchase price) in Annexe III and point 9.).

**Price of energy**: The prices for fuel in the station in Andapa, Madagascar (the 22. 05. 2006) were:

- Lamp petrol 1.682 Ar
- Diesel 2.168 Ar
- Gasoline 2.488 Ar

In the village of Ambalamanasy II, at the end of the road to Doany and without an official station, the price for diesel is already gone up to 2.500 / 2.600 Ar.

In the village of Doany, 35 km from Andapa, 25 km from Ambalamanasy II, without access by road, the price for diesel is already gone up to 3.000 Ar and that of lamp petrol to 2.500 Ar.

The costs of transport (on humans back) for 1 kg of goods between Doany and Ambalamanasy II are 200 Ar.

**Salary**: In Sambava and Andapa the workers are paid by day, which means 2,000 Ar per day of 5 hours, which are 400 Ar per working hour. The salaries are lower. (BAMEX calculates with a salary of 2,500 Ar per day of 8 hours, which are 313 Ar/h, GEM in Toliara pays 2,000 Ar for 6 hours of work, which are 333 Ar/h.

**SAVA**, region north-east of the island of Madagascar, contains the districts Sambava, Antalaha, Vohemar et Andapa. It is the region of the vanilla production.
**Sayari expeller**: Le Sayari expeller est la version Tanzanienne du Sundhara expeller, qui était développé par la GTZ pour extraire de l’huile de colza au Népal. L’avantage de cet expeller est son simplicité. Il peut être produit dans des petits ateliers avec des tours et une possibilité de trempage des pièces. Cet expeller, ou presse mécanique, avec un vis sans fin, est actionné par un moteur, soit électrique ou diesel. Le moteur diesel peut être adapté à la consommation de l’huile de Jatropha comme carburant. Dans ce façon, le moteur consomme environ 10 % de l’huile produite.

**SMIG** : (salaire minimum d’embauche garantie) : Salaire minimum garantie par le gouvernement, c’est actuellement à 50 000 Ar par mois (environ 260 Ar/heure).

**Sundhara expeller**: This is the name of the Sayari expeller during its development and dissemination phase in Nepal.

**Torch**: The kernel of these seeds contain about 45 to 50 % of oil. Traditionally these kernels are used to make torches for lighting or to start a fire (lighter, see photo at the right side).

**White kernels (deshelled seeds) on a piece of rafia or wire to be used like a torch**
**Traditional extraction:** The production of Jatropha oil is done in the villages ouestr of Andapa on Madagascar. The oil is used by the women for their hair. The production process is the following: The black seeds are deshelled and pounded very fine. The paste is boiled with much water. The oil which floats on the water is taken off and cleaned by boiling it.

The time needed to produce 1 liter of oil is about 12 working hours (estimation by the authors after a demonstration in Ankiaka Be, Andapa, Madagascar). To press 1 liter of oil with a hand press (Bielenberg Ram press) about 1 hour work is needed (see detailed description in ANNEX VII).

**Support plant:** The vanilla plant is an orchid, a climbing plant. It needs a support to climb up which gives about 50% shade at the same time. In Madagascar the use Jatropha for that. So the plant is maintained in a way, that it meets the 2 functions at the same time: support and shade. That means the plant is cut at the sides and only some branches at the top are left for the shade.

That means clearly, that the plant Jatropha as a support for vanilla cannot develop its potential as a producer of oil seeds. The production of a support plant is estimated at 100 grams per plant and year, which is about 200 kg of seed per ha of vanilla plantation.

About 30% of the vanilla plantations use another species as support plant: Gliricidia. Gliricidia is mainly used in the poor soils, because in the rich soils it produces too many new branches and it is necessary to cut the branches several times per year.

**Valavelona:** Madagassy name for Jatropha in the region of SAVA (vala = hedge, fence, velona = living).
Yield: The yield in seeds of the plant Jatropha is one of the most important figures to judge the economic feasibility of the production of Jatropha oil.

The “wild Jatropha plants » (up to now no agricultural research into the improvement of the Jatropha species to a high yielding variety has been done), have a big variation in the production of seeds. There are plants with 10 grams of production per year, and others near by with 1,000 grams.

To get high yielding plants, you have to evaluate the yields of existing plants and multiply these high yielding plants vegetatively (by cuttings or by tissue culture). In this case you have clones of the plant with the same genetics and therefore with the same yield. The 2 photos above show this situation: at left you have a plant with a good yield (fruits at every branch) whereas at the right side you don’t find fruits at all: you have low yielding plant.
The yield of the plants has a very big influence on the economy of Jatropha oil production. A good yield facilitates the harvest. Per hour 2 times or 3 times more seeds can be harvested.

Now you have to identify the 20% best plants (here the plants 7 to 10) and multiply them by cuttings or by tissue culture (vegetatively, as fruit trees in general are multiplied.

In the long run, an agricultural research to improve the yield, is needed. It would be important to have only plants like the numbers 7 to 10 of India, so they can be multiplied by seeds.

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1. The Idea

1.1 History of the Use of Plant Oil as Fuel

Already the famous Diesel engine was running for demonstration on plant oil (peanut oil) at the world exhibition 1900 in Paris.

Rudolph Diesel said (in 19...:

1.2 Use of Jatropha Seeds in the 30s and 40s of the 20th Century

The French colonialists in Mali in the «Office du Niger», made already tests with Jatropha oil as fuel in the years before 1939. Then these tests were stopped by order of the French governor of Dakar, because “plant oil is too precious to be used as fuel in the colonies, it has to be shipped to the metropoles”. There Jatropha oil from seeds from Madagascar, Dahomey (now Benin) and Guinea became the raw material for the famous «Savon de Marseille».

From the 50s onward, the production of chemical tensides reduced the importance of plant oil for soap production.

Jatropha seeds of Cape Verde Islands were exported to Lisbon (about 35,000 tons per year) after the second world war.

1.3 Revival of the Idea

1.3.1 Germany/ Cape Verde Islands

In the beginning of the 1980s the discussion on renewable energy sources led to the development of a special plant oil engine by ELSBETT (see www.elsbett-technology.com).

After the discovery of the toxic Jatropha plant as a source of a nonedible plant oil as renewable energy by Friedel von Bismarck, the German Agency for Cooperation and Development (GTZ), decided to try the possibility of producing Jatropha oil and using it as fuel in the Integrated Rural Development Project in Cape Verde Islands. The project was closed when the economic evaluation showed that the oil could not compete with the cheap diesel fuel. The material (a volkswagen pick-up, a Komet oil-press and a generator unit) of the project was given to the new Jatropha project in Mali (see point 1.3.2).
1.3.2 Mali

After the energy crisis in the 1970s a serious discussion on renewable energies started in the industrialized countries. This led to the decision of the governments of the big industrialized countries (G7) at their summit in Cancun, Mexico, to support the developing countries. The German government started a « Special Energy Program, SEP » to apply renewable energy technologies. In 1987 the SEP-Mali was asked by the Division of Agricultural Mechanization to look into the use of Jatropha oil as fuel, in continuation of the experiences of the Office du Niger in the 1940s. The author of this book then started his work with Jatropha and continued it up to now (2006).

1.3.3 Nicaragua

In Nicaragua the Austrian Cooperation started in the late 1980s a « Proyecto Biomasa » at the university of Managua. The large scale production of Jatropha oil and its esterification to a Diesel substitut for the national energy authority became the main component of the project. After some basic research in 1994 the first 1,000 hectares of Jatropha plantation were installed. In 1997 the international conference Jatropha 97 in Managua presented the Nicarguan experiences to a wide public and showed also the activities of other parts of the world, like India, Mexico, the Phillipines and Mali.

2. The Jatropha System

The Jatropha System is an integrated approach of rural development. By planting Jatropha hedges to protect gardens and fields against animals, the oil from the seeds can be used as fuel in precombustion chamber diesel engines and for soap production. In this way the Jatropha System covers 4 main aspects of rural development:

- energy supply in the rural area;
- erosion control by the plantation of hedges;
- promotion of women by local soap production;
- poverty reduction by selling seeds.
The big advantage of this system is the possibility to keep all steps of processing and therefore all the added value within the rural area or even within a village. No centralized processing (like in cotton production) is necessary.

3. The Realization

With higher prices of fossil energy (almost 80 USD per barrel in mid 2006), the use of renewable energies becomes more and more attractive to policy makers in industrial and developing countries. In many cases decisions to use Jatropha oil as a renewable energy source are not based on realistic assumptions.

And the activities to produce Jatropha oil in large scale plantations, seem to be spontaneous and lack a lot of realistic figures.

3.1 The Strategy

The strategy I propose, is the result of the knowledge of disseminating the Jatropha know how in Mali, West Africa, where I worked for about 10 years within the German co-operation, and the different approaches I got to know in different countries by feasibility studies and/or by contacts through the Jatropha website, www.jatropha.de, which I started and maintain since 1997.

A strategy to disseminate the know how of the Jatropha system should formulate different activities on 3 different levels:

- a local level, i.e. farmers who plant Jatropha hedges to protect their crops, women groups who look for income, NGOs which look for possible actions to support rural development.
- These local activities should be supported by know how centres on a national level.
- These centres are supported by a promotion centre which acts on an international level.

In a graphic, this is presented in the following way:
3.1.1 Local level

On a local level “Jatropha Project Modules” should be developed, which can be realized by development groups and/or small NGOs. The centre of such a module is an active women or farmer group, which is engaged to utilize the economic potential of the Jatropha System.
If Jatropha is not yet available, the project needs a preparatory time of 4 to 5 years to plant Jatropha and wait for the production.

These local groups are supported by the national centres of excellence with know how (broshures, videos, papers in local language), with addresses of suppliers (in the broshures) and with equipment (oil presses, lamps, plant oil stoves, conversion tools for engines).

“The Jatropha Booklet”, which is available on the Jatropha website for downloading in different languages (www.Jatropha.de/documents/index.html), contains a chapter on Jatropha promotion. This booklet has been written by the author to give some hints to people who wish to initiate a Jatropha project.
Support by the Centre of Excellence

Graphic 2: Schema of Jatropha know how transfer on a national level
3.1.2 National level:
On a national level “Centres of Excellence” should be created in each country. They should play the role of a “know how centre” and support the implementation of Jatropha activities by groups and organizations of rural development.

Such a “Centre of Excellence” is a number of persons who are familiar with all the aspects of Jatropha production, oil extraction, soap production and marketing. These persons have to be up to date with regional development in extraction technology and marketing techniques (“eco-label”).

These persons can easily be invited by some organisations to start Jatropha projects in their region:

- Support of the supply of material & chemicals to projects; list of suppliers; Organisation of the exchange of information;
- Creation of a national JCL network; Support of the marketing of products; Facilitation of credits.
- Organization of national workshops;
- Looking for wholesale buyers for Jatropha soap and / or oil in national markets;
- Presentation of Jatropha products on agricultural & bio-product exhibitions (national / international);
- Approach of national / international trading companys of natural products.

3.1.3 International level
On an international level a “Jatropha Promotion Centre” should be created, which supports the different “Centres of Excellence” by various activities:

- Publication of available and useful information concerning the application of the Jatropha know how into the internet. This internet presence will supply up to date information to all members of the “Centre of Excellence” and will facilitate the exchange of information between the “Centres of Excellence” in different countries.
• Organization of a Q & A service;
• Creation of a Jatropha network for mutual support and exchange of know how, including workshops, seminars and visits of different projects with different approaches and in a different socio-economic environment (capacity building);
• Publication of Jatropha information
• To keep the Jatropha network alive, regular workshops on regional level should be held, accompanied by some central seminars (capacity building);
• Supply of tools & blueprints & contacts with experts;
• The “Jatropha Promotion Centre” can also identify research topics and coordinate the work on these topics by different organisations / universities and distribute the results. Such topics could be:
  - Selection of high yield Jatropha plants (seeds, cuttings);
  - Selection of high oil yield Jatropha plants;
  - Selection of a pure line of the non toxic variety from Mexico (edible oil, press cake as animal feed);
• Establishment of a seed bank to provide Jatropha projects / initiatives with high yield and / or non toxic seeds;
• Conception of small scale projects, which can be financed by small donor agencies (modular project system) and executed even by small NGOs.
• Looking for export / import possibilities on international markets;
• Presentation of Jatropha products on agricultural & bio-product exhibitions (national / international);
• Approach of national / international trading companies of natural products.

3.2 Practical Approach

The day by day reality looks very different. Since there is no large scale Jatropha project, only small components of a Jatropha strategy can be realized. The farmers are interested in using Jatropha as an energy source or as an income generation possibility, but in many cases they don’t have the know how and the equipment to extract the oil and to use it. Therefore a national Jatropha centre of excellence (see point 3.1)is important, to support such farmers or groups.
In many cases, Jatropha plants are known by the local population, as medicinal plants and as plants for living fences. But the population is not familiar with the extraction of oil out of the seeds.

3.2.1 Difficulties

- As soon as the value of the seeds as a source of energy and therefore as a source of income is known, the Jatropha hedges become private and people can only harvest seeds on their own hedges. These are in many cases only a few hundred meters. Therefore the amount of money, which can be earned from the own hedges, is very limited.

- In West Africa, a gender problem blocks the development of the exploitation of the Jatropha plants: The men are the owners of the land and all permanent plants which grow on the land. Therefore the women usually grow tomatoes and other vegetables in their gardens. Traditionally women are responsible for soap production in West Africa, and they did it from different oil seeds and fruits, mainly shea butter, but also from Jatropha seeds.

Since the Jatropha seeds give an excellent oil for soap production, women were very interested in the use of the Jatropha oil once it was produced in expellers as a renewable source of energy. With the sale of the soap the women could really earn some money and started to think of their own Jatropha plantations.

But the men as owners of the existing Jatropha hedges, wanted part of the money. The women refused. So the men did not allow the women to produce more soap than needed for the own family.

This led to the situation, that the women used Jatropha oil for income generation, but only in a very limited extent, i.e. in a subsistence way. The Jatropha System did not develop. It will take quite some time, until a new socio-economic scenario is developed, where the exploitation of the Jatropha plant will be part of rural life.

4. The Plant « Jatropha curcas L. »

The Jatropha System - An integrated approach of rural development
The botanic genus Jatropha has about 175 different species, which are usually used as ornamental plants. A detailed description of many Jatropha species with photos can be seen in the internet at the following address: www.euphorbia.de

In Madagascar an endemic species of Jatropha exists in the south of the island, Jatropha mahafaliensis. This J. mahafaliensis exists in large quantities on calceric soils and has about the same properties as J. curcas. It is used by the local population as a living fence. The seeds don’t have a hard shell. Nothing is known about the content and the properties of the oil.

4.1 Botanical Description

Jatropha curcas L. is a drought resistant species which is widely cultivated in the tropics as a living fence. The seeds are toxic to humans and many animals.

The Jatropha plant is a small tree or large shrub which can reach a height of up to 6 m. The branches contain latex.

Normally, five roots are formed from seeds, one central (tap root) and four peripheral. Cuttings, when planted, do not form a tap root. The plant is monoecious and flowers are unisexual. Pollination is
by insects.
The life-span of the Jatropha curcas plant is more than 50 years.

5.2 Botanical classification

<table>
<thead>
<tr>
<th>Class:</th>
<th>Rosidae</th>
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<tbody>
<tr>
<td>Order:</td>
<td>Malpighiales</td>
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<tr>
<td>Family:</td>
<td>Euphorbiaceae</td>
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<tr>
<td>Sub-Family:</td>
<td>Crotonoideae</td>
</tr>
<tr>
<td>Tribus:</td>
<td>Jatrophiæ</td>
</tr>
<tr>
<td>Genus:</td>
<td>Jatropha</td>
</tr>
<tr>
<td>Species:</td>
<td><em>Jatropha curcas</em> L</td>
</tr>
</tbody>
</table>

Table 1: Botanical classification of the Jatropha plant

4.3 Names and synonyms of Jatropha curcas in different languages

see GFU website ([http://www.underutilized-species.org](http://www.underutilized-species.org))
completed by Henning with own researched expressions

<table>
<thead>
<tr>
<th>Language</th>
<th>Local name of Jatropha curcas L.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Afrikaans</td>
<td>purgeerboontjie</td>
</tr>
<tr>
<td>Arabic</td>
<td>habel meluk</td>
</tr>
<tr>
<td>Bambara (Mali)</td>
<td>baganfi</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Language</th>
<th>Translation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinese</td>
<td>yu lu tzu</td>
</tr>
<tr>
<td>Dutch</td>
<td>purgeernoot</td>
</tr>
<tr>
<td>English</td>
<td>Physic nut, Purging nut</td>
</tr>
<tr>
<td>Fijian</td>
<td>bagbherenda</td>
</tr>
<tr>
<td>French</td>
<td>Pourghère, pignon d’Inde</td>
</tr>
<tr>
<td>German</td>
<td>Purgiernuss</td>
</tr>
<tr>
<td>Haití</td>
<td>médicinier, metsiyen</td>
</tr>
<tr>
<td>Hindi</td>
<td>bagbherenda, bakrenda, rani jada, ratanjot</td>
</tr>
<tr>
<td>Indonesian</td>
<td>jarak pagar</td>
</tr>
<tr>
<td>Italian</td>
<td>fagiola d’India</td>
</tr>
<tr>
<td>Kimbundu, Angola</td>
<td>cassiu</td>
</tr>
<tr>
<td>Khmer (Cambodia)</td>
<td>hong kwang</td>
</tr>
<tr>
<td>Language of Mali</td>
<td>koushini fli (trow your trousers away)</td>
</tr>
<tr>
<td>Maya (Mexico, Yucatan)</td>
<td>sikil-té</td>
</tr>
<tr>
<td>Nepali</td>
<td>ramjeevan</td>
</tr>
<tr>
<td>Portuguese (Brazil)</td>
<td>Andythygnaco (Brazil), Figo-do-inferno (Brazil), Grão das ilhas Molucas, Grão das Molucas, Jetrofa da Índia, Mandubiguaçu (Brazil), Manduigaçu (Brazil), mundubi assu, Mandubi-guaçu, Manduri-graça, Pinhão bravo, Pinhão da Índia, Pinhão-de-purga (Brazil), Pinhão-de-cerca (Brazil), Pinhão-de-purga, Pinhão-do-Paraguay, Pinhão-manso, Pinhão-paraguai (Brazil), Pinheiro-de-purga, Pinheiro-do-inferno, Pulguiera (Cape Verde), Purgante-de-cavalo (Brazil), Purgueira, Purgueirav (Brazil), Ricino-maior, Semente de purgueira.</td>
</tr>
<tr>
<td>Portuguese (Portugal)</td>
<td>purgueira</td>
</tr>
</tbody>
</table>
Table 2: Local names of the Jatropha plant in some languages
(Côte d’Ivoire has already 70 languages)

4.3 Varieties
The Jatropha variety in Nicaragua has fewer, but larger fruits. The yield per ha seems to be the same or a bit lower for the Nicaragua variety. No exact figures are available.

In Madagascar, in the town of Sambava in the SAVA region (north-east), a variety is found, with much larger leaves and larger fruits and seeds. Nothing is known about the yield and the oil content of the seeds.
A non-toxic variety exists in Mexico which is used for human consumption after roasting (see point 4.3.2).

4.3.1 Genetic of Plants of Different Origin

Very little is known about the genetic differences of plants of different origin. No systematic research has been done so far.

The University of Hohenheim, Germany, establishes plantations with seeds and cuttings of different origin to see, if there are differences which can be used for seed selection.

The University of York, Great Britain, did some analysis of the genetics of plants and found out, that the biggest difference is within the Jatropha plants of Central America. The genetics of the plants in other parts of the world are very similar.

This means, that the origin of the Jatropha plants is probably Central America (Yucatan of Mexico, the place of the biggest genetic difference. All other plants have such a small genetic difference, that they support the theory, that they were distributed by Portuguese seafarers around the world.

4.3.2 Non Toxic Variety

In Mexico, in Veracruz state, a non-toxic variety of Jatropha is known. Analysis by the University of Hohenheim, Germany, has shown, that they are free of phorbol esters.
4.5 Pollination
Pollination is by insects. It is not yet clear, if Jatropha is a good feed for bees, i.e. if it gives a
good tasting honey.

4.6 Distribution of Jatropha curcas L. in the World
The Jatropha plant is found all over the world in tropical and subtropical countries. It
originates from Central America, Yukatan, Mexico, and was distributes by Portuguese
seafarers. It is well known to farmers as a living fence, because it is not eaten by animals, and
as a medicinal plant.
4.6.1 Geographical Distribution

This map is not very good. Local situations have to be respected. But it shows, that Jatropha is distributed in the tropical and subtropical part of the world. In South Africa, Tanzania, Zambia, Zimbabwe and Malawi, there are large populations of Jatropha. Whereas in Ethiopia, there are only small amounts. Large parts of the world are not suitable for Jatropha, either because it is too cold, or there is not enough water (rainfall).

4.6.2 Climatic and Soil Conditions

Jatropha likes high temperatures like in the tropics and subtropics. But it grows also in areas with lower temperatures and does even resist to light frost. There are no data available about the production of seed in non-tropical climate.

In Harare, Zimbabwe, it resists to light frosts. But the effect on the production rate (yield) is not known. Also frost resistance is reported from Vietnam.
Jatropha grows well in gravely, sandy, well drained soils. It does not stand standing water. In some reports it is said, that Jatropha can grow in saline soils, but it is not known, to which extend it can support irrigation by salty water.

It can even grow in the crevices of rocks. Its water requirement is extremely low (min. 600 mm, but for seed production the water requirements are higher, about 800 to 1000 mm) and it can stand long periods of drought by shedding most of its leaves to reduce transpiration loss. Jatropha is also suitable for preventing soil erosion and shifting of sand dunes (if enough water is available, drip irrigation, irrigation with waste water).

If grown on marginal or waste land, the leaves which are shed during the cold months form a mulch under the plant. By decomposition of this biomass (earth-worm activity), this leads to an improvement of the soil fertility and in a long term view to the rehabilitation of waste land (mineral pump).

5. The Agriculture

5.1 The Hedges

In almost all tropical and subtropical countries Jatropha curcas is found in the form of protection hedges against animals around gardens and fields, because it is not eaten by animals. Even goats die of starvation underneath Jatropha trees. The hedges are planted for limitation/demarkation, as a living fence and against erosion. It is possible to use Jatropha hedges against bush-fire and soil improvement.

5.1.1 Hedges for Limitation

In many cases, Jatropha hedges are planted to mark the borders of a compound or homestead, because Jatropha is easy to plant and the animals don’t browse it. At left you see a thin and young Jatropha hedge, photographed by Richard Knodt in Diégo Suarez (Antsiranana) in the very
north of Madagascar.
5.1.2 Hedges Against Animals

These 2 photos show the use of the Jatropha plant as a protection hedge (living fence) around gardens and fields. On the left side is a Jatropha hedge in the centre of a Massai village in Tanzania, where the hedge protects the garden of a family against cattle, if they are within the village.

The photo on the right hand side shows a Jatropha hedge around a field in Mali, West Africa, which is about 10 years old. These hedges are not only effective against roaming animals, they also reduce the wind velocity and are therefore effective against wind erosion.

These hedges can be so dense, that even chicken cannot pass. It depends on the way, the hedges are planted.

Photo 6: A 10-years old Jatropha hedge in Mali around a field.

Photo 7: A dense Jatropha hedge at the market place in a Massai village in Tanzania (Engaruka)
Photos 8, 9, 10: The above pictures show some examples of Jatropha hedges: At left a Jatropha fence of cuttings in Mali, which will get roots and develop into a very dense permanent hedge. In the middle a Jatropha hedge in the Philippines (photo D1) and at right a young (1 year) Jatropha hedge in India (photo D1).

5.1.3 The Anti-Erosion Effect

Very effectively Jatropha can be planted against hydraulic erosion (water) in tropical countries. Usually, if grown from seeds, the Jatropha plant develops a tap root and lateral roots. These lateral roots grow near the surface and are can protect small earth dams against erosion by runoff water after the heavy rains, which are often in the tropical countries.

If these hedges are dense enough and/or reinforced by other plants like agaves, a very dense hedge can be formed, which serves as a filter and fixes the soil, which otherwise will be washed away with the runoff surface water. In the case, where the hedges are well planted along the lines of the same niveau, the water will be kept and will infiltrate the soil, which leads to an improved production (more water during a longer...
5.1.4 The Effect Against Bush Fire

It seems, that the Jatropha plant, as member of the euphorbia family, is quite resistant against bush-fire. It seems, as the photo at right shows, that in case of fire the plant may be damaged, but it doesn’t die or burn itself.

That means, that a dense hedge of Jatropha, or better a double or triple hedge, can serve as a natural barrier to a bush-fire. If the Jatropha hedges are planted in a chessboard way, a bush-fire cannot develop into a large scale fire. This effect can lead to an extinction of bush-fires, if Jatropha hedges are carefully planted and maintained.

This effect has to be verified. The project PLAE (Projet Lutte Anti-érosive) in Madagascar is trying to collect data on this anti-bush-fire effect of Jatropha hedges.

5.1.5 Soil improvement

If grown from seeds, the Jatropha plant develops a tap root and some lateral roots. The tap root reaches deep into the soil and transports minerals to the plant. The leaves, fruits and all organic material, which derives from the plants, contain minerals. Left underneath the plants, this organic material decomposes and leaves its minerals at the surface.

In this case, the plant serves as a mineral pump. In the long run, this can lead to the rehabilitation of wasteland.
5.2 The Jatropha Plantation

To see a short (1 min) video on Jatropha on YouTube:
http://www.youtube.com/watch?v=q4JI9RbxbH8

5.2.1 Germination of seeds

The germination of seeds is very different, depending on the time of harvest, the origin of the seeds and their storage. It is useful to determin the germination rate prior to seeding, because this can avoid a lot of trouble, e. g. if only each third plant will grow because of the bad germinatin rate. New plants have to be added.

In general one can calculate with a germination rate of 70 %. A higher germination rate is preferable, but not always realistic.

The germination rate has an important influence on the cost of plantation. At a germination rate of only 30 %, you need more than double the amount of seed as with a germination rate of 70 %. And I had already often only a germination rate of 10 % and less.

I even know of a project in East Africa, which bought 20 tons of seed in India. Unfortunately the germination rate was zero.

5.2.2 Direct planting of Jatropha from seeds

Seeds are plantd at the beginning of the rainy season. To get a dense hedge to protect gardens against browsing animals, a seed should be plantd every 5 cm. The germination should be controlled and missing plants replaced by new seeds. To achieve a dense hedge it is also possible to plant the seeds alternately in two rows, 20 cm apart. The seeds themselves should be 10 to 15 cm apart.
Since the young Jatropha plants have not yet developed their repellent smell, they might be eaten by roaming animals, so they should be protected during the first year with some tree branches. After three rainy seasons the plants are big and dense enough to protect the crops.

A plantation with direct planting of seeds need also an intensive care. The grass has to be cut around the seedlings, so they can grow well and get enough sun. If the maintenance is neglected, the young plants will disappear in the weed.

5.2.3 Direct planting of Jatropha from cuttings

Jatropha cuttings can be stored quite a long time. They start to decompose before they get dry. A thin layer of wax avoids the evaporation of water.

The farmers in Mali, West Africa, therefore use cuttings for new plantations, mostly hedges (see point 5.2.4). They plant the cuttings in the dry season, where there are no other agricultural works to do, about 2 to 3 months before the beginning of the rainy season. At the arrival of the rains, the cuttings develop roots and start living as an own plant. They develop flowers in the same rainy season and the first seeds can be harvested within 6 to 8 months after plantation. The photo shows Jatropha cuttings 6 months after planting in a coco-plantation in the SAVA region, north of Madagascar. The cuttings had a length of about 1 m.

5.2.4 Planting of Jatropha in a nursery

Nurseries should be in the shade to protect the small plants against drying. The shade can be produced by
trees (small nurseries just under a tree) or by woven layers of grass or straw, put on bars above the soil high enough that a person can work underneath. The light can be reduced by 50 to 70% (see photo at left, nursery by ERI in Madagascar).

If the nurseries are in the open sunlight, more care has to be taken to protect the small plants against drying.

To plant Jatropha first in a nursery, has many advantages: In regions with a long dry season, the growth of the plants can begin already a couple of months before the beginning of the rainy season. At the age of 3 to 4 months the plants can be outplanted into the field at the beginning of the rainy season.

5.2.4.1 Direct seeding in a nursery
Direct seeding in a nursery has the advantage, that many plants can be grown on a small surface and the amount of work is reduced. But the plants are more sensitive to transport and can get dry, if not enough care is taken. The place for final planting should not be too far away from the nursery.

If the plants have to be transported, care has to be taken to keep the roots humid. Transport costs are reduced by this kind of nursery.
5.2.4.2 Direct seeding in polybags

Direct seeding in polybags needs a lot of more labour for the preparation of the plant. The polybags have to be prepared with appropriate soil (1/3 sand, 1/3 humus, 1/3 normal soil, all well mixed and humidified).

Precultivation of Jatropha seedlings in poly-ethylene bags can accelerate the installation of a plantation by at least 3 months. One seed is planted in each bag. If well watered every 3 days, the seeds start germinating after about 10 days. After 3 months, at the beginning of the rainy season, the 30 to 40 cm high plants can be planted out.

These plants can produce seeds after only 2 rainy seasons.

Because of difficulties of transport (weight of the bags) these plants are not suitable for hedges. For a Jatropha plantation a distance of 3 m between the rows is appropriate, and a distance of 2.5 m between the plants.

5.2.4.3 Cuttings in polybags

As well as seeds, also cuttings can be pre-cultivated in polybags and grown prior to outgrowing in the field for about 3 to 4 months. The loss of plants after plantation due to the attack of termites might be less, but the transport of the polybags to the site of plantation will be more expensive (more weight).

5.2.5 Planting Jatropha as hedges

It is better to plant a hedge from cuttings, if they are available. The best time to plant cuttings is during the dry season, 1 to 2 months before the beginning of the rainy season. The cuttings should be already lignified, i.e. more than 1 year
old. Old branches of some years of age can also be used as cuttings.

The cuttings can be placed 3 to 5 cm into the soil and fixed 1 m above the soil with a horizontal wooden bar. The protective function is thus achieved right from the outset and the fence will start living during the rainy season. Old and strong branches can also be used as poles for fencing with barbed wire, because the poles start growing and are less likely to be attacked by termites.

**5.2.6 Planting Jatropha in a plantation**

For a Jatropha plantation a distance of 3 m between the rows is appropriate, and a distance of 2.5 m between the plants. This is necessary, to give access to the plants to the harvesting workers.

All 3 to 4 rows a larger distance of about 5 m should be respected to enable carts to pass to collect the harvested seeds.

In this way, about 1,100 plants per ha are planted (40 plants in a row of 100 m, 27 rows on 1 ha).

As the photo of a plant in India shows, that the bush reaches easily a diameter of 2 meters. To have access to the seeds for harvesting and to be able to pass from one bush to the other, it is necessary to have a distance of 3 m between the rows. A distance of 2,5 m between the plants in a row is enough.

**5.2.7 Jatropha as a support for vanilla**

In many countries (Madagascar, Uganda, Papua New Guinea, Kenya, Comores Islands) Jatropha is used as a support plant to the vanilla bean. Besides the support of the bean, the aspect of shade is very important, because vanilla as an orchidea plant needs a 50 % reduced sunlight.
To serve as a vanilla support, the branches of the Jatropha plant are cut, and only some branches at the top are left for the shade aspect. In this way, the yield of the Jatropha plants is reduced, and the time needed for the harvest of a certain amount of seeds is improved.

A feasibility study in the vanilla region in Madagascar showed, that it is not feasible to produce Jatropha oil cheaper than the diesel at the local petrol station, just because of the difficulties in harvesting the seeds in the vanilla plantations.

5.3 The Jatropha Pests & Diseases

The Jatropha plant is known as a very robust plant, and not many pests are known.

But with the establishment of large plantations (monocultures), such pests will probably be recognised and hopefully researches in a scientific way. Up to now there are some descriptions of the symptoms and of some insects, but no systematic analysis.

Up to now the largest Jatropha plantation was in Nicaragua, about 1,000 ha. There the project team discovered some insects, which attacked the Jatropha plants. Abstract of a report:

The key pest is *Pachycoris klugii* Burmeister (Heteroptera: Scutelleridae), which damages the developing fruit. Second most frequent true bug is *Leptoglossus zonatus* (Dallas) (Het.: Coreidae). Twelve further species of true bugs also feed on physic nut. Other pests include the stem borer *Lagocheirus undatus* (Voet) (Coleoptera: Cerambycidae), grasshoppers, leaf eating beetles and caterpillars as well as leaf hoppers. Among the beneficial insects pollinators, predators and parasitoids are found.

The Jatropha System - An integrated approach of rural development
5.4 The Yield

The yield of Jatropha plantations in the form of dry black seeds is not known, but many different figures can be found in different reports. These figures often don’t have any relevance, because it is not explained, how they were found. These figures reach from 3 tons per ha to 30 tons per ha.

For an economic evaluation of the production costs of Jatropha oil, the yield and in close connection to this, the amount of seeds harvested in a certain time, is the key element in the economic calculation.

5.4.1 The Production Rate

In Mali the production rate of Jatropha hedges was measured during different years and with different sizes of hedges. In general the harvest of seeds was 0.8 kg/year per m of length of a hedge. In Mali only the yield of hedges was measured, but if these figures are converted, they give a yield equivalent to 2,800 kg per ha and year (Jatropha hedges are planted at a distance of 3 m on a surface. This gives a length of 3,300 meters per ha. Multiplied by 0.8 kg/m, this gives a yield of 2,640 kg per ha.

Old hedges (not pruned) had a yield of 2 kg of seeds per year and per m of hedge (measured 1988 in Mali).

In India yields of 10 metric tons per ha and year and more are mentioned. But I think, these figures are exaggerated.

In a conference of Jatropha experts 2007 in the Netherlands, the people agreed to a proven yield of 3 to 5 metric tons per ha (of black dry seed).

In Nicaragua the yield of a Jatropha plantation was said to be 5,000 kg per ha (N. Foidl, personal communication).

In India, the DaimlerChrysler project mentions a yield of 2,500 kg per ha and year (on waste land)(G. Francis, personal communication).
5.4.2 Oil Content of Seeds
The oil content of the seeds varies between 30 and 35%. There don’t exist high oil yielding varieties up to now.

5.4.3 The Harvest
The harvest of the seeds is by hand. Up to now no machines have been tried. But this will probably be only a question of time. But the developers of machines have to make sure, that the machine does not consume more energy that it is harvesting.

5.4.3.1 Collection of the Fruits
The fruits are harvested, either the dry ones, which are black and already open, or the yellow ones, which contain already ripe seeds.

If the fruits are dry, the fruit shells are about 35% of the organic material.

The yellow fruits are not yet dry, and contain seeds which have still a high content of humidity.

In Mali we used a sort of an apple picker to collect fruits from high Jatropha plants i.e. a long wooden stick with a circular comb with a cotton bag at one end. With this tool the dry fruits can be picked from the trees, the fruits fall into the bag and do not have to be found in the grass.

Without this “Jatropha picker” the fruits are hit with a stick. Then they have to be collected on the ground. But the farmers (village women) were not enthusiastic on this tool. I never saw that they...
used it.

In establishing Jatropha plantations, the possibility of easy harvesting of the fruits is an essential aspect of plant selection/breeding, because the amount of seeds harvested in a certain time, defines as a key figure the economic feasibility of Jatropha oil production.

If the harvest is done with machines, the size of the machines has to be respected in defining the distance between the rows in a Jatropha plantation.

If one thinks of a sort of vacuum machine to suck dry fruits and/or seeds onto a trailer, the surface has to be prepared for that (not too many grass and other weed, not too much gravel or sand) and the distance between the rows has to be large enough that the machine can pass.

Ripe Jatropha fruits are yellow. The fruit dries and the hull becomes hard and black. The dry fruits remain on the branches.

Harvesting by machines: See a YouTube video from Ghana. But there are too many green fruits in the collected fruits: http://www.youtube.com/watch?v=68wcBF7Bv4.

**Content of the video:** Oxbo’s model Korvan 9000 picking jatropha. Oxbo is excited about its entry into jatropha harvest market. A mechanical jatropha harvester is just another extension of our commitment to providing mechanized solutions for agriculture worldwide. We are committed to further development of our machine based on the needs of this new industry. Jatropha offers a great biofuel solution for the world and Oxbo is working to promote and to encourage this dramatically growing industry.
5.4.3.2 Drying

If the fruits are not picked from the branches, they dry (get black) and keep hanging. The fruit shells open partly, but the seeds don’t fall out (see photo at right).

If the branches with fruits in this stage are shaken, the fruits will fall down. With a sort of a vacuum cleaner, the fruits and/or the seeds can be sucked onto a lorry.

The drying of the fruits and seeds can be done in the sun. Usually there is always enough sunshine (even in the rainy seasons) to make sure, that the fruits can dry.

5.4.4 Seed processing

5.4.4.1 Dehulling of the Fruits

The women in Mali collected the yellow fruits and opened them by hand, which is a very tiring work.

In Mali, Martin Schinke developed in 1996 an interesting device to dehull the dry fruits in an improved way. He put the dry fruits of a hard smooth surface (concrete floor, table), and
crushed them with a small wooden board, which he rolled over the dry fruits. The board had a handle, like a wooden board for plastering house walls.

Photo 25: Crushing dry Jatropha seeds with a wooden board. Photo by M. Schinke
5.4.4.2 Separating Seeds and Hulls

Also Martin Schinke developed in 1996 a device, a raddle, to separate the seeds from the hulls (see photos at left and right).

This was a very simple raddle, which could be produced by the village craftsmen (village technology).

Photo 26: Raddle for separation of seeds and fruit hulls and sand. Photo by M. Schinke

Photo 27: Seeds and seed hulls on a simple raddle. Photo by M. Schinke

Seeds have to be dry and should be stored in a dry place, and well aerated. If they are still humid, they easily are attacked by fungi.

They are also easily attacked by certain insects (beatles). But usually seeds can be stored for over a year without losing much of its oil content or germination capacity.

5.4.5 Selection of high yield plants

The identification of high yielding plants is a very time consuming task, because the plants are only in full production at an age of about 5 years. At that age the plants should be evaluated carefully to identify those with the highest yields. These plants should be multiplied vegetatively by tissue culture (see point 5.4.8).
5.4.6 Improvement of the yield by improvement of the root system

The improvement of the root system by application of plant hormones to cuttings does not seem to be very effective. The cuttings develop lateral roots very easily, if planted into humid soil. A comparison of the root development of treated and non-treated cuttings in Cambodia was not convincing.

5.4.7 Improvement of the yield by cloning

If you look into the variation of yields of different plants (visit the Jatropha website: www.Jatropha.de/plant/yield.htm), you see that only about 20% of the plants show a reasonable yield. 80% show an insufficient yield, even down to zero.

![Photo 29: Non-treated cuttings in Cambodia](image)

<p>| | | | | |</p>
<table>
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<tr>
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<tbody>
<tr>
<td>1</td>
<td>198</td>
<td>673</td>
<td>276</td>
<td>87</td>
</tr>
<tr>
<td>2</td>
<td>830</td>
<td>769</td>
<td>434</td>
<td>133</td>
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<tr>
<td>3</td>
<td>157</td>
<td>644</td>
<td>380</td>
<td>158</td>
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<tr>
<td>4</td>
<td>117</td>
<td>55</td>
<td>80</td>
<td>22</td>
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<tr>
<td>5</td>
<td>290</td>
<td>602</td>
<td>165</td>
<td>144</td>
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<tr>
<td>6</td>
<td>82</td>
<td>469</td>
<td>170</td>
<td>79</td>
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<td>7</td>
<td>36</td>
<td>234</td>
<td>245</td>
<td>63</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-</td>
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</tbody>
</table>

The Jatropha System - An integrated approach of rural development
Table 3: Yield of 20 Jatropha plants during 4 years (by G. Francis, see Graphic Nr. 4)

<table>
<thead>
<tr>
<th>Year</th>
<th>Yield (grams)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>619</td>
</tr>
<tr>
<td>10</td>
<td>232</td>
</tr>
<tr>
<td>11</td>
<td>61</td>
</tr>
<tr>
<td>12</td>
<td>9</td>
</tr>
<tr>
<td>13</td>
<td>787</td>
</tr>
<tr>
<td>14</td>
<td>305</td>
</tr>
<tr>
<td>15</td>
<td>34</td>
</tr>
<tr>
<td>16</td>
<td>31</td>
</tr>
<tr>
<td>17</td>
<td>1094</td>
</tr>
<tr>
<td>18</td>
<td>385</td>
</tr>
<tr>
<td>19</td>
<td>137</td>
</tr>
<tr>
<td>20</td>
<td>48</td>
</tr>
</tbody>
</table>

Graphic 4: Variation of average yields of 19 plants in India, grown from seeds
(data = table 3 from G. Francis)

The Jatropha System - An integrated approach of rural development
If somebody screens a lot of plants, he will find some with a good yield about 20 %, as shown in the graphic Nr. 4). These plants have to be used as a source of cuttings. These cuttings should be planted, either directly or in a polybag. The plants which will develop from these cuttings, have the same genetic properties like the mother plants, and therefore also the same yield.

The yield influences directly the amount of seeds, somebody can harvest per hour, and therefore it has a strong impact on the economic feasibility of the Jatropha oil production.

5.4.8 Tissue culture

Multiplication of plants by tissue culture is the same like multiplication by cuttings, except that the new plant develops from only a few cells.

It seems that roots are formed quite easily, if Jatropha tissue is put onto an appropriate substrate in a test tube. It is much more difficult to initiate the stem/shoot development of this plants. And then they have to undergo a hardening process, that they can be planted outside successfully.

It seems that the laboratory at Jains farm in India succeeded in this technique. They showed me some plants, that were growing outside in a protected place, and they told me, that these plants derived from tissue culture, as it was also indicated on a board.
The big advantage of this technology is the fact, that high yielding plants can be multiplied in large numbers and the yield of plantations can be improved by selecting and multiplying high yielding plants.

The costs of this technology is high at the beginning. It is the technology, the big companies of palm oil production use. They improved the yield of palm oil production to about 10 tons of oil per ha in Malaysia.

This might not be possible with Jatropha, but at least the yield of about 1 ton of oil per ha can be improved substantially.
5.4.9 Improvement of the yield by fertilizing and irrigation

The Jatropha plant even grows on marginal land and/or waste land, even in the crevices of rocks (point 4.5.2). This is true. But it is wrong to expect a high yield of these plants, of 5 or more tons of seeds per ha. This is not possible.

The photo shows a young Jatropha plant in India, which is just 14 months old, but which is well irrigated and fertilized, with liquid fertilizer. It is also pruned.

5.4.9.1 Improvement of the yield by intercropping with leguminoses (N2-fixation)

The N2 fixation element in the soil to build up plant available N-compound is an organism, which lives in symbiosis in the roots of leguminoses. This bacteria belong to the family Rhizobiaceae.

5.4.9.2 Improvement of the yield by inoculation with Mycorrhiza

Mycorrhiza (AM-funghi) is a fungus, which is everywhere present and invades about 80 to 90 % of the plants. The AM-funghi exist probably already since 900 or even 1200 million years. They are already much older than the oldest land plants.

The mycel of Mycorrhiza It forms a network of hyphae within the root system of a plant and between some plants, to make water and minerals (like P) available for the plants. In contrast to the Rhizobiae, these fungi are not specialised to certain plants.

Some researchers estimate that mycorrhizal fungus hyphae can explore volumes of soil hundreds to thousands of times greater than can roots.

5.4.10 Improvement of the yield by pruning

Pruning is a very important maintenance work to improve the yields of Jatropha plantations. As the inflorescences develop terminally (at the end of branches), it is important to induce the development of many branches. That means, one cannot leave the Jatropha bush growing by itself (photos hereunder). In this case it will develop only some long branches, and at the end of these branches the inflorescence will appear.
For a plantation, this means, that a lot of manual labour is needed for this maintenance of the plants. No detailed figures about the work needed for pruning 1 ha are available. The result of pruned bushes in a plantation is the photo in point 5.4.5.

Photo 33: A 14 months old Jatropha plant in a test plantation in India, irrigated, fertilized and pruned
Pruning will induce the development of new branches, i.e. if the branch is longer than about 50 cm, it can be cut about 10 cm behind the last diversion, or above ground. Just at this new end, some (3 to 4) new branches start to appear and will grow fast. If these are about 50 cm, they should be cut again, and new sprouts develop. In this way a nicely formed round bush will be formed, with a lot of branches and therefore also with a lot of inflorescences, which will form the fruits.

Besides of this pruning, the yield, i.e. the number of fruits developed on one bush, will be determined by the genetic properties of the plant (see point ). Therefore clones of good yielding plants should be used for plantations (see point 5.4.7.)
The Jatropha System - An integrated approach of rural development
5.4.11 Improvement of the yield by grafting

Grafting is the technology to put the vegetative tissue of a good yielding plant onto a wild plant which has been raised from seeds and therefore has a tap root. In this case the advantages of a strong plant with tap root and the good yield of the plant are put together.

The problem is, that this grafting process takes a lot of time. (in the world, all fruit trees are grafted on wild species).

5.5 The Flowers

Inflorescences are formed terminally, individually, with female flowers usually slightly larger. They occur in the hot season. In conditions where continuous growth occurs, an unbalance of pistillate or staminate flower production results in a higher number of female flowers.

5.5.1 Botanical description of the flowers

5.5.2 Male and female flowers

5.5.3 Development of flowers

Photo 42: Male (left) and female flower of a Jatropha plant in Cambodia

Photo 41: Grafted Jatropha plant in Pedro Santana, Dominican Republic. Photo: Jochen Esser

m - An integrated approach of rural development
The male and female flowers exist in a ratio of about 29 to 1. It is said that the female flowers are bigger, but I couldn’t distinguish them up to now.

Male and female flowers are difficult to distinguish, except when they are open.

Inflorescences are developed only at the end of branches. That means, that it is important to initiate the development of many branches, to achieve high yields (see also point 5.3.5).

Flowering starts at the end of the dry season. Therefore it is important, not to cut the heges during this time, if a good yield of seeds is expected.

5.5.4 Fertilisation, the role of insects

5.6 The Fruits

The Jatropha plant may produce several crops during the year if soil moisture is good and temperatures are sufficiently high. Each inflorescence yields a bunch of approximately 10 or more ovoid fruits. A three, bi-valved coccis is formed after the seeds mature and the fleshy exocarp dries.

1 fruit contains mostly 3 seeds, quite often only 2 or 4.
5.7 The Seeds

See also the Jatropha website: [www.jatropha.de/plant/seed-analysis.htm](http://www.jatropha.de/plant/seed-analysis.htm)

![Photo 44: Seeds of the Cap Verde type (left) and the Nicaragua type (right)](image)

5.7.1. Seed description

The seeds become mature when the colour of the fruits changes from green to yellow, after two to four months from fertilization. The blackish, thin shelled seeds are oblong and resemble small castor seeds (see photo above).

The size of the seeds is about 18 mm in length and 10 mm in width. See average of size in table below:

<table>
<thead>
<tr>
<th>Origin of seeds</th>
<th>Length of seeds (av. of 20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nicaragua</td>
<td>20,0 mm</td>
</tr>
<tr>
<td>Belize</td>
<td>18,8 mm</td>
</tr>
<tr>
<td>Mali (non toxic seeds from Mexico)</td>
<td>17,2 mm</td>
</tr>
<tr>
<td>Tanzania</td>
<td>16,8 mm</td>
</tr>
</tbody>
</table>

Table 4: Length of Jatropha seeds
5.7.2. Seed Weight
The weight of 1000 seeds/graines is about 680 grams (Tanzania). That means, 1 kg of seeds has about 1,450 seeds (Cap Verde type), or 1,150 (Nicaragua type).

<table>
<thead>
<tr>
<th>Origin of seeds</th>
<th>Weight of 1000 seeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nicaragua</td>
<td>878 g</td>
</tr>
<tr>
<td>Belize</td>
<td>813 g</td>
</tr>
<tr>
<td>Mali (non toxic seeds from Mexico)</td>
<td>542 g</td>
</tr>
<tr>
<td>Tanzania</td>
<td>682 g</td>
</tr>
</tbody>
</table>

Table 5: Weight of Jatropha seeds

1 litre of dry seeds has a weight of about 430 grams. I.e. 1 m³ of a container can be loaded with about 430 kg of seed.
Therefore it is economically much more interesting to transport the oil and to do the extraction at the place of Jatropha seed production.

<table>
<thead>
<tr>
<th>Origin of seeds</th>
<th>Weight of 1 litre of seeds</th>
<th>Volume of 1 ton of seeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mali</td>
<td>436 g / liter</td>
<td>2.3 m³ / ton</td>
</tr>
</tbody>
</table>

Table 6: Weight and volume of seed

5.7.3 Seed Composition
Analysis of the Jatropha seed shows the following chemical composition (from Reyadh, Egypt):
- Moisture 6.20 %
- Protein 18.00 %
Fat 38.00 %  
Carbohydrates 17.00 %  
Fiber 15.50 %  
Ash 5.30 %

The oil content is 35 – 40% in the seeds and 50 – 60% in the kernel. The oil contains 21% saturated fatty acids and 79% unsaturated fatty acids. There are some chemical elements in the seed which are poisonous and render the oil not appropriate for human consumption.

5.8 The Leaves

The leaves are large and green to pale-green, alternate to sub-opposite, three-to five-lobed with a spiral phyllotaxis. Some varieties have larger leaves (Sambava, Nicaragua) and a rounded form (see also photo 3).

Jatropha leaves are used as food for silkworms, but not very successfully.

The leaves are also used as a local medicine.

5.9 The Wood

The wood has no use as fuel wood, because it is not an energy dense wood. But it is said, that it can be used to make small boxes for cheese.

In Thailand (Jatropha School of Kasetsart University), they use the wood of Jatropha

Photo 45 and 46: JCL-leaves.
At left, the Sambava variety see also photo 3

Photo 47 and 48: Paper and charcoal from dried Jatropha wood in the Jatropha school of the Kasetsart University in Thailand
branches for paper and charcoal production, after the chipped branches are dried.

### 5.10 The Sap (liquid latex)

The sap, i.e. the transparent liquid which comes out of cut leaves or branches, has medicinal effects. In many countries, people say that it is used against tooth pain. And it is used for wound healing (cuts in the skin), because it stops bleeding and accelerates the healing process of wounds.

### 5.11 Other Uses of the Plant (from wikipedia.org)

- **Leaves**
  
  The young leaves may be safely eaten, steamed or stewed. Cooked with goat meat, they are said to advantageously counteract its smell.

  Pounded leaves are applied near horses’ eyes to repel flies in India. HCN (Hydrogen cyanide) is present in the leaves.

- **Flowers**
  
  The species is listed as a honey plant. HCN is present.

- **Nuts**
  
  Sometimes roasted and eaten, although they are purgative.

  They can be burned like candlenuts when strung on grass. HCN is present.

  Used as a contraceptive in South Sudan.

- **Seeds**
  
  Also used as a contraceptive in South Sudan.

  The oil has been used for illumination, soap, candles, the adulteration of olive oil, and making Turkey red oil. Turkey red oil, also called sulphonated (or sulfated) castor oil, is the only oil that completely disperses in water. It is made by adding sulfuric acid to pure Jatropha oil. It was the first synthetic detergent after ordinary Soap, as this allows easy use for making bath oil products. It is used in formulating lubricants, softeners, and dyeing assistants.
The seeds in the zone around Misantla, Veracruz are very appreciated by the population as food once they have been boiled and roasted. It is unclear if this is due to the existence of a non-toxic variety of Jatropha in Mexico and Central America, or if the seeds become edible once processed by cooking.

It is also similarly reported that Jatropha seeds are edible once the embryo has been removed. Again it may be so because of these seeds coming from a local non-toxic variety. HCN is present.

- Roots
  Their ashes are used as a salt substitute. HCN and Rotenone are present.
- Bark
  Used as a fish poison. HCN is present.
- Latex
  Strongly inhibits the watermelon mosaic virus.
- Sap
  It stains linen. Sometimes used for marking.
- Shrub
  Mexicans grow the shrub as a host for the lac insect, which is used in medicine as hepatoprotective and antiobesity drug. (Picture of lac insect here, drawing of insect, its larva and a colony here).
  Used for erosion control.

6. The Oil Extraction

Besides the time needed to collect the seeds needed for the production of the oil, the oil extraction process is a key element in the economic calculation of the production process of Jatropha oil.
6.1 Traditionnal Ways

I only found a tradition in Jatropha oil production in Madagascar. In the south of the island, in the province of Fianarantsoa, women produce Jatropha oil and sell it in very small quantities, mainly to hair dressers in the capital.

In the north of Madagascar, in the village of Ankaika Be near Andapa in the SAVA region, an old lady showed the production of Jatropha oil. She needed 3 hours of time to produce about 0.25 liters of oil, i.e. about 12 hours of manual work for 1 liter of Jatropha oil.

This is an explication, that the oil is sold for a very high price, for about 25.000 Ar per liter. But the women buy only very small quantities, i.e. 100 Ar or 5 US cent per spoon.

To produce Jatropha oil the traditional way, the seeds have to be shelled. Then the pure white kernels are roasted and then ponded to get a paste. This paste is mixed with water and boiled for about 20 minutes. The oil is floating up and is scimmed with a spoon.

This oil is boiled again to get rid of the surplus water. This oil is then filtered to get rid of the particles.

As mentioned above, this process takes about 12 hours manual working time for 1 litre of oil, the collection of the seeds not included.

The Jatropha System - An integrated approach of rural development
Photo 52: Ponding the shelled seeds

Photo 53: Boiling of the Jatropha paste with water

Photo 54: Scimming the floating oil

Photo 55: Purification of the scimmed oil

Photo 56: Three hours time of hand work for less than a quarter of a litre of Jatropha oil

The Jatropha System - An integrated approach of rural development
6.2 Manual Presses

Manual presses for oil extraction are available in many countries. One of the most available presses is the Bielenberg Ram press, because it was and still is disseminated by Enterprise Works, former ATI (Appropriate Technology International), an American organization working in close relationship with USAID, the American organization for co-operation.

Looking into economical aspects, it is important to note, that the oil extraction by hand is mostly more expensive than by a motor driven expeller, just because the yield of oil by working hour is very limited.

6.2.1 Ram Press

The “Bielenberg Ram Press” was developed by Carl Bielenberg in Tanzania to facilitate the extraction of edible oil from seeds like sesame, sunflower and/or peanuts. The design is very simple, drawings are available, and the press can be produced in small workshops for a reasonable price (around 150 USD).

Photo 57: Bielenberg Ram Press, copy produced in Madagascar,

Photo 58: Cage of Bielenberg Ram Press of KAKUTE, Tanzania

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**Video 1:** Video of the Ram press demonstrated by Madagassy farmers of a Koloharena near Fianarantsoa: [http://jatropha.de/madagascar/PICT1720.AVI](http://jatropha.de/madagascar/PICT1720.AVI)

**Video 2** on YouTube about the Bielenberg Ram Press in Arusha: [http://www.youtube.com/watch?v=9KLQe5lF7ec](http://www.youtube.com/watch?v=9KLQe5lF7ec)

**Video 3:** Mrs Voon of the Anti-Erosion Programme of the KfW in Madagascar, working with a Bielenberg Ram Press: [http://www.youtube.com/watch?v=ih_FaL6ZGdM](http://www.youtube.com/watch?v=ih_FaL6ZGdM)

The press has a capacity of 1 to 2 liters of Jatropha oil per hour (depending on the skill of the extraction worker). Therefore it is useful only for small scale oil production for subsistance production of farmers or for demonstrations.

<table>
<thead>
<tr>
<th></th>
<th>Bielenberg Press SFX</th>
<th>Bielenberg Press ACAMECA</th>
<th>Bielenberg Press VALY</th>
<th>Kakute-Press TANZANIE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield in oil for 1 kg of seed</td>
<td>148.4 g</td>
<td>165.2 g</td>
<td>110.8 g</td>
<td>144.5 g</td>
</tr>
<tr>
<td>Amount of oil extracted per hour</td>
<td>0.445 kg</td>
<td>0.892 kg</td>
<td>0.604 kg</td>
<td>0.722 kg</td>
</tr>
</tbody>
</table>

Table 7: Overview of test results of the Bielenberg RamPress reproduced in Madagascar (from; Test des presses à main par ERI (Résultas du test))

### 6.2.2 Madagascar Press

In Madagascar traditionally a wooden oil press is used, but I didn’t understand well the function of that press. In any case, it doesn’t work well. In the screw press, a round plate is forced upon a oil containing biomass by turning the screw by long levers.

### 6.2.3 Komet Press

### 6.2.4 Screw Presses

The Jatropha System - An integrated approach of r
In the screw press, a round plate is forced upon a oil containing biomass in a metal cylinder with holes by turning the screw by long levers. The oil runs out of the holes.

From its design and the experiences so far screw presses are working well for the extraction of oil from soft seeds, like from oil palms.

The screw presses are relatively easy to produce, but they are difficult to manipulate (see the photos below) and the spare parts, like the screw, are difficult to be produced in small workshops in developing countries. For the Bielenberg Ram Press this is different: It doesn’t have parts which are difficult to produce.

**Photo 60: Screw press of ITDG**

**Photo 61: Women working with the screw press of ITDG**

### 6.2.5 Hydraulic Presses

In the hydraulic presses, the pressure on the cage is effectively produced by a hydraulic crick, which is usually used to change wheels of lorries.

This system works perfectly, because it is very easy to produce the necessary pressure. But the crick is not designed for this work, and soon the technology shows problems: The seals of the hydraulic pump have to be replaced soon, and the crick itself gets fine cracks, where the hydraulic oil sorts.
This can be explained by the fact, that for a lorry, the crick has to work perhaps 3 or 4 times a year, whereas for oil extraction, the crick was used about 10 to 15 times a day. The material just could not stand the heavy work.

6.3 Engine Driven Expellers

6.3.1 Tinytech Expeller

The interest of Tinytech was to improve their design of the press for their main market, which has a strong focus on expelling peanuts. Thus it is important to know that the Tinytech press is designed to suit particular this seed. Peanuts have a low fiber content thus it is required that the nuts are steamed prior to expelling and this is the reason the Tinytech expeller has a boiler and cooker. This preprocessing is not necessary for Jatropha provided the expeller has the appropriate screw. The type of screw/cage design the Tinytech expeller is using is not the best for Jatropha in fact it requires the preprocessing to perform properly.

Actually Tinytech had concentrated on mass production to keep the cost low and has this approach up to date. The disadvantage of this otherwise very positive approach is that the machine design needs to be kept constant as much as possible and modifications necessary to process other seeds than peanut are avoided.

6.3.2 Chinese Expeller

Some words on the Chinese expellers by Mr. Metler, the engineer, who designed the Sundhara expeller:

The Jatropha System - An integrated approach of rural development
We had evaluated the Chinese models as well and found the following: the expeller has a gear box which is difficult to replace once it fails. The screw is hardened and thus made from high carbon steel. Once it is worn, and it will be worn, it can not be rebuild by welding because of the high carbon content. We decided to make the screw from mild steel and hardface the surfaces subject to wear. so a local technician with basic welding skills can rebuild the screw. The screw is a “single stage” arrangement which is known for low extraction efficiency. The cage is made up of rings which are not possible to be rebuilt when worn. If wear starts the through put drops sharply.

The entire concept of this expeller relies on replacing worn screw and cage parts by new parts from China which proved to be expensive and very difficult. In the SOE design we made it a point that all wearing parts can be reconditioned locally, and not depend on expensive imports from overseas.

Caution: the economics of the expeller depend on the long run mainly on the reconditioning cost of worn screw and cage parts and on the energy needed to drive the machine. The initial investment cost counts much less than felt. In this sense a cheap machine can be very expensive.

6.3.3 The Sundhara Expeller
The Sundhara expeller is a motor driven oil extraction device with a worm as a central part.

This expeller was designed by German engineers by order of the German co-operation (GTZ) to be implemented in villages in Nepal and to be produced within the country.

Introducing a motorised expeller in Madagaskar:
In February this year I had proposed a procedure which I would still find the best approach regarding the technology transfer.

Since then, triggered by the ever rising fuel prices, various governments have started Jatropha projects. We get more and more requests for technology transfer of the SOE 60 technology. I am just back from a consultation with experts from the Philippines and Indonesia. In these talks the idea was born not to just concentrate on the expeller alone but consider the entire system of after harvest processing jatropha seed. The result is the "Plant Oil Generating Unit (PGU)" which is a unit operated by the community and combining oil expeller, diesel engine running with raw plant oil and an electric generator for village electrification. It appears that this unit would have a high acceptance in the communities as it is not only an expeller but uses the necessary diesel engine in a multiple form. Please find attached the brochure describing this unit. I would suggest to think of an introduction of the PGU in Madagaskar. I would be happy to help where necessary.

At this moment we are working on programs implementing this idea and its technology transfer in Tanzania, the Philippines and in Indonesia. The government of the latter two countries have started a vigorous program on Jatropha Biodiesel recently and are pushing hard to introduce the PGU quickly.
The prototype of the Sundhara expeller was sent to Mali for Jatropha oil extraction by a women group in Falan, about 80 km south of Bamako.

During the project time in 1993 another 6 expellers were imported from Nepal.

6.3.4 The Sayari expeller

The Sayari expeler is the same design as the Sundhara expeller, but it is produced in Tanzania to extract sunflower seed. 2 private workshops produced the press in Morogoro for a price of about 3 000 USD per unit. The engine (electric motor or Indian diesel engine) was included in this price. About 40 units of this expeller were produced.

To introduce the production of this expeller in Tanzania, a project of “Bread for the World” sent 2 of the engineers to Tanzania to train the people in the workshops.

An important part is the maintenance of the expeller, because the worm has to be reestablished regularly (after a defined amount of seeds extracted, usually two times per year.

**Photo 63:** Sundhara expeller from the side, visible is the cage composed of iron bars with a worm inside.

**Photo 64:** Sayari expeller driven by an Indian diesel engine (Lister type)
7. The Jatropha Oil

Jatropha oil is extracted from the seeds. They contain about 30 to 35% of oil. With the Bielenberg Ram press only about 18% of the seed weight can be extracted in the form of oil (example of ERI in Madagascar). With an expeller (Sundhara or Sayari) usually 25% of the weight can be extracted as oil.

The oil is not edible. It is poisonous, because of the content of phorbol esters.

7.1 The Properties

Some chemical analysis of Jatropha curcas oil are given in following tables

1.- from Reyadh, Egypt:
   - Acid value 38.2
   - Saponification value 195.0
   - Iodine value 101.7

2.- from Siaka Koné, Workshop of CCA-ONG, Bamako, march 1995 (95.19):
   - Saponification value 196
   - Iodine value 92

3.- from Münch/Kiefer, Die Purgiernuss, University of Hohenheim, Germany, Febr. 1986, p. 128 (86.2-1):
   - Acid value 3 - 38
   - Saponification value 185 - 210
   - Iodine value 95 - 110

Remark: a low acid value occurs using chemical extraction

4.- from Henry Lamotte GmbH, Bremen, Analysis of Jatropha oil from Mali in 1996:
   - Free fatty acids 3.69%
Chemical properties of *Jatropha curcas* oil from different sources

7.1.1 Physical Properties

- Specific weight 0,92 (general figure);

7.1.2 Chemical Properties

7.1.2.1 Composition of Fatty Acids

Chemical analysis of *Jatropha curcas* show the main fatty acids:

1.- from Reyadh, Egypt

- Palmitic acid % 4.2
- Stearic acid % 6.9
- Oleic acid % 43.1
- Linoleic acid % 34.3
- Other acids % 1.4

2.- from Henry Lamotte GmbH, Bremen, Analysis of *Jatropha* oil from Mali in 1996:

- C 16:0 Palmitic acid 15,6%
- C 18:0 Stearic acid 6,7%
- C 18:1 Oleic acid 42,6%
- C 18:2 Linoleic acid 33,9%
- C 18:3 Other acids 1,3%

*Table 8: Fatty acid composition of Jatropha curcas oil from different sources*

7.1.2.2 Content of Free Fatty Acids

The content of free fatty acids improves during storage. The older the oil is, the higher is the content of free fatty acids.
7.1.2.3 Content of Sulfur and Phosphorus

The content of Sulfur is very low, if any. It is neglegtable.

The content of Phosphorus depends very much on the way of oil extraction. A cold extraction gives oil with a low content of Phosphorus.

The washing of the oil with water to eliminate particles (parts of cell walls) reduces the Phosphorus content as well.

7.1.2.4 Storage Problems

The oil has to be stored in the absence of oxygen (air), because the oxygen leads to a polymerization (gel) of the oil molecules.

If the containers are always filled to the edge and no air can access the oil, a long storage is possible. Otherwise the gaseous upper part of the container has to be filled with an inert gas like CO$_2$ or Nitrogen which does not react withe oil.

7.1.3 Energetical Properties

7.1.3.1 Comparison Jatropha oil / Diesel as fuel

The following tables with figures of the composition of Jatropha oil are from different authors. It is not always clear, where they got the figures from. Therefore these figures should be treated with caution.

Property Jatropha oil / diesel oil (from Reyadh, Egypt):

- Viscosity (cp) (30 °C) 52.6 (5.51)2 / 3.60
- Specific gravity (15 °C/4 °C) 0.917/ 0.923 // (0.881) 0.841 / 0.85
- Solidifying Point (°C) 2.0 / 0.14
- Cetane Value  51.0 (38) / 47.8 .59
- Flash Point (°C) 110 /340 / 80
- Carbon Residue (%)  0.64 / < 0.05 . < 0.15
- Distillation (°C) 284 . 295 / < 350 . < 370
- Sulfur (%) 0.0 / < 1.0 . 1.2
Properties of Jatropha curcas oil versus diesel oil

Standard specification of Jatropha oil / Standard specification of Diesel (from Reyadh, Egypt):

- Specific gravity 0.9186 / 0.82/0.84
- Flash point 240/110 °C / 50 °C
- Carbon residue 0.64 / 0.15 or less
- Cetane value 51.0 / 50.0 up
- Distillation point 295 °C / 350 °C
- Kinematics Viscosity 50.73 cs / 2.7 cs up
- Sulphur % 0.13 % / 1.2 % or less
- Calorific value 9 470 kcal/kg / 10 170kcal/kg
- Pour point 8 °C / 10 °C
- Colour 4.0 / 4 or less

Table 9 (above): Standard specification of Jatropha oil versus diesel oil

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Diesel</th>
<th>Jatropha Oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy content (MJ/kg)</td>
<td>42.6 - 45.0</td>
<td>39.6 - 41.8</td>
</tr>
<tr>
<td>Solidifying point (°C)</td>
<td>-30</td>
<td>2</td>
</tr>
<tr>
<td>Flash point (°C)</td>
<td>80</td>
<td>110 - 240</td>
</tr>
<tr>
<td>Cetane value</td>
<td>47.8</td>
<td>51</td>
</tr>
<tr>
<td>Sulphur (%)</td>
<td>1.0 - 1.2</td>
<td>0.13</td>
</tr>
</tbody>
</table>

Table 10: Basic properties of diesel oil versus Jatropha oil (Mike Lawton, Futuretec, October 2004)
8. The Use of the Oil

8.1 As Fuel

One should know that Air New Zealand made a test with Jatropha oil as fuel in a Boeing 747 airplane (1 engine) in December 2008 (see the news section of the Jatropha website the 19. 01. 2009 (http://jatropha.de/news/jcl-news.htm).

Usually plant oil cannot be used as fuel in engines. Either the fuel has to be adapted to the engines, or the engines have to be adapted to the plant oil.

The adaptation of the plant oil to the engine is a chemical dimination of the fuel molecules by transesterification. This means, that a big oil molecule (molecular weight of about 900) is chemically split into 3 smaller molecules. This process is called transesterification.

8.1.1 Trans-esterification of the Oil

The 3-valued alcohol glycerol, which binds 3 long chained fatty acids, is replaced by 3 mono-valued alcohol molecules, methanol or aethanol, which replaces the glycerol at the end of the fatty acids. 1 big oil molecule is split into 3 smaller molecules. This process is catalysed by caustic soda NaOH. The glycerol is set free. The resulting fuel is called biodiesel, because it has properties which are very similar to diesel fuel.

Molecular formula of the transesterification process:

In practical terms, 1 liter of oil gives about 1 liter of bio-diesel.

8.1.2 Pure Oil as fuel

The use of plant oil as fuel is not new. Already Rudolf Diesel, who invented the Diesel engine, run his first Diesel engine with groundnut oil in the year 1895. The new engine was publicly demonstrated at the World Exhibition in Paris in 1900 running with groundnut oil.
The idea of Rudolf Diesel was to use cheap waste products of the petroleum industry to run his engine. So he tested the heavy oils for his engine.

But the petroleum industry was also quick to offer another cheap alternative to plant oil, by labeling one of its by-products as “Diesel-fuel”. In comparison with the cheap waste product “Diesel-fuel”, plant oil was not an economically feasible alternative and was quickly forgotten.

Now (in the years from 2005 onward) the rise of the fossil fuel prices gives plant oil a new chance as fuel in Diesel engines.

Todays diesel engines are sophisticated machines, which still can run on plant oil as fuel for a short time. But for a longtime use, the engines have to be adapted at the use of plant oil. The adaptation process is mainly due to the high viscosity of the plant oil.

That means, the oil has to be heated to about 70 ° centigrade before entering into the engine with the injection pump. Only at that temperature the

8.1.2.1 Precombustion Chamber Engines

In the precombustion chamber engine the fuel is injected not directly into the combustion chamber (the cylinder), but into a prechamber, where the combustion will take place. Usually the combustion in these prechamber engines is more complete (higher temperatures in this pre combustion chamber). Therefore this kind of engine (developed in the years around 1920) is suitable to use pure plant oil as fuel. This precombustion chamber can even be opened from outside with a large screw, for cleaning or general inspection. The paper No. 17 in the bibliographie gives the results of the test of a Lister-type Indian engine (Fieldmarshal II), with plant oil as fuel and lubrication oil.
8.1.2.2 Direct Injection Engines

Pre combustion chamber engines are outdated nowadays (2009). Only direct injection diesel engines exist.

8.1.2.3 The Plant Oil Engines

8.1.2.3.1 Principles of Plant Oil Combustion

The main big difference between diesel and plant oil fuel is the viscosity. This is usually overcome by heating the plant oil to about 80 °C. At this temperature the plant oil behaves almost like diesel fuel, i.e. it vaporizes when injected into the cylinder. These small droplets can easily be burnt. Sometimes there is even a small advantage in the power output with plant oil fuel, because the plant oil molecules contain oxygen, which is needed for the combustion.

It is important to make sure, that the plant oil fuel is burnt completely. Otherwise it passes alongside the cylinderwalls into the lubrication oil and can damage because of gel building (polymerisation). This gel cannot function properly as lubrication oil and the engine gets destroyed.

The Lanz Bulldog tractor seems to be comparable to the Lister type engine. It can use all kind of fuel. It can use plant oil as fuel without any modification. But the efficiency of this engine is quite poor. It will take a couple of years to develop good engines, which use plant oil efficiently. Up to now only the diesel was used as fuel and the development went into the direction to optimise the engine to the diesel fuel and to apply strong norms for the diesel fuel.

This development has to be restarted for plant oil engines. This will not be easy, because different countries will have different fuels in the future. Plant oil as fuel will be probably limited to the developing countries. The industrialized countries will keep their standard and use artificial diesel fuel which will have the same properties as diesel. So they still can use their engines.

8.1.2.3.2 German Engines

8.1.2.3.2.1 Hatz E89
This engine is not produced anymore. It was a very tough engine, used mainly in construction machines. It had 1 cylinder, a precombustion chamber, and could use Jatropha oil directly, without modifying the engine (1 Hatz engine was installed in Falan, Ouélessébougou, Mali). The GTZ-Jatropha-project used this engine to drive a grain mill and alternatively a Sundhara expeller in this village.

8.1.2.3.2.2 Deutz

The German company DEUTZ produces a precombustion chamber engine, which can be used easily for plant oil as fuel. Usually this engine is used underground in coal mines, because it is regarded safe and not to initiate ignitions (in the case of higher methane concentrations).

8.1.2.3.2.3 Elsbett

The Elsbett-engine once was developed by the engineer Ludwig Elsbett as a very economic engine. It had only 3 cylinders and a complete injection system (pump-fuse-system) for each cylinder. This design made the engine able to use pure plant oil as fuel.

So Elsbett offered his engine as a plant oil engine. But the big engine producers did not buy the patents. They just waited 25 years until the right were free. And now you find this low consumption engines in many cars (3 cylinders, pump-fuse system). The company ELSBETT went bankrupt and is now only converting existing engines into plant oil engines.

8.1.2.3.3 Indian Engines

The Indian plant oil engines, we talk about, are called Lister type engines, because they are Indian copies of the English Lister engines from about 1920. The design of these engines in India did not change since that time, because the production process in Rajcot (the Indian state, where these engines are built) is divided in so many small steps, which are carried out by independent small entrepreneurs, that a modernisation or change is not possible, without questioning the whole process in that region.
So the Indian engines represent an old fashioned pre combustion chamber engine, which is solid enough to support pure plant oil as fuel without any modification.

8.1.2.3.4 Other engines

Principally all diesel engines can be converted to run on plant oil as fuel (watch the video), the main thing is to get the viscosity of plant oil near to the viscosity of diesel. This is done by heating the plant oil to about 80 °C, before it enters the injection pump of the engine (heat exchanger).

Mr. Schoen in Phnom Penh, Cambodia, converted his car (an Izuzu 4 wheel drive) to run with used cooking oil. He installed an extra fuel filter and a heat exchanger in his car. The oil he collected in the town, was filtered in a Kapok-filter.

**Video 5:** Lister type engine run with Jatropha oil as generator engine in an asynchone design:

**Photo 67:** Lister type Indian diesel engine with precombustion chamber, which can run directly with pure plant oil
8.1.2.4 The Plant Oil Cookers

Plant oil is a very different material for combustion than kerosin or petrol. This difference in its physical and chemical properties makes it so difficult to use plant oil as fuel in cookers.

8.1.2.4.1 Hohenheim/BSHG (Bosch-Siemens Haushaltsgeräte) Pressure Cooker

The BSHG cooker, which was developed at the University of Hohenheim by Elma r Stumpf in its first phase, works at the principal of a pressurized kerosene cooker: the fuel is pushed by pressure through a pipe and is gazified by the heat, the burning cooker produces by the flame, which is supported by the gaseous fuel, which sorts from a fuse in the pipe.

To my understanding, this cooker principally cannot work properly, because the heat to gazify the oil also forces a certain amount of oil molecules to crack, i.e. to fall into pieces. This gives a deposit of carbon, which blocks the pipe and the fuse after a certain time.

Another important disadvantage is the fact, that the cooker has to be preheated with pure alcohol or kerosin, so that the oil is gazified.

Since many years the company BSHG is trying to finalize this plant oil cooker. But they did not succeed, because the effort to clean the cooker seems to be too high. The pipe has to be cleaned once a day with a steel rope and the fuse has to be cleaned every 20 or 30 minutes.
This seems to be too difficult for the housewives, because they have to kneel down and clean the fuse during combustion, with a 20 liter pot on the stove.

Up to now this stove cannot be bought on the market.

**Video 7 (26 sec):** The BSHG-Cooker in YouTube: Pressurized cooking stove operating on jatropha oil: [http://www.youtube.com/watch?v=R3OOFHcIa_o](http://www.youtube.com/watch?v=R3OOFHcIa_o)

### 8.1.2.4.2 KAKUTE Jatropha Oil Cooker

The KAKUTE stove, which has been copied and tested by the stove programme of GTZ (Green-Mad) in Madagascar, works after a completely different principal. It is more or less a wick cooker, where pieces of used cloth play the role of the wick. They are placed around a round “chimney” (air access) and soaked with oil. The oil soaked cloth is lit and the cloth burns. But a structure of carbon rests and gives the oil the possibility to mount by capillary forces to the surface and be burnt.

During combustion the oil heats up and the cooker develops more heat.

### 8.1.2.4.3 Principals for the design of a Jatropha oil cooker

The oil should not be evaporated, because it decomposes. Since the oil does not evaporate, the structure (wick) which is used to bring up the oil by capillary forces, is burnt and only a structure of carbon is used for the capillary effect.

### 8.1.2.5 The Plant Oil Lamps

Plant oil has different physical properties than petrol or paraffin. Therefore it behaves also differently and the lamps have to be adapted to these properties:
E.g. the higher viscosity of the oil prevents it to get up a wick to be burnt like in a petrol lamp. And the high evaporation point prevents the oil to burn as a gas, a bit away from the wick.

8.1.2.5.1 Traditional Plant Oil Lamps
Already during the Pharaonic times some thousand years ago plant oil lamps have been used. This principle has not changed since.

8.1.2.5.2 Binga Oil Lamp
The first Binga oil lamp was just a glass with an iron cover with a hole. In the hole was a wick, that entered into the oil (like a petrol lamp). This light became smaller and got off, when the surface of the oil sunk and not enough oil could get up the wick to nourish the flame (because of the high viscosity of the oil).

This was overcome by the second generation of Binga lams, where the wick was floating in the oil and the flame was only a few millimeters above the surface of the oil. Somebody said that the inventors of the “Binga lamp” must belong to the catholic religion, because the eternal flames in the catholic churches have the same principle.

8.1.2.5.3 Floating Device
To overcome the restrictions imposed by the high viscosity of the Jatropha oil, the wick of the Jatropha oil lamp is fixed at a floating disc. In this way the distance between the surface of the oil and the flame is only some few millimeters. This distance can be traveled by the big plant oil molecules (molecular weight about 3 times as big as that of lamp paraffin or lamp petrol). Since the plant oil does not evaporate, the oil burns right at the surface of the wick, which has the consequence that the wick itself burns, too. By the heat of the flame some plant oil molecules crack, and pure carbon is disposed on the wick, which serves as a support for the capillary forces to bring more plant oil to the flame.
After a short time the wick does not exist any more and it has to be pushed from below to light the flame again.

To better understand the principle, see the description of the “Binga lamp”

The flame, and therefore the light, is always very small. To have more light, several such lamps have to be put into the room.

8.1.2.5.4 Cotton Wick Disk

The glass with the floating wick seemed a very simple technology to me. I was very much impressed by a woman from Dominican Republic, who showed me even a more simple method to make light with plant oil:

She formed a device of cotton, like a reversed mushroom, i. e. a broad base and a thin pin sticking upwards, and put it on a saucer. The oil was poured over the pin and then lit with a match. The pin functioned as wick, and the saucer functioned as a reservoir.

8.2 For Soap Production

Soap is one of the basic needs for human beings to wash themselves and to wash the clothes and the dishes. Soap is the alkali-salt of the fatty acids of plant oil or animal fat. The glycerin can be left within the soap and gives it a smooth effect.

Animal fat is a bit more difficult to convert to soap, because it has to be heated to be liquid (there are always rests of cells which form a sediment after heat extraction of the animal fat.

The soap making process from liquid plant oils is very simple. In some regions (like West-Africa), soap making by the village women is a well known and widespread technology. In

The Jatropha System - An integrated approach of rural development
former times the women used potash to make soap. Nowadays caustic soda is found everywhere on the markets in West African countries, even in remote villages. In other regions (like East-Africa) soap making is not known in the villages.

8.2.1 On Village level

In West Africa, soap making is a common work for rural women. In former times they used potash as a salt, now they use caustic soda, which is available on the markets, even in remote villages.

8.2.1.1 Traditional Soap Making in Mali

Traditionally soap was also made from Jatropha seeds. For this, the women knocked each seed with a small stone to get the kernels out of the shell. These kernels were pounded and sieved, to get a sort of “flower”. This “Jatropha flower” was mixed with caustic soda and water and cooked. Underneath you find some photos to this kind of soap making. The material was formed into small round balls (like tennis balls). This balls had a brown colour due to the seed material, which was oxidised.

Photo 74: Dehulling the seeds by knocking the seed with a stone

Photo 75: Cooking the “Jatropha flower” with caustic soda

Photo 76: Soap balls from Jatropha sediment

The Jatropha System - An integrated approach of rural development
8.2.1.2 Improved Soap Making with Oil

An improved soap can be made from Jatropha oil. See in the photos underneath the Jatropha oil, the liquid soap (mixture of oil and dissolved caustic soda and flower, a mould and the cutting of the soap pieces:

![Photo 77: Jatropha oil for soap production](image)

![Photo 78 Mixture of oil and water and caustic soda](image)

![Photo 79: Pouring the liquid soap into a muld for hardening](image)

![Photo 80: Cutting soap pieces out of the soft material in the village of Ouélessébougou, Mali](image)

8.2.2 Artisanal Soap Production

The artisanal soap production in our ase did not differ very much from the Village soap production with oil. Only the cutting of the soap into pieces and the packaging differed, and the artisan added some honey to the soap.
8.2.3 Industrial Soap Production

The industrial soap production in Bamako, Mali, was done with Karité (Shea butter) by a Libanese entreprenuer. I cound not convince him to do it with Jatropha oil. He made a test production and was satisfied from the technical point of view. But the oil was not available for him.

8.3 Other High-Valuated Uses

8.3.1 As Lubrication Oil

The IFO Lorry production company in Nordhausen, Thüringen, Germany, made a test on a test bunch with Jatropha oil as lubrication oil in the Indian type Lister engine. They said, that the Jatropha oil can be used as lubrication oil in this kind if slow turning diesel engines (about up to 850 rpm). See report (with test report in German): bibliographie Nr. 17.

Other high valued uses might be: the use of the oil as drilling oil, as hydraulic oil, and as leather softener
8.3.2 For Medicinal Use

In the Indian Journal of Pharmacology was an article indicating, that one component of the Jatropha oil, the curcain, accelerates the healing process of wounds substantially. I don’t know of any practical use of this knowledge.

8.3.3 As Chemical Raw Material

Out of the Jatropha oil, several components can be isolated and used as raw material for chemical products. The first step is to destroy the fat (triglyceride) molecule into glycerine and fatty acids. The fatty acids (or its mono-esters) can be used as raw material for different chemical reactions. The following examples show the possibilities, which are offered by a company in Nigeria (http://www.kenergyinternationaltd.com). They usually use palm oil.

Oleic Acid Methyl Ester, as a kind of greasy raw material widespread, can be mainly used on surface-activated solvents, detergent, hair dye, lubricants, leather-softener, stuffing medicinal preparation as well as medicine raw material.

C16C18 fatty acid methyl ester, as a kind of organic chemical raw material, can be widely used to synthesize many fine chemical products, such as fat mellow, alkyd resin, alkyl alcohol amide, myristic acid different propyl ester, α-sulfonation fatty acid methyl ester, sucrose fat diethylene glycol dinitrate,etc. It also can be used as the pigment dispersing solvent of plastic color-parent material, leather stuffing medicinal preparation.

The SBRC in Jakarta, Indonesia and and the research request of Mr. Robert Manurung, IT-Bandung, Bandung, Indonsia, work on the use of Jatropha oil as a chemical raw material for different chemical products.

9. The Use of the By-products

For the moment (June 2009) the fossil oil prices are quite low. This means, Jatropha oil production is only economically feasible if there are other uses beside (development goals like income generation, erosion control, etc.).

In the long run, the prices for fossil fuel will get up and then Jatropha oil production will turn to be economically feasible.
9.1 Use of the Sediment

9.1.1 Production of Soap on Village Level
The women in the village of Falan in Mali used the sediment of oil purification to make soap. It was a black soap, but it was very useful. For them it was interesting, because the raw material for this kind of soap making was free of charge.

9.2 Use of the Oil Cake

9.2.1 Press Cake as Organic Fertilizer
The press cake is a very good organic fertilizer (from its composition, it is almost like chicken manure). It seems to be better than mineral fertilizer and the farmers in Mali paid for the press cake, mainly for 2 reasons:

1. The press cake is not washed out of the soil by heavy rains;
2. The press cake has a long lasting fertilizing effect, which might be due to the fact, that the proteins as the source of nitrogen, are only slowly decomposed by bacteria.

9.2.2 Press Cake as Animal Feed
The press cake cannot be used as animal feed, because an economic feasible detoxification has not yet been developed. Detoxification can be achieved in the laboratory, but not yet in practical terms.

9.2.3 Press Cake as Protein Source
The press cake contains a very high valued protein mix, if it would be edible. Unfortunately it is toxic, so the value of the proteins is just a theoretical one. Detoxification was only possible in laboratory scale.
9.2.4 Press Cake as Cooking Fuel

The press cake can be used as cooking fuel in the form of pelets. DILIGENT inm Tanzania is not using it in this ay, because it produces too much smoke. They use the press cake for biogaz production.

9.2.5 Press Cake for Biogaz Production

The press cake is sa very interesting raw material for biogaz production, due to its content on fats and proteins. During the fermentation process the minerals will be kept in the slurry, only the Nitrogen of the proteins will be eliminated in the form of ammonia and is almost not any more available for the plants, if the slurry is used as an organic fertilizer.

DILIGENT in Tanzania produces biogaz with the press caske. 1 kg of press cake gives about 1 m$^3$ of biogaz.

9.3 Use of other By-products

Other by-products in this sense are chemical compou ds, extracted from the oil or from the press cake. These compounds can be used in different applications, as a medicin or as a chemical raw material. As Jatropha is part of the botanical family of the Euphorbiaceae, it is rich in different components, which can be used in medicin.

The latex, e. g. Contains a chemical compound, which accelerates the wound healing process. If this component could be extracted, the wound healing accelerator could be used and the rest of the material could still be used as fuel or raw material for soap makig.
9.3.1 Phorbol Esters

This is a phorbol molecule (with several alcohol-groups). This can react with an organic acid to become an ester. These phorbol-esters are interesting biological insecticides. See publication by Ratnadass (Bibliography Nr. 18).

9.3.2 Insecticides

These phorbol esters can be easily extracted from the oil by washing it with aethanol. These phorbol esters have a co-carcinogenic effect, which means, they strengthen the carcinogenic effect of other substances.

The extract was tested by ICRISAT in Mali. They found out, that it is a good biological insecticide (M. Alain Ratnadass) which reduces the insects on mais by about 50%. Prof. Wink of Heidelberg University even said, that that Jatropha oil seems to be a stronger insecticide then Neem-extract. See bibliography Nr. 18.

9.3.3 Molluscicides

Ms. Melanie Rugg did a PHD thesis to see the effect of different extracts of the Jatropha plant on molluscs. The idea behind was to find a substance, which works against the transmitter
snails of the Bilharziose. This would have a very important effect on the health of the rural population in developing countries. See bibliographie Nr. 15.

9.3.4 Jatropha in the Homoeopathic Medicine

Jatropha seeds are a strong purgative with many side effects. But other parts of the plant have also medicinal aspects, like the latex or the leaves.

In the internet, Jatropha is only mentioned in a D4 dilution against diarrhoe.

Other medicinal uses of Jatropha

In Bénin, West Africa, they report that a decoction of the leaves of Jatropha are used against Malaria. This was also found in Mali.

Here are some photos of the preparation of Jatropha leaves against malaria:

- Jatropha leaves and lemon
- Jatropha leaves are put into a bowl
- Preparation in process
- Triturated leaves are making froth
- Leaves remains
- The juice is poured through a filter
- Filtering process
Photos 83: Preparation of Jatropha leaves as a medicine against malaria

The seeds are used against intestinal worms

There are also indications, that Jatropha with another plant of Benin, is active against HIV (AIDS):

D’après de récente recherche sur les différents usage de Jatropha, certains affirme que le juice de Jatropha curcas associer à une autre plante qui existe ici au Bénin, guéri une personne atteintes du VIH Sida. Pour le moment je n’ai pas encore approfondie, les recherches sur cet aspect. Donc une nouvelle piste de recherche pour les scientifiques.

La personne que j’ai interviewée est porteur du virus du sida et me confirme qu’il utilise le jus de Jatropha associé à une autre plante pour sa guérison, et qu’il se sent parfaitement en plaine forme.

Je crois certainement que même si cela ne peut tue pas le virus mais cela pourrait avoir un impact sur le virus.

Mais d’après le monde des scientifique le Jatropha serait nuisible à l’homme, mais voilà qu’ici au Bénin on en fait des usages de consommation et de bain.

Alors fait-il remettre en cause, le fait que le Jatropha est nuisible à l’homme?
10. The Socio-economic Aspects

10.1 The Role of Monitoring and Evaluation
To estimate or calculate the economic feasibility of Jatropha exploitation, a lot of data is missing. Only with a functioning system of monitoring and evaluation these data can be obtained. So it is still not clear, with which yield under which conditions a farmer can calculate, and which is the oil content of the seeds. And which are the minimum climatic conditions to grow Jatropha.

10.2 The Ownership of the Hedges
In West Africa the soil and all perennial plants growing on it, belong to the men. This seems to be the case also in East Africa, but it is handled there not so strict.

In Mali, West Africa, the women could not start a Jatropha plantation on their own. Somehow it was always sabotaged by the men.

10.3 The Harvesting Rights
Up to the beginning of our project in Mali, the seeds on the Jatropha hedges were free for harvesting to anybody. As soon as the possibility of gaining income by soap making was established, the Jatropha hedges became privatised and harvesting was possible only after permission by the proprietor.

Since the women are not the proprietors of the hedges, they are not allowed to harvest the fruits/seeds.

See also point 10.6 Socio-economic Effects by Commercializing Jatropha

10.4 The Role of Men
see point 10.2 The Ownership of the Hedges
10.5 The Rights of Women

Traditionally, the women harvest the seeds to make soap for the family household (subsistence economy).

10.6 Socio-economic Effects by Commercializing Jatropha

With the introduction of presses and expellers to extract oil, the women can produce and sell soap in quite substantial quantities. This developed a certain jealousy and forbade the women to use the Jatropha oil to make really money, and not only some cents. The women were allowed only to make soap for the family, not to sell it. Or the men wanted the money for themselves or at least part of it, because they are the owner of the hedges. The women refused and got back to the subsistence production.

The following table shows the economic evaluation of soap making by women groups in Tanzania (Mto wa Mbu):

**Table 11: Production and sale of soap by Massai women in Mto Wa Mbu (between Arusha and the Ngorongoro-Crater), Tanzania (calculation by Henning in 2003):**

<table>
<thead>
<tr>
<th>Input</th>
<th>Output</th>
<th>Total of revenues</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 hours work for 252 bars of soap, 1 bar sold for 500 TZS, purchase of 20 l oil for 40.000 TZS, purchase of 3 kg of caustic soda for 6.000 TZS, plastic for wrapping 3.000 TZS</td>
<td>20 l of oil 40.000 TZS 3.000 TZS 6.000 TZS 49.000 TZS 126.000 TZS 77.000 TZS</td>
<td>38,10 USD 2,86 USD 5,71 USD 1,90 USD 46,67 USD 73,33 USD</td>
</tr>
</tbody>
</table>
11. The Economic Analysis

The economic analysis in this chapter tries to find out, how much money somebody could gain with working on Jatropha, if possible in comparison with other income generating activities, mainly in agriculture. A source of data is the thesis at the university of Utrecht of Lode Messemaker in the year 2008 in Northern Tanzania: The Green Myth?, Assessment of the Jatropha value chain and its potential for pro-poor biofuel development in Northern Tanzania. This thesis tries to give some real data concerning the economic feasibility of the Jatropha system.

11.1 Basic Data for Economic Analysis

The problem of a serious economic analysis of the rentability of Jatropha oil production is the lack of verified basic data.

One of the most important basic data is the yield of a Jatropha plantation or of a plant. Up to now people in the rural areas did not look into the seed production of the plants, they just used the plants as living fence against animals or as boundaries. But the did not see the plant as a resource of oil. So the did not take care of the yield of fruits of the different plant and did not make any selection of high producing plants.

One of the most sensitive data is the price for seeds for oil extraction. This price varies in Northern Tanzania between 100 and 300 Shilling. For the calculation I took the average price of 200 TZS per kg, which is 0.12370 Euro per kg (or 0.15692 USD in mid March 2009).

Another important factor to the economic calculation is the time people are really working. Officially it is 8 hours per day. But in reality it is only 6 hours. This is already a difference of 25%. And in Madagascar people told me, that you can calculate with an unskilled worker only 5 hours in the morning, because afterwards he has to work on his own field. But you have to pay him the daily minimum salary.
11.2 Oil extraction by a hand press

This Excel spreadsheet tries to evaluate the production price of Jatropha oil produced with a hand press (Bielenberg Ram Press). As it can be seen easily by changing some of the basic data, the production price depends very much on the amount of seeds, which can be harvested in 1 hour of time, and this depends very much on the yield and the maintenance of the plantation: If the yield is high and the branches (fruits) low (by pruning), then a worker can harvest a lot of kg of seeds in 1 hour. But if the yield is low, and the new branches long (the fruits high), then the worker can harvest much less seeds, and the production costs will rise.
### Economic estimation of Jatropha oil production with hand press
#### in SAVA, Madagascar (may 2006)

<table>
<thead>
<tr>
<th>Basic data</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working hours per day</td>
<td>5,00 hours / day</td>
</tr>
<tr>
<td>Working days per week</td>
<td>5,00 days / week</td>
</tr>
<tr>
<td>Working weeks per year</td>
<td>48,00 weeks</td>
</tr>
<tr>
<td>Working days per year</td>
<td>240,00 days / year</td>
</tr>
<tr>
<td>Salary for a whole day</td>
<td>2000,00 Ar / day</td>
</tr>
<tr>
<td>Costs of labour per hour</td>
<td>400,00 Ar/heure</td>
</tr>
<tr>
<td>Exchange rate for US Dollar</td>
<td>2148,00 Ar</td>
</tr>
<tr>
<td>Exchange rate for Euro</td>
<td>2685,00 Ar</td>
</tr>
<tr>
<td>Name of national currency</td>
<td>Ariary Ar</td>
</tr>
<tr>
<td>Yield in harvest of dry black seeds (kg / hour and per person)</td>
<td>3,00 kg / hour</td>
</tr>
<tr>
<td>Yield of extraction by hand press (kg of seeds for 1 liter of oil):</td>
<td>5,00 kg</td>
</tr>
<tr>
<td>Yield of production of oil per hour with hand press</td>
<td>1,00 liters</td>
</tr>
<tr>
<td>Working hours for the extraction of 1 liter of oil</td>
<td>1,00 hour</td>
</tr>
<tr>
<td>Persons needed to work with the hand press</td>
<td>1,00 personne</td>
</tr>
<tr>
<td>Local price for the press (234 USD, = offer by ACAMECA + 30 %)</td>
<td>502632,00 Ar</td>
</tr>
<tr>
<td>Depreciation of the handpress for 1 liter of oil</td>
<td>167,54 Ar</td>
</tr>
<tr>
<td>Lifetime of the handpress</td>
<td>5,00 years</td>
</tr>
</tbody>
</table>

#### Production costs of Jatropha oil with hand press
(without plantation, storage & transport):

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work for harvesting 5 kg of seed + time for extraction + depreciation</td>
<td>1234,21 Ar</td>
</tr>
<tr>
<td>0,57 USD</td>
<td>0,46 €</td>
</tr>
</tbody>
</table>

#### Table 12: Estimation of production costs of Jatropha oil with a hand press

In this estimation a Jatropha oil production price of 0.46 Euro or 0.57 USD is calculated, without respecting the costs of plantation, storage, transport and maintenance.
11.3 Oil extraction by a motor driven expeller

Installation costs of plantation as well as storage and transport are not considered

Basic data

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working hours per day</td>
<td>8 hours/day</td>
</tr>
<tr>
<td>Working days per week</td>
<td>5 days/week</td>
</tr>
<tr>
<td>Working weeks per year</td>
<td>45 weeks</td>
</tr>
<tr>
<td>Working days per year</td>
<td>225 days/year</td>
</tr>
<tr>
<td>Minimal wage per day</td>
<td>5000 Riel</td>
</tr>
<tr>
<td>Minimal wage per hour</td>
<td>625 Riel</td>
</tr>
<tr>
<td>Exchange rate for 1 USD</td>
<td>4000 Riel</td>
</tr>
<tr>
<td>National currency</td>
<td>Riel Riel</td>
</tr>
<tr>
<td>Amount of seed harvested in 1 hour</td>
<td>3 kg</td>
</tr>
<tr>
<td>Time needed to harvest the seed for 1 liter of oil</td>
<td>2 hours</td>
</tr>
<tr>
<td>Extraction rate with mechanical expeller</td>
<td></td>
</tr>
<tr>
<td>(kg seeds for 1 liter of oil)</td>
<td>4.55 kg of seed / l of oil</td>
</tr>
<tr>
<td>Diesel consumption of expeller</td>
<td>2.00 liter per hour</td>
</tr>
<tr>
<td>Extraction capacity of expeller</td>
<td>250 kg seed per hour</td>
</tr>
<tr>
<td>Extraction rate of expeller</td>
<td>22 %</td>
</tr>
<tr>
<td>Production rate of expeller</td>
<td>55.00 liters oil per hour</td>
</tr>
<tr>
<td>Working time to extract 1 liter of oil with expeller</td>
<td>0.04 hours</td>
</tr>
<tr>
<td>Persons working with the expeller</td>
<td>2 persons</td>
</tr>
<tr>
<td>Misc. time for oil extr. (buying spare parts, transport of seed &amp; oil, etc)</td>
<td>0.25 hours/liter</td>
</tr>
<tr>
<td>Local price of expeller (1500 USD, Hak bought from nephew)</td>
<td>6000000 Riel</td>
</tr>
<tr>
<td>Depreciation of the expeller per 1 liter of oil</td>
<td>135 Riel</td>
</tr>
<tr>
<td>Actual diesel price</td>
<td>3200 Riel</td>
</tr>
<tr>
<td>Life time of expeller</td>
<td>10 years</td>
</tr>
</tbody>
</table>

Cost of oil production with expeller (without plantation, storage & transport):

Harvest of seeds + cost of working time for extraction 1 l oil + depreciation 1104.24 Riel 0.28 USD 0.20 €

Table 13: Estim. of the production costs of Jatropha oil with a motor driven expeller
In this estimation (above) a Jatropha oil production price of 0.20 Euro or 0.28 USD is calculated, without respecting the costs of plantation, storage, transport and maintenance.

12. List of Addresses

For addresses, please look into the Jatropha website, there I try to update all important addresses: http://www.jatropha.de/links.htm

And look into Google to find interesting websites with Jatropha.

Look as well into YouTube for videos. There are many. I put also some in: http://www.jatropha.de/links-videos-youtube.htm
13. The Bibliography

A large number of papers can be downloaded from the Jatropha website (http://www.Jatropha.de/literature/documents/index.htm). There is also a very large number of available Jatropha documents listed in the Jatropha website (grey literature, www.Jatropha.de/lit-list-1.htm).


8. Henning R., Barry O.; Production des haies de Pourghère: Enquête sur la production des plants Pourghère dans trois sites différents, Bamako 1988

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12. Purdue University, USA: Internet page on Jatropha curcas: \texttt{http://newcrop.hort.purdue.edu/newcrop/duke_energy/Jatropha_curcas.html}
13. M. Reyadh, Under Secretary of State for Afforestation, Ministry of Agriculture and Land Reclamation: The cultivation of Jatropha curcas in Egypt
15. Rug, Melanie: Wirkung verschiedener Extrakte aus \textit{Jatropha curcas} L. auf Vektorschnecken und Larven von Schistosomen, Promotion am Institut für Tropenhygiene der Universität Heidelberg (2000);
17. Plant Oil as Fuel and Lubrication Oil, Experience with Small Lister Type Diesel Engines of Indian Origin, by Reinhold Metzler with a test report by Dr. Kampmann, Thüringer Motorenwerke, Nordhausen, in September 1996.