Growing Jatropha

Including propagation methods for Jatropha curcas and production and use of Jatropha products





By Ab van Peer MAsc

Contents of growing Jatropha curcas.L

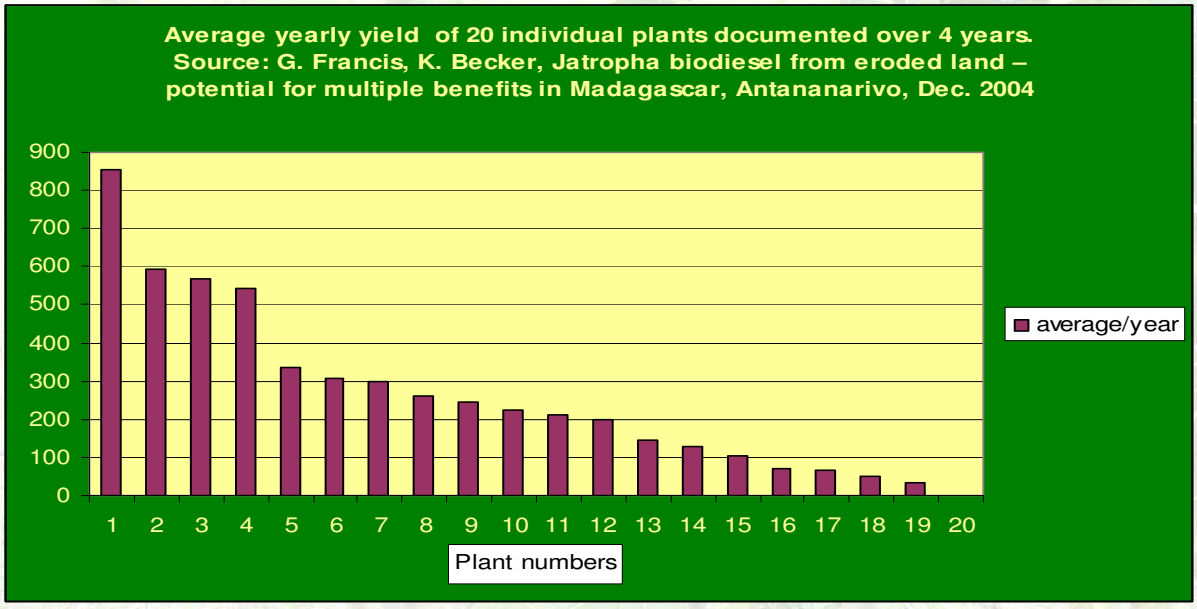
Growing Jatropha curcas

1. Preface

Of all the many aspects of growing plants, an understanding of soils is probably the most important. In subtropical and tropical area's variation in soil type, pH and nutrient content is huge. In the case of growing Jatropha it is even more crucial to understand (at least) the soil conditions since there is very little information about Jatropha itself. The world is actually busy to turn a wild plant into a crop, without the back up of existing solid agricultural science.

In principle growing Jatropha should not be easier or more difficult than any other agriculture crop. By using proper agricultural methods under the climatically right conditions, Jatropha can become a useful additional cash crop for small farmers, in combination with the crops they already grow. But since there is lack of basic knowledge, growers or growers groups should start right from the beginning with growing experiments next to proper agricultural practices and in the mean time set up a proper knowledge system. In any new crop data collection is a must.

Jatropha curcas has many uses and propagation is relatively simple. This is the reason that you find the plant all over the world, mainly transported by seeds and locally propagated by cuttings.
Seed or plant selection never took place, so the whole Jatropha industry is working with a wild plant without known characteristics. Early trials however showed a lot of variation between individual plants, which simply means that yield will be unpredictable and far from optimal.



Therefore proper plant selection is crucial for the development of a well yielding Jatropha crop.

Propagating large quantities of Jatropha curcas is not a complicated task.
However, successful propagation depends on proper logistics, because the plants are growing very fast, so they have to be moved and planted very fast as well.

This document is meant to understand how to grow Jatropha curcas more successful by matching the right methods with the right conditions.

Jatropha Curcas L.

2. Introduction

Jatropha is a genus of approximately 175 succulent plants, shrubs and trees (some are deciduous, like Jatropha curcas L.), from the family Euphorbiaceae. The name is derived from (Greek **iatros** = physician and **trophe** = nutrition), hence the common name **physic nut**. Jatropha is native to Central America and has become naturalized in many tropical and subtropical areas, including India, Africa, and North America. Originating in the Caribbean, Jatropha was spread as a valuable hedge plant to Africa and Asia by Portuguese traders. The mature small trees bear separate male and female flowers in bunches, and do not grow very tall. As with many members of the family Euphorbiaceae, Jatropha contains compounds that are highly toxic. The Jatropha genus has many ornamental plants a well.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Species of *Jatropha* include among others:

- ***Jatropha curcas*,(1)** also known as physic nut, piñoncillo and Habb-El-Melúk, is used to produce the non-edible Jatropha oil, for making candles and soap, and as a feedstock for producing biodiesel.
- ***Jatropha gossypifolia*, (2)** also called bellyache bush: its fruits and foliage are toxic to humans and animals. It is a major weed in Australia and that is the reason that even Jatropha curcas is a forbidden plant in Australia
- ***Jatropha integerrima* Jacq.(3**), or spicy Jatropha: ornamental in the tropics, continuously crimson, flowers almost all year. This plant is widely used in the streets of Jakarta in Indonesia. It is not a vigorous grower and therefore sometimes grafted on Jatropha curcas.
- ***Jatropha multifida* L.(4),** or coral plant: bright red flowers, like red coral, characterized by strongly incised leaves.
- ***Jatropha podagrica* (5)** or buddha belly plant or bottleplant shrub was used to tan leather and produce a red dye in Mexico and the Southwestern United States. It is also used as a house plant.


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3. Botanical description (adapted from Heller-Physic nut.)

The physic nut is a drought-resistant species which is widely cultivated in the tropics as a living fence. Many parts of the plants are used in traditional medicine. The seeds, however, are toxic to humans and many animals. Considerable amounts of physic nut seeds were produced on Cape Verde during the first half of this century, and this constituted an important contribution to the country's economy. Seeds were exported to Lisbon and Marseille for oil extraction and soap production. Today's global production is, however, negligible.

The physic nut, by definition, is a small tree or large shrub which can reach a height of up to 5-7 m. The plant shows articulated growth, with a morphological discontinuity at each increment. Dormancy is induced by fluctuations in rainfall and temperature/light. The branches contain latex. Normally, five roots are formed from seedlings, one central and four peripheral. A tap root is not usually formed by vegetatively propagated plants (Kobilke 1989). The physic nut has 5 to 7 shallow lobed leaves with a length and width of 6 to 15 cm, which are arranged alternately. Inflorescences are formed terminally on branches. The flowers are unisexual; occasionally hermaphrodite flowers occur (Dehgan and Webster 1979).

Pollination of the physic nut is by insects. Dehgan and Webster (1979) believe that it is pollinated by moths because of "its sweet, heavy perfume at night, greenish white flowers, versatile anthers and protruding sexual organs, copious nectar, and absence of visible nectar guides". When insects are excluded from the greenhouse, seed set does not occur without hand-pollination. The rare hermaphrodite flowers can be self-pollinating. During field trials, Heller (1992) observed a number of different insects that visited flowers and could pollinate. In Senegal, he observed that female flowers open later than male flowers in the same inflorescence. To a certain extent, this mechanism promotes cross-pollination. Münch (1986) did not observe this chronological order in Cape Verde. The exocarp remains fleshy until the seeds are mature. The seeds are black, 2 cm long and 1 cm thick.

male and female flowers

male flowers only

4. Soils

Of all the many aspects of growing plants, an understanding of soils is probably the most important. In subtropical and tropical area's variation in soil type, pH and nutrient content is huge.

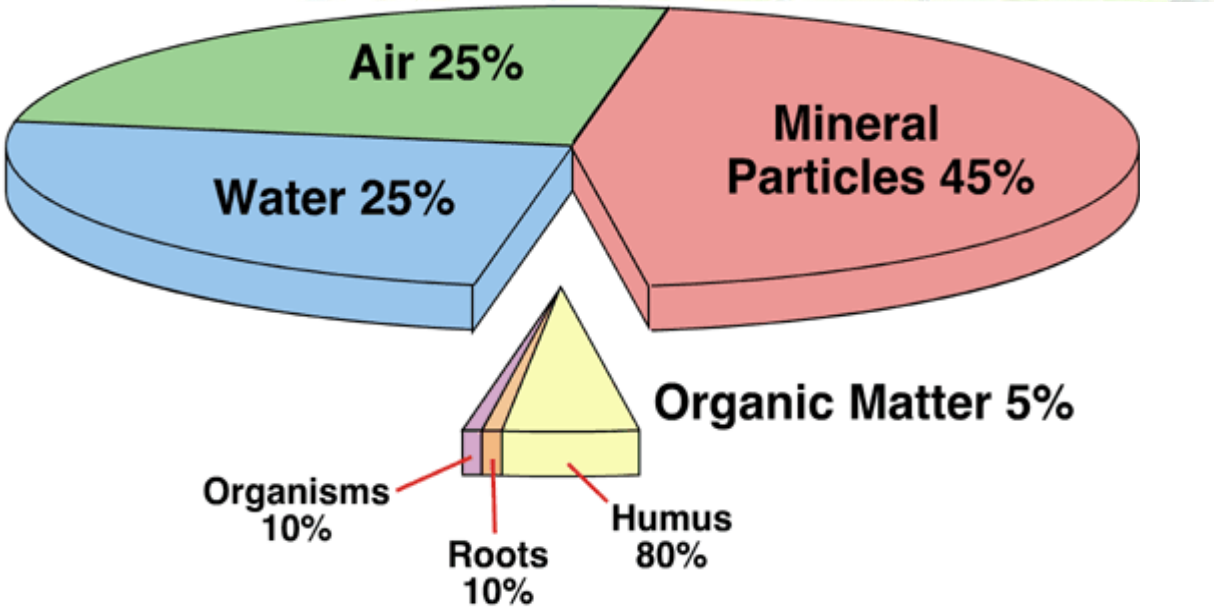


Table 1. Most soils contain four basic components: mineral particles, water, air, and organic matter. Organic matter can be further sub-divided into humus, roots, and living organisms. The values given above are for an average soil. Source: PhysicalGeography.net

Soil fertility.

Definition: Soil fertility is a combination of the following elements:
Soil structure and texture, soil pH, content of nutrients, nutrient storage capacity, soil depth, soil organic mater content, soil organisms.
The next pages are covering the main aspects.

Simple characterisation of soils

Soil texture

The first and very rough characterisation is based on visual aspects.
Most soils are characterised by the presence of clay, silt and sand.
Depending on the mixture of these particles we characterise soils as "heavy or "light"

Particle size ranges for sand, silt, and clay.	
Type of Mineral Particle	**Size Range**
Sand	2.0 - 0.06 millimetres
Silt	0.06 - 0.002 millimetres
Clay	less than 0.002 millimetres

Table 2.The texture of a soil refers to the size distribution of the mineral particles found in a representative sample of sil. Particles are normally grouped into three main classes: sand, silt, and clay.

Soil Structure

Heavy soils (clay, silt) do have a texture determined by very small particles. When this type of soil becomes wet, it takes a long time to dry up, even when proper drainage is applied. These soils are difficult to work with, and growth is difficult to control. On the other hand, most clay soils (like black cotton) are relatively rich in nutrients.Their structure is determined by how the individual soil granules clump or bind together and aggregate, and therefore, the arrangement of soil pores between them. Soil structure has a major influence on water and air movement, biological activity, root growth and seedling emergence.

Soil structure, especially in heavy soils is degraded by over-fertilization, compaction trough heavy machinery and frequent traffic, and over irrigation. In temperate area's frost repairs a lot of soil degradation. In tropical area's it is much more difficult to maintain a good soil structure. Organic material, which is among others for the exchange of nutrients from the soil to the plant, is burned very vast by high temperatures, high humidity and intensive labour. **Never work a soil when it is to wet!**

Jatropha on heavy black cotton soil in Kilwa, Tanzania.

Light soils like sand are based on a very course particles size. This means that water drains very fast which is a good thing if you have enough water. On the other hand, a lot of water and good drainage leaches the available nutrients very fast, so light soils are mostly poor soils.

Soil Colour

Soils tend to have distinct variations in colour both horizontally and vertically. The colouring of soils occurs because of a variety of factors. Soils of the humid tropics are generally red or yellow because of the oxidation of iron or aluminium, respectively. The heavy leaching of iron causes coniferous forest soils to be gray. High water tables in soils cause the reduction of iron, and these soils tend to have greenish and gray-blue hues. Organic matter colours the soil black. The combination of iron oxides and organic content gives many soil types a brown

colour. Other colouring materials sometimes present include white calcium carbonate, black manganese oxides, and black carbon compounds.

Nutrients and their specific role in plant growth.

Table 3.Plants contain practically all (92, periodic table) natural elements but need only a few for good growth.

Nutrient	Role in plant growth	Characteristics in soil	Deficiency	Excess
(N) Nitrogen	Stimulates growth (cell elongation)	Easily leached, uptake blocked by to much K	yellow leaves, stunted growth.	dark green leaves, scorching
(P) Phosphorus	Induces new cell formation, flowers and seeds	Leached by low pH, Blocked by high pH Too much P blocks trace elements. Deficiencies more pronounced in sandy soils with low organic matter content	Reddish leaves, less branching and rooting Reduced growth. Production of dark green foliage. Reddening or yellowing of leaf margins and necrosis of older leaves	Causes lack of Cu and Fe, resulting in chlorosis
(K) Potassium	Improves cell structure, drought tolerance	Uptake blocked by to much N	Curling leaf margins, leaf dying	Lack of N, Ca, Mg, resulting in yellow leaves
(Ca) Calcium	Needed for transport of other nutrients. Cell division and elongation. Proper working and permeability of cell membranes	Less mobile at low temperatures	Blossom end rot of fruits,	Lack of Boron and Mg
(Mg) Magnesium	Needed for proper photosynthesis and P transport	Low pH decreases availability	Discolored spots on leafs, intervenial chlorosis	Lack of Ca and K
(Fe) Iron	Needed for proper photosynthesis Necessary for the formation of proteins	High P inhibits uptake of Fe, becomes immobile at low temperatures and wet soils	Interveinal chlorosis and necrosis.	Lack of Mn
(Mn) Manganese	Green parts of leaf, chloroplasts	Low pH causes deficiency. Becomes more mobile at low temperatures and wet soils	Veins form Christmas tree model	Lack of Fe and Mo
(Zn) Zinc	DNA	Becomes less soluble at lower temperatures	Stunted leaf growth	Lack of Mn and Fe, looks like nitrogen deficiency
(Cu) Copper	Lignin formation (cell walls) and seed	Uptake of Cu can be blocked due to soil characteristics	Critical in conifers (yellow tips)	Lack of Mn, Fe,Mo
(Mo) Molybdenum	Needed for proper enzymatic functions		Yellow spot on citrus, clamp hart of Cauliflower	Lack of Cu
(B) Boron	Sugar transport, cell division, Meristem growth... Pollen germination	Very little difference between deficiency and excess	Necrosis and stunting, heart-rot. Leaf distortion and leaf texture changes. Death of growing points. Cracking and rotting. Poor fertilization and fruit set	Boron toxicity, Increased by high pH soils. Sandy soils. High levels of nitrogen or calcium. Cold wet weather and periods of drought

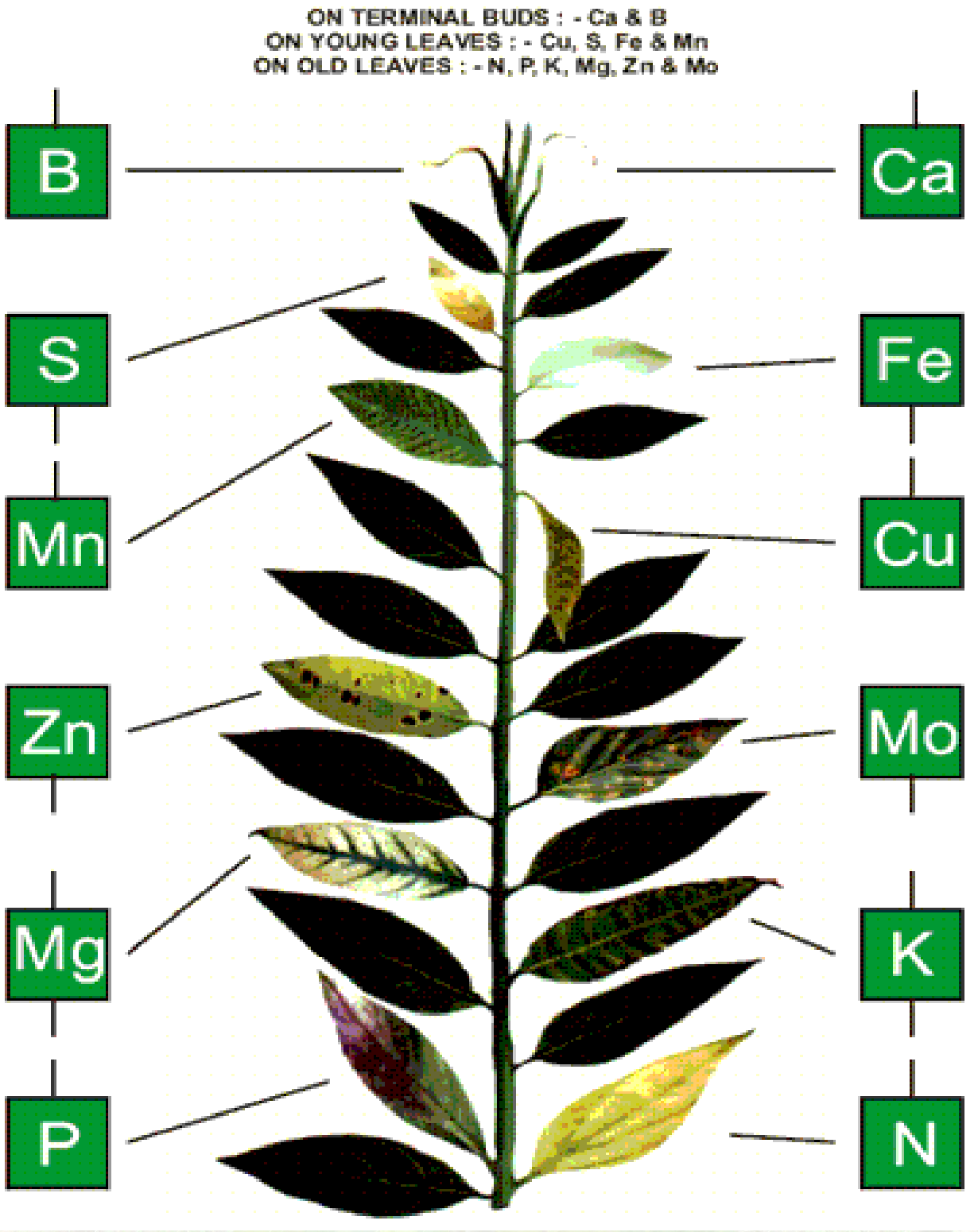


Chart from Micnelf USA Inc.

Location of nutrient related deficiencies in the plant.

Soil pH

Soil fertility is directly influenced by pH through the solubility of many nutrients. At a pH lower than 5.5, many nutrients become very soluble and are readily leached from the soil profile. At high pH, nutrients become insoluble and plants cannot readily extract them. Maximum soil fertility occurs in the range 6.0 to 7.2.

Soils support a number of inorganic and organic chemical reactions. Many of these reactions are dependent on particular soil chemical properties. One of the most important chemical properties influencing reactions in a soil is pH. Soil pH is primarily controlled by the concentration of free hydrogen ions in the soil matrix. Soils with a relatively large concentration of hydrogen ions tend to be acidic. Alkaline soils have a relatively low concentration of hydrogen ions. Hydrogen ions are made available to the soil matrix by the dissociation of water, by the activity of plant roots, and by many chemical weathering reactions.

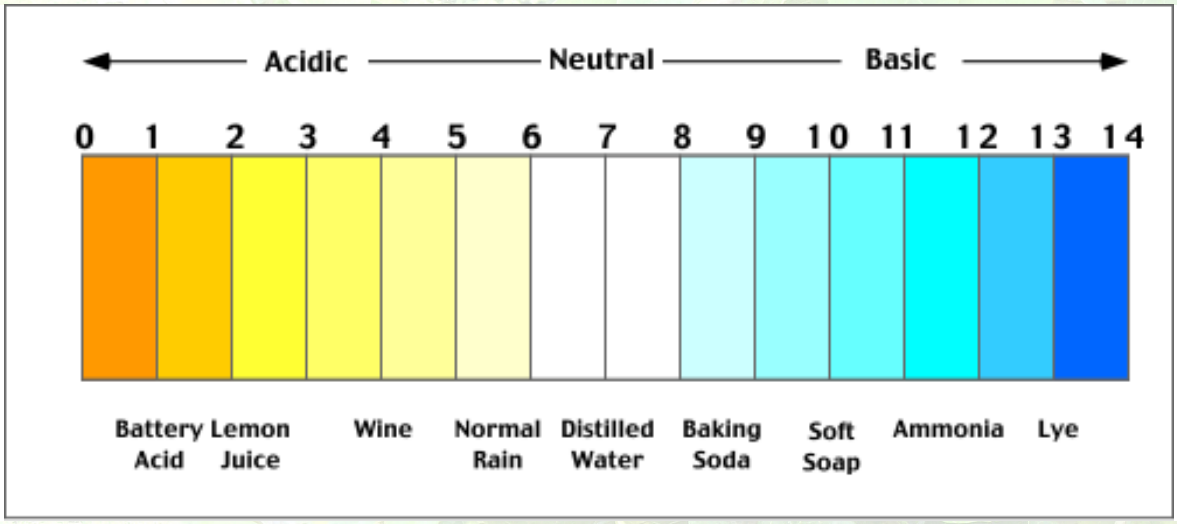
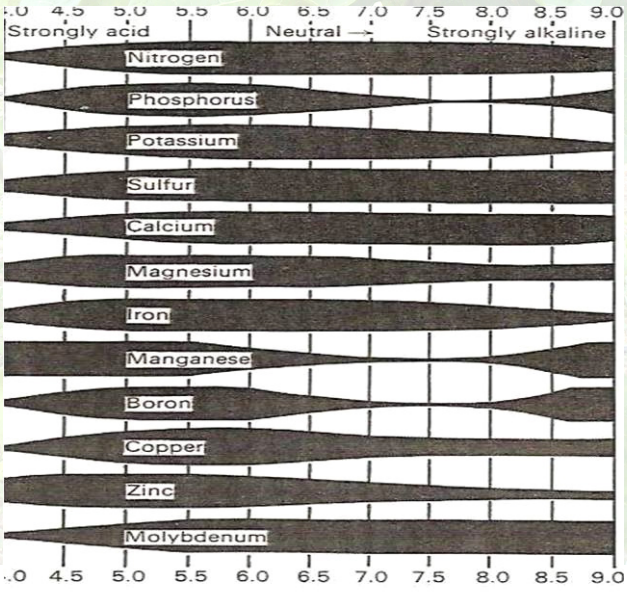


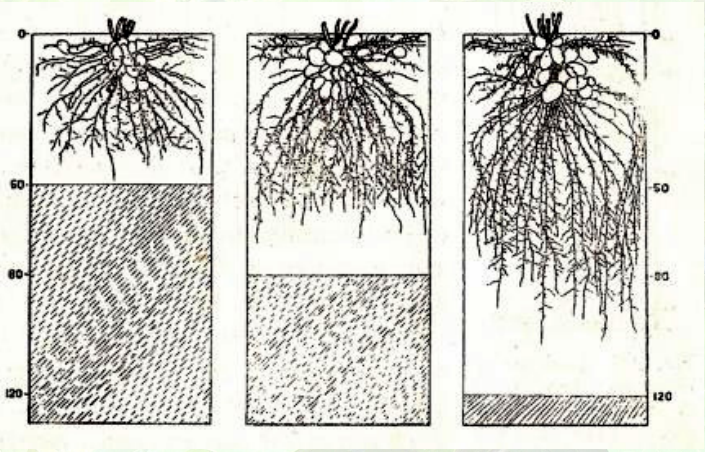
Table 4.The pH scale. A value of 7.0 is considered neutral. Values higher than 7.0 are increasingly alkaline or basic. Values lower than 6.0 are increasingly acidic. The illustration above also describes the pH of some common substances. (Source: PhysicalGeography.net)



Influence of pH on the availability of plant nutrients in organic soils:widest parts of the shaded area's indicate maximum of availability. (after Lucas and Davis[1961])

Soils and water

Without water plants do not grow. With to much water they do not grow either, except for e.g. aquatic plants.
Water is the carrier for nutrients, sugars and any other elements that has to be transported from roots to leaves or v.v. Besides that, water is also one of the building elements, responsible for growth. Plants cells contain a lot of water.
Outside the plant water is responsible for transport of nutrients and air to and from the plants root system. Without water the plant suffers lack of everything it needs. With to much water the plant suffers lack of oxygen.
In spite of its reputation Jatropha loves water, with one exception; Jatropha does not survive flooding. Flooding means lack of oxygen and Jatropha will show the effects of flooding within a couple of days. (Yellow leaves, no growth, start of root decay.)
Soils with high water tables are not necessarily unsuitable for Jatropha. It depends on the height of the water table (min.80-100 cm) and the stability. Continues variation in water table height is a disaster every plant and in Jatropha it causes the same problems as flooding.



Root system of potato at different water tables.
(TNO Groningen)

Heavy soils have a tendency to stay wet for a long time after flooding. Growing Jatropha in these soils is however not a problem, as long as they are planted on ridges or on a slope. Since heavy soils are usually fertile soils, Jatropha will grow and produce very well on these soils.
Light soils usually are poor soils, due to heavy leaching. (Nutrients drained away by water). For the same reasons these soils have a tendency to become very dry.
Growing Jatropha on these soils means that one has to except the influence of a dry climate or to organize irrigation. Irrigation on dry soils is the ideal way to control growth of a Jatropha stand, but it all comes at a cost. (According to Netafim drip irrigation will roughly cost $1000/ha)

Comparing water use efficiency between surface, sprinkler and drip systems in the Middle East

Irrigation System	Wetting area	Amount water used	Water Losses (evaporation and conveyance)	Water saving relative to surface
	%	m^3/ha	%	
Surface	100	500	40-45	-
Sprinkler	100	320	15-20	30%
Drip	< 50	122	Very low (1-2%)	75%

Source: Khalifeh, 2002.

Practical solutions for yield improvement.

Soil fertility.

Definition: Soil fertility is a combination of the following elements:
soil depth, soil structure, soil pH, content of nutrients, nutrient storage capacity, organic mater content, soil organisms.

The most practical way to improve yield is to improve (yield-limiting) minimum factors

Correcting pH

The most important reason to know the pH of your soil is that it makes it easier to understand growing problems in the field. Adjusting pH large scale by surface applications of lime (pH goes up) or organic material (pH goes down) can be very expensive. On top of that it has to be repeated after a couple of years. Fortunately Jatropha curcas is rather tolerant regarding pH. The pH however can be influenced in the case fertilization is being applied. (see correcting nutrient levels). In heavy soils pH can also be increase by frequent harrowing.

Correcting nutrient levels

Adjusting nutrient levels large scale can become quite expensive. Therefore one should take soils samples on a regular base, to find out the real growth limiting factor.

Soil samples from various tropical countries with some common characteristics. (all samples analyzed by BLGG in Oosterbeek, Netherlands)

Country	Remarks	pH	remark	N= kg N/ha	remark	P=P-Al, mg P2O5/100gr	remark	K= mg K/kg	remark
Thailand	unused land	4.4	very low	30	low	<3	very low	32	low
Indonesia	agriculture land	5.7	low	115	good	14	very low	122	good
Indonesia	neglected construction site	4	very low	45	low	<3	very low	27	low
Thailand	agricultural land	6	good	20	low	4	very low	97	good
Indonesia	neglected construction site	4	very low	49	low	10	very low	20	low
Tanzania	cleared bush, suitable for agriculture	7.6	high	251	high	<3	very low	139	good
Cambodia	neglected agriculture land	3.8	very low	18	very low	6	very low	20	low
Thailand	former agriculture area	4.4	very low	24	low	<3	very low	58	low
Cambodia	cleared bush	6.8	good	91	rather low	<3	very low	154	good

Table 6. Soil samples showing some of the most important nutritional characteristics of soils, namely: pH and the nutrients N,P,K. In this particular case they have one characteristic in common: There is a structural lack of Phosphorus. The role of Phosphorus in perennial crops is highly underestimated. In the ornamental horticulture it is very well known that a sufficient supply of Phosphorus guarantees a better root system, more branching and more flowering. In annual oil seeds like sunflower, sufficient P increases both yield and oil content.

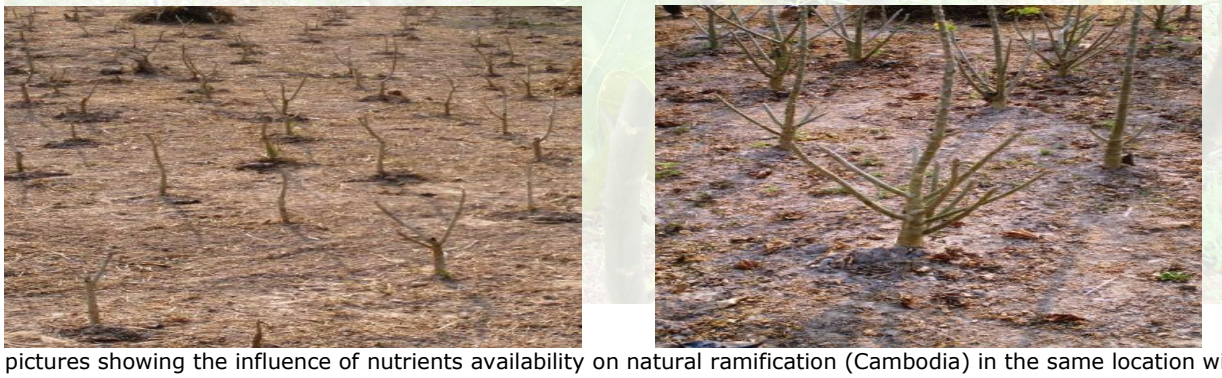
(N) Nitrogen, (P) Phosphorus and (K) Potassium are the most important nutritional elements to influence plant growth.

N. Nitrogen can be applied both as an organic or inorganic fertilizer.
Organic fertilizers come as compost, manure or green manure and as seedcake from oil crops like Jatropha. It can be applied as a planting hole filler (see planting Jatropha) or as a mulch in existing plantation.
Nitrogen as an inorganic fertilizer comes in various forms. Urea usually is the most effective and cheapest fertilizer. However, under certain conditions (water and high temperature) some of the nutrients might evaporate. Ammonium nitrate and ammonium sulfate are also popular fertilizers. Their secondary benefit is that they will acidify (lower the pH) gradually.
Most of the composed fertilizers also contain Nitrogen. Usually these fertilizers are more expensive and less specific.

Sample nr.	Laboratory	Date	Org. matter	Total N	Phosphate	Potassium
232548	Sucofindo (Indo)	01 May 2007		3.7	1.1	1.6
501065	BLGG (NL)	01 June 2007	85.6	4.1	1.9	1.9
501066	BLGG (NL)	01 June 2007	81.3	4.2	0.2	2.3
Internet	SRCVO Mali	01 June 1990		4.1	0.5	1.2
19201	South Africa	01 June 2007		3.5	0.3	1.2
	Henning	01 June 1990		5.7	2.6	0.9
average	seedcake		83.4	4.2	1.1	1.5
	Cattle dung		25.5	1.2	0.2	1.1
	EFB Palm		43.11	0.8	0.2	2.6
	Chicken		35	3.0	2.7	1.5

Table 7. Various organic fertilizers compared with Jatropha seedcake from several sources

P. As mentioned before, the negative effects of a lack of Phosphorus in the soil is highly underestimated. The element P is very important for the development of young plants, roots and flowers and therefore at most important when Jatropha is being planted.
There is very efficient P inorganic fertilizer available, like superphosphate and triplesuperfosfate. However, some tropical countries have abundant reserves of rock phosphate, which is an excellent long lasting fertilizer.
The availability of sufficient nutrients and P in particular is very important for the development of a new plantation. Jatropha plants need to have many branches in order to have many flowers. Branching after pruning or even natural branching is stimulated by the availability of sufficient nutrients. Foliar application of P will also stimulate flowering.



pictures showing the influence of nutrients availability on natural ramification (Cambodia) in the same location with different soil conditions. Left: lack of nutrients, Right: sufficient nutrients

K. Potassium plays a key role in water relationships in plants. Potassium affects water transport in the plant, maintains cell pressure and regulates the opening and closing of stomata and is responsible for cooling and absorption of carbon dioxide for photosynthesis. It also acts as a catalyst, regulating enzymatic processes in the plant that are necessary for plant growth. Potassium is important for a plant's ability to withstand extreme cold and hot temperatures, drought and pests. It makes a plant tough!
The other nutritional elements are needed in very small amounts. (micro nutrients or trace elements)
However, specific deficiencies of these elements can become growth limiting factors

Table 8.
Buckwheat plants growing on water.

I.	All nutrients except potash (K)
II.	All nutrients available
III.	All nutrients except iron (Fe)

Some closing remarks.
Leaf samples are representing the balance or unbalance of nutrients in the plant. If certain deficiencies are expected, leaf samples should be taken from the proper leaves. (See plate on page 9) Always compare healthy plants with affected plants.

To ensure continuous productivity of Jatropha, the amount of nutrients absorbed by the seed production has to be substituted on a regular base, otherwise long term production will recline. This can be done by proper fertilization and/or mulching, or the choice for a proper intercrop. (see intercropping)

Using a mulch of organic material and nutrients (compost) around the plant creates a healthy and vigorous environment for the plants root system.

5. Selecting planting material

For any type of crop or individual plant, the selection of planting material is crucial to achieve the set objectives. In the case of Jatropha the main objective is to have healthy plants with a high production of seed containing a high percentage of oil, of which the quality has to meet certain characteristics.

Without going into plant breeding, propagation material can be improved a lot by simple data collection and observation from plants grown out of local seeds.

As already mentioned in the preface, there is a lot of variability between individual Jatropha curcas plants. There is variability in yield but also in shape or habitat and in vigor. These three characteristics are easy to evaluate in existing Jatropha stands and therefore the first criteria to select on.

High yielding plants usually have many branches and fruit bunches with more than 10 fruits per bunch. These plants are suitable for selecting your seed stock from. In practice this seed should be used to set up a seed orchard. Even in the seed orchard a lot of variation will be noticed, but by gradually removing poor performing plants, the quality of the seed orchard will improve over the years.

The same counts for plants that show natural ramification characteristics. The more branches the plant makes under natural conditions, the less pruning is needed. (Note that there is a correlation between ramification and soil fertility, see page 13)

Vigorous plants are healthy and usually do have less problems with diseases.
Attention: Vigorous plants are not always high yielders!

One more step into plant selection is setting up selection trials with Jatropha seeds coming from different sources. The philosophy behind these trials is that local Jatropha plants not automatically are the best plants to start with. They probably are the best survivors for a particular area due to natural selection, but that does not mean that they are the high yielding ones you are looking for.

Selection trials are not difficult and do not require a lot of area. They only require time for proper care and data collection.

An example of how to set up a proper selection trial is given in annex 1

6. The nursery.

It is the type of project that dictates the type of nursery needed.

Big plantations usually have a central nursery, mainly for research, and local nurseries as close as possible to the plantation site, in order to avoid long distance transport of plants.

Projects serving small farmers usually do have a central nursery serving both production and research purposes. An example of this type of nursery is added in annex 2

A nursery should at least be equipped as follows:
1. Acces to good water. (pipe, pump or river)
2. Acces to good soil, sand, manure etc. and a place to mix these
3. A covered area. Either for sun- or rain protection
4. A simple storage for material like poly bags, watering tools etc.
5. Should be located close to a road
6. Proper drainage

Usually this type of nursery has a double function, namely both seedling production and demonstration. The size should be adapted to the number of plants being produced.
Remark: A full cycle of Jatropha seedlings takes too months, so depending on climate several cycles could be realized within one year.

Three key roles for a nursery to be monitored

1. Input versus output of seedlings or cuttings (germination and survival rate)
2. Testing of soil mixtures for poly bags
3. Control of diseases

7. Plant propagation

A. Generative propagation of Jatropha curcas

When seeds are being collected and used for propagation purposes, seed quality and selection is crucial. (see previous chapter) Jatropha seed maintains a good germination rate during almost 6 months, provided that the seeds are stored properly, which means dry and at a temperature below 25°C.
Before storage, clean the seeds, select the best seeds only (the biggest ones) and disregard seeds with different size, different colour, damaged seeds etc**.**
Seed for propagation should never be dried in direct sunlight.
Freshly collected seed with a moisture content of 15-20 % gives good germination up to 80-95%. Dry seeds with 7-8% moisture content might give a germination rate of 70-75% even after 6 months, if properly stored. Seeds older than a year should not be used for propagation.

Direct seeding

Direct seeding in the field is the easiest and most cost effective method for setting up a Jatropha plantation. It also provides an excellent quality plant for the future, since the Jatropha seedling is developing a taproot and therefore can stand dry periods. On top of that direct seeding is a method commonly known by most farmers, since they plant their maize and other crops in the same way.
Drawbacks of direct seeding
More seed is needed, since 2 seeds are needed for each planting hole.
Rain is crucial during the first ten days of germination and should continue regularly for at least two months.
Usually with direct seeding there is no planting hole preparation, which will result in poor seedling development, especially on poor soils.

2 bottom pictures D1, Malaysia

Seeding in poly bags.

Direct seeding in poly bags filled with soil, sand and manure or compost (1:1:1) or other mixtures depending on local availability.
Sown bags are watered daily but once the germination is complete they should be watered as per need.
If field planting is delayed, the polythene bags should be shifted timely to check excessive root growth anchoring in the soil.
In practice, germination of seeds in poly bags usually is rather poor due to poor drainage or insufficient irrigation. Seeding in poly bags requires a well aerated soil mixture with good drainage and a moderate nutrient level. Too much nutrients usually generates high salt contents in the bag.

Seeding in beds and transplanting into poly-bags.

In the nursery, raised beds of I meter large are prepared and a space of 20 cm is left in between two beds for drainage and walking.
Generally sand, soil and compost mixtures are being used, but only river sand also gives good results.
Seeds should be sown 3-4 cm deep in soil. Light and frequent irrigation should be given. Cover the bed during the fir/or to protect against excessive rain.
Healthy seeds germinate within 2-10 days after sowing.
After about 20-30 days, the seedlings can be transplanted into poly-bags and hardened during a period of about one to two months, depending on climate. If transplanted bare rooted, seedlings should be kept in the seed bed for at least 6 weeks.

Raised beds usually give the highest germination rate of Jatropha seeds.

All pictures taken in Indonesia

B.Vegetative propagation of Jatropha curcas

(producing cuttings is a fast way to multiply plants with given characteristics)

Preparation of hard cuttings.

(hard cuttings are parts of fully grown Jatropha plants).

How to make as many hard cuttings as possible?

1. Use branches with a diameter of maximum 3-4 cm and a length of 4-6 nodes. The colour of the wood should be greyish. Green wood is too young and can easily be attacked by fungi.
2. Use sharp knives or scissors in order to make a clean cut. Do not use a machete because it will damage the cuttings. Cut the stems slightly slanted.

3. After cutting, wash the cuttings in water with 1-2grams/litre carbendazim or equal to protect the cuttings from an early attack of fungi. (This is much easier and more realistic than disinfecting your knife or scissor after every cut with ethanol as sometimes recommended)
4. Let the cuttings dry in a shady place for some hours.
5. Before sticking the cutting in the pre-filled poly bag, poke a small hole with a stick in it.
6. *Special attention has to be paid to the soil mixture. Soil in the bags should be light and good draining. Too many nutrients is not necessary and in fact will negatively influence rooting. Different local mixtures can be used to fill the bags. Coco peat turns out to be an excellent rooting medium, but might be too expensive. Mixtures of soil and sand and compost (1-1-1) are doing quit well. Make sure water and soil do not content too much salts. Farm yard manure can be very salty. Do a small trial with different mixes from local available material before you start a big nursery. The trial takes you only 4 weeks. Materials that can be used: sand, soil, compost, rice husk, peat, coco-peat, charcoal, saw dust.*
7. After placing the cuttings, water the poly bags slightly.
8. Fresh hard cuttings do not need direct sunlight the first days (there are no leaves), so place them in a shaded area for the next 10 days and maintain a high enough humidity*, not by watering but covering them with white plastic or placing them in a greenhouse or plastic tunnel.

*Humidity is a trade off, the higher the humidity, the faster the rooting but also the development of unfavourable fungi. Once planted in a poly- bag or plastic pot, the cuttings are treated like seedlings and will be ready for transplanting after 6-8 weeks. If cuttings are directly being planted in the field, they should have a length of 20-40 cm.

Drawbacks for direct planting are the same as from direct seeding. On top of that the root system is not as good as with a seedling.

picture D1, Malaysia

Propagation by soft cuttings.

Producing soft cuttings is a fast way to multiply plants with known characteristics.

Soft cutting method from IPB-Indonesia

Principals:

1. Mother-plants of Jatropha curcas are being planted in uncovered beds with a base of organic fertilizer like goat or chicken manure. Plants will be fertilized and irrigated if needed. Usually NPK 15-15-15 will be used; eventually foliar feed Grow More will be used as well.
2. Soft cuttings are placed in small tunnels under shade.

Preparations for planting the mother-plants.

Beds for the mother-plants should be raised and loosened at least 40 cm. Organic manure should be mixed with the soil.
The mother-plants should be planted at a spacing of 50 per m2.

Preparations for planting the cuttings.

The cutting beds are placed under shade- net with about 50 % shade. Beds are raised and should have parabolic shape in order to avoid accumulation of excessive moister in the centre. The top of the bed is covered with at least 10 cm saw dust, preferably from soft would. The saw dust has to be moistened but not wet.
In stead of saw dust, good quality coco peat could be used as well, probably with better results. Coco peat should be tested on salt content.
The beds are being covered with plastic but it should be easy to open them for hardening the cuttings.

Taking the cuttings.
Top shoots from the mother-plants with a length of about 6 cm or 3 leaves should be cut with a sharp knife or razor blade. Cuttings are being washed in water in order to get rid of the latex. After washing, cuttings are put in the cutting bed without rooting hormone. Beds are closed but have to be opened every day to check moister contend and to clean the cuttings from dropping leaves. After 8 days the cuttings should start to grow and have to be sprayed with water soluble fertilizer every week. After 4-6 weeks the cuttings should be ready to be transplanted.

Tissue culture

Tissue culture is a proven method to vegetative propagate vast numbers of plants with given characteristics. Although this technique is being tested in Jatropha curcas in various countries, so far no proven results have been showed. It will become an important method once new varieties of Jatropha have been developed trough a lengthy breeding process.

Grafting

Grafting is the technique of growing a part of a plant (cutting, graft) on the root system of another plant. This is usually done because the graft's own root system has unfavorable characteristics. (diseases, wild growth, etc) Jatropha curcas has been used as a root system for Jatropha integerrigma for its vigorous growth.

8. Planting Jatropha

As already mentioned in the chapter about propagation, there are different types of Jatropha planting.

1. Planting trough direct seeding
2. Planting trough direct planting of hard cuttings
3. Planting of bare rooted seedlings
4. Planting of seedlings in poly bags
5. Planting of cuttings in poly bags

Apart from the amount of time involved in the different planting systems, there is a big difference in the way the plants get established and make a root system.

Direct seeding produces a plant with a tap root. Theoretically this type of plant will survive better than cuttings in drought conditions. However, there is not much data supporting this claim. On top of that, there is no data regarding yield in relation to root system.

Plants out of poly bags (either cuttings or transplants) make more lateral roots and are supposedly more vulnerable to drought. Again there is no data supporting this.

An important noticeable difference between cuttings and seedlings however is that cuttings are yielding earlier than seedlings, due to the fact that cuttings usually come from adult plants, with the exception of soft cuttings.

No taproot from cuttings.

Taproot from seedlings

Pictures by Naresh Kaushik, regional research station Bawal, India

A. Land preparation

There are distinct differences between land preparation for monoculture Jatropha plantations, Jatropha intercropping and Jatropha hedges.

Land preparation for Jatropha monoculture.

Since monoculture Jatropha plantations usually cover large area's, most of the preparation is done mechanically. In the case mechanical harvesting is foreseen, sloops more than 10-15% should be avoided and distance between rows should not limit harvesters. To level the land, topsoil has to be put aside before levelling and returned after levelling. Planting holes can be drilled with an auger; however in heavy soils this can only be done during the dry season, in order to avoid a "bucket" effect in the planting hole. (Roots will not be able to penetrate the walls of the planting hole)

Planting holes should have a volume of about 10-15 litres and filled with a good soil, mixed with at least 1 kg organic manure.

After planting plants should be watered immediately, if no rain is expected.

Large scale Jatropha plantation from Bioshape in Tanzania. (+/- 8 months)

Land preparation with organic fertilizers in Mbulu, Tanzania

Land preparation for proposed intercropping.

The land should be emptied from previous crops and crop rests in order to execute proper land preparations. Rows of Jatropha should be planted before any other crop. Planting holes should be filled with a mixture as mentioned before. Use a rope to plant Jatropha in straight lines, this facilitates maintenance and intercropping. In hilly area's the Jatropha should be planted along contours. (Possible intercropping systems are mentioned in the chapter Intercropping.) To plant a reasonable amount of plants on a certain area, double rows of Jatropha could be planted

Land preparation for planting hedges.

A 10 years old Jatropha hedge in Leguruki, Tanzania

Boundaries are everywhere. Housing plots, streets, canals, maize fields, soccer fields; they all have boundaries, requiring maintenance. So most of the time these boundaries become a mixture of poles and trees and wire and weeds or in other words, they become a mess and a burden. Why not planting all these boundaries with Jatropha, becoming a blessing in stead of a curse.

Hedges can produce a lot of seed. It is estimated from a project in Mali (by Henning) that a hedge could produce 0.8kg per meter/per year. So if an average farmer has a plot of 0.5 ha (100x50 m), he can plant 300 meter of Jatropha hedge which will bring him 240 kg of seeds. And so will his neighbour, and his neighbour etc. etc. A km of Jatropha hedge can produce 800 kg of seeds.

To plant a proper Jatropha hedge, (either from seeds or from cuttings) a ditch of 30 cm wide and 30 cm deep should be created along the boundaries. The soil should be mixed with organic material and than the ditch should be refilled. After this seeds or cuttings or plants from poly bags can be planted when the rains start or when irrigation water is available

9. Pruning

The three main factors to make a Jatropha bush productive are:

Pruning, light and nutrition.

Jatropha flowers appear at the end of a branch. Ergo: A Jatropha bush should have as many branches as possible to get many flowers. Simple but not true.

Apart from many branches, a Jatropha bush also needs light. With to many branches many of them will not receive enough light and the branches will stay "blind", in other words they do not produce flowers.

Although it seems attractive for early yield (which means no pruning) it is recommended to prune Jatropha in order to get a good framework for future flowering branches.

Pruning should take place as follows:

1e pruning-plant is knee height. This is usually 3 months after planting (depending on climate

2e pruning-plant is waste height

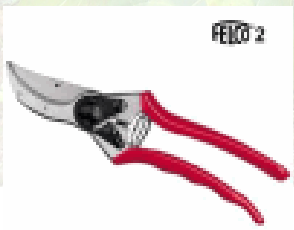
3e pruning-shoulder height. This is the moment to select the right branches that should form the frame work and dispose of any useless branches.

1e pruning, 2e pruning, 3e pruning, (pictures D1)

Remarks.

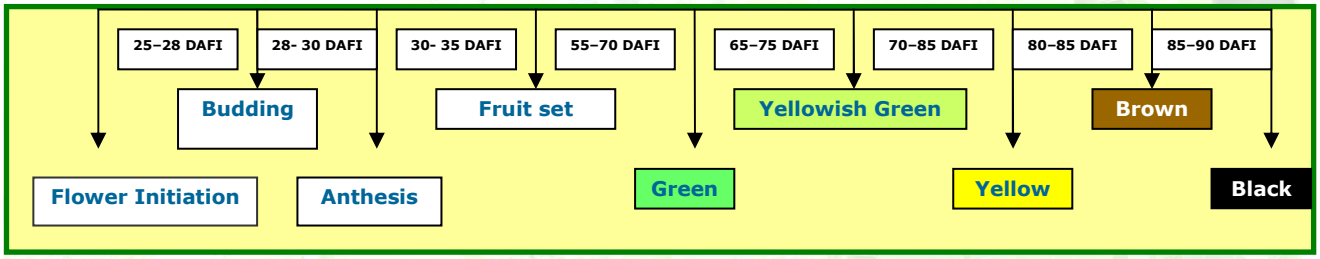
Always use secateurs to prune. Machetes make nasty wounds with infection risks.

The best moment to prune is before the plant starts growing. (Just before rain or irrigation.)



10. Flowering, fruiting and picking

The flowering of Jatropha is strongly depending on rain and/or irrigation. Usually flower initiation takes place shortly after the plant receives its first water.



It takes about 90 days for a Jatropha fruit to develop from the moment of flower initiation. Once the fruit has been set (around day 40), the seeds start to develop.

Picking the seeds at the right time gives the maximum oil yield. From various studies it is advised to pick fruits when they are yellow. The oil content might be optimal at this stage, but there still is a substantial amount of moisture in the fruit. (45 %) During the brown stage the fruit is drying rapidly (35%), which means saving a lot of weight when picking. On top of that, the brown and black fruits are easier to dehull than the yellow ones.

In future mechanical harvesting is going to take place on plantations or other large scale operations. However, like in other crops (coffee), mechanical harvesting will always be a trade of between yield and quality.

Picture: (Oxbo) over the top harvester

11. Intercropping= Double cropping

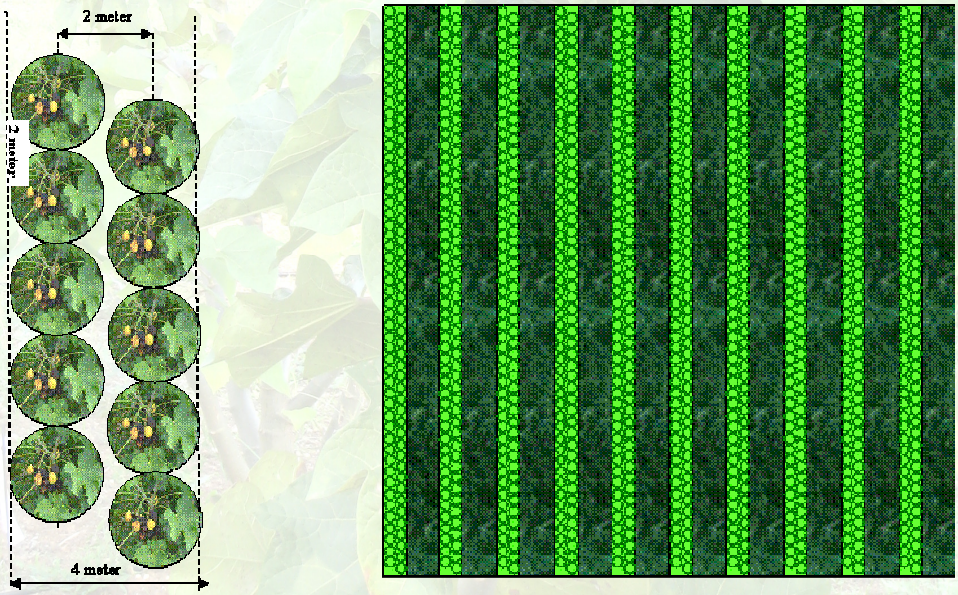
To be successful in intercropping Jatropha with other crops (or other crops with Jatropha), farmers should consider Jatropha as a normal agricultural crop. Forget about the story that Jatropha does not require much water and grows on any soil. The production of Jatropha should be embedded in other crops as within a normal mixed farming system, with all its needs and attention. Even more, growing Jatropha should go hand in hand with improved agricultural practice for food crops as well, like using better seeds, planting in time and in rows, weeding, using fertilizer or organic manure, etc. etc. In this way, the production of Jatropha will enhance food production as well.

Planting more than one crop in the same field has many advantages.

1. Small farmers are used to intercrop, looking for different food plants to spread the risk of a crop failure and anticipating on erratic rainfall.
2. If more than one crop is cultivated and harvested with different growing cycles, farmers can use their time more economically.
3. With a better coverage of the area, weeds are suppressed.
4. Pest and disease incidence is lower with intercropping.
5. Crops can benefit from each other

Example

A double row of Jatropha planted 2x2 (=4 meter) and than 6 meter for other crops and/or machinery or animal ploughing. This gives us 1000 Jatropha plants per ha and still 6000m2 for another crop to grow in between the Jatropha. (See drawing.)



The space in between the double Jatropha rows is a variable. Actually, it is depending on the type of intercrop and/or the equipment which is going to be used.

The effect of Jatropha on poor soils

Initially poor soils will result in poor harvests. You get nothing for nothing. However, in due time a couple of systems are going to work. Jatropha will gradually develop into a large shrub, providing shade and/or shelter to other crops (depending on planting distance). Furthermore the roots of Jatropha grow pretty deep and will touch layers where the normal annual crops or weeds do not reach. The nutrients picked up from these layers are reaching the surface via the Jatropha plants. Through pruning and shedding of the leaves, the nutrients will return to the surface, enriching the upper layer where other crops are intended to grow. As the seeds from Jatropha are pressed, the remaining seed cake should be returned to the surface, because it is rich in N, P and K, equal or even richer than chicken manure.

Nutrient value of Jatropha seedcake from different sources compared with other manures.

Sample nr.	Laboratory	Date	Org. matter	Total N	Phosphate	Potassium
232548	Sucofindo (Indo)	01 May 2007		3.7	1.1	1.6
501065	BLGG (NL)	01 June 2007	85.6	4.1	1.9	1.9
501066	BLGG (NL)	01 June 2007	81.3	4.2	0.2	2.3
Internet	SRCVO Mali	01 June 1990		4.1	0.5	1.2
19201	South Africa	01 June 2007		3.5	0.3	1.2
	Henning	01 June 1990		5.7	2.6	0.9
average	**seedcake**		**83.4**	**4.2**	**1.1**	**1.5**
	Cattle dung		25.5	1.2	0.2	1.1
	EFB Palm		43.11	0.8	0.2	2.6
	Chicken		35	3.0	2.7	1.5

How can Jatropha benefit from intercropping.

Food in between Jatropha.

Presume we are growing beans in between the Jatropha. With a row distance of 6 meter between the Jatropha rows the beans have plenty space to grow. The beans or other crops will grow between the Jatropha, protected from strong winds and excessive radiation. After harvest the root systems will deteriorate, providing the soil with nitrogen. On top of that the flowering beans or other crops will attract insects, badly needed for the pollination of the Jatropha. Many crops could be intercropped with Jatropha in a way that the intercrop takes advantage of the Jatropha and vice versa. Vanilla is a good example as well but unfortunately the world does not need much Vanilla nowadays. Farmers should concentrate on the local market. Whenever they can make a good price for melon, they should grow melon in between the Jatropha. The melon crop will make sure that the Jatropha plants get pollinated by insects. Same counts for ground nuts, cow peas, pigeon peas, sweet potatoes, peppers, corn, sunflower etc.

Ground nuts in between Jatropha (Thailand, 2007)

Trees in between Jatropha

In principle you should not grow Jatropha in a forest, because the forest creates shade and Jatropha needs sun! However, Jatropha plants could take advantage of existing trees (Acacia) or introduced trees (Prosopis*) because those trees attract insects badly needed for pollination of Jatropha flowers. So why not interplanting Jatropha rows with this kind of pollinator trees. The moment they become too big you cut them or prune them and use them for charcoal production or even firewood. You create a sustainable source of firewood and charcoal.

* There are many varieties of Prosopis and Acacia and some become a weed under certain circumstances. Be sure you verify the characteristics of a plant before you introduce it.

Honey Bees

These trees also have the potential to become important for the production of honey, provided there is water available for the honey bees!!

Prosopis juliflora

Acacia sp.

Beehives in Kenya

Life stock in between Jatropha

It is known that cattle (goats, sheep, and cow) do not eat Jatropha leaves. This means that you can grow Jatropha in grazing area's. As with food intercropping, ample attention should be given to grow the right type of pasture.

Life stock grazing in Kenya (Picture Bedford) Cattle grazing in Brazil. (Picture Green Power))

12. Diseases

Many internet sites will tell you that due to the toxic constituents of Jatropha curcas, the crop does not have many diseases. This is wishful thinking, not true and not backed by practical experience.

Indeed, as long as Jatropha is growing in the wild, single plants or small patches, you hardly see any fungus or insect attack.

How big is the difference when you start to plant Jatropha large scale on nurseries and as an intercrop.

Not much research has been done, but already there is a whole list of pest and diseases that are observed in actual Jatropha plantations.

The list in annex 4 is not complete and still growing. On top of that, there are no recommended treatments for Jatropha since the crop only recently catched the attention of the pesticides manufacturers. So there are no labelled pesticides for Jatropha which means that you are using the pesticides at your own risk. In some countries this is an offence.

13. Jatropha products

1.PPO can be used for transport and cooking oil

2. Soap. See recipe. Soap has healing characteristics versus skin diseases. (Maasai)

4. Briquettes are made from seedcake with a simple extruder. They should be turned into charcoal for better cooking characteristics.

5. Fertilizer is seedcake directly applied in the field or passed trough a biogas installation.

6. Dye, from bark and roots

7. Paper, from pruning material

Papermaking, regardless of the scale on which it is done, involves making a dilute suspension of fibers in water and allowing this suspension to drain through a screen so that a mat of randomly interwoven fibers is laid down. Water is removed from this mat of fibers by pressing and drying to make paper.

The art of papermaking. Medieval festival at Monselice.

The fibers are made from the Jatropha bark and/or wood. Bark alone gives a greenish color. Wood or bark is left soaking in water for a day or to and than grinded or pounded to obtain the fibers. First the fibers are suspended in water to form a slurry in a large vat. The mold is a wire screen in a wooden frame (somewhat similar to an old window screen), which is used to scoop some of the slurry out of the vat. The slurry in the screen mold is sloshed around the mold until it forms a uniform thin coating. The fibers are allowed to settle and the water to drain. When the fibers have stabilized in place but are still damp, they are turned out onto a felt sheet which was generally made of an animal product such as wool or rabbit fur, and the screen mold immediately reused. Layers of paper and felt build up in a pile (called a 'post') then a weight is placed on top to press out excess water and keep the paper fibers flat and tight. The sheets are then removed from the post and hung or laid out to dry. A step-by-step procedure for making paper with readily available materials can be found online.[8]

When the paper pages are dry, they are frequently run between rollers (calendered) to produce a harder writing surface. Papers may be sized with gelatin or similar to bind the fibers into the sheet. Papers can be made with different surfaces depending on their intended purpose. Paper intended for printing or writing with ink is fairly hard, while paper to be used for water color, for instance, is heavily sized, and can be fairly soft.

The wooden frame is called a "deckle". The deckle leaves the edges of the paper slightly irregular and wavy, called "deckle edges", one of the indications that the paper was made by hand. Deckle-edged paper is occasionally mechanically imitated today to create the impression of old-fashioned luxury. The impressions in paper caused by the wires in the screen that run sideways are called "laid lines" and the impressions made, usually from top to bottom, by the wires holding the sideways wires together are called "chain lines". Watermarks are created by weaving a design into the wires in the mold. This is essentially true of Oriental molds made of other substances, such as bamboo. Hand-made paper generally folds and tears more evenly along the laid lines.

8. Medical uses, see soap.

Feedstock for soap production from plant oils

Handbook on Jatropha Curcas First draft March 2006 FACT Foundation

(Picture Mali Folk centre)

(Picture Lode Messemaker)

It is fairly easy to produce soap from vegetable oil. Technically spoken the triglycerides of the plant oil are converted to salts of metal ions (natrium, potassium) and fatty acids (stearate, palmitate). The components necessary for soap making, and their ratios, are:

1 litre of plant oil,

0, 75 litre of water and

150 g of caustic soda

per litre of oil.

Adding less water gives a harder soap, adding more water requires addition of flour or starch to get a consistence that is solid enough. As the ingredients are relatively cheap and the soap can generally be sold at a good price, soap making can be an attractive option. The outline of the recipe is as follows:

1. Prepare a solution of the caustic soda by dissolving the soda into the water (never mix these components the other way around – risk of burning!)Stir until everything has dissolved. The bowl will get hot, cool it using cold water at the outside, or just let it cool down for a while.
2. Pour the oil into a bowl and put it beside the bowl of caustic soda solution. Pour the caustic soda solution slowly into the oil, stirring all the time. Immediately the mixture will go white and soon it becomes creamy.
3. Continue stirring until the mixture is like mayonnaise. This is the moment to add additives like glycerine, perfume etc. If the mixture is still creamy, pour it into a mould, where it can harden overnight. The moulds can be made from a wooden tray or a cardboard box, lined with a plastic sheet. Alternatively, consider using convenient and attractive shapes like small plastic bowls or pipes
4. The mixture hardens overnight in tropical temperatures or in several days in temperate regions. Then it can be released from the mould and cut if necessary.
5. Even after this first hardening the soap continues to mature for some time. It should be stored for some two weeks on shelf before sale.

Plant selection

Seeds or cuttings should be taken from plants with known characteristics, such as healthy growth, frequent branching and full fruit branches.

If no data exist, one should start to set up a selection field to create mother stock for seed and plant production

Selection Trial Form
Country: Tanzania
Trial nr:
Location:
Planting date:
Trial supervisor:

Nr. of selections:……
Nr. of treatments: …. 1 (or 2, pruned and non pruned)
Nr. of repetitions:…… minimum 4
Nr. of plants per plot: 9
Total nr. of plants……
Spacing 2x2 mtr

Selection identification nr.
1='……
2=……
Etc.

Objective of the selection trials
Compare various accessions in order to define the best accession for a particular area.

Materials:
Seeds from local and outside selections

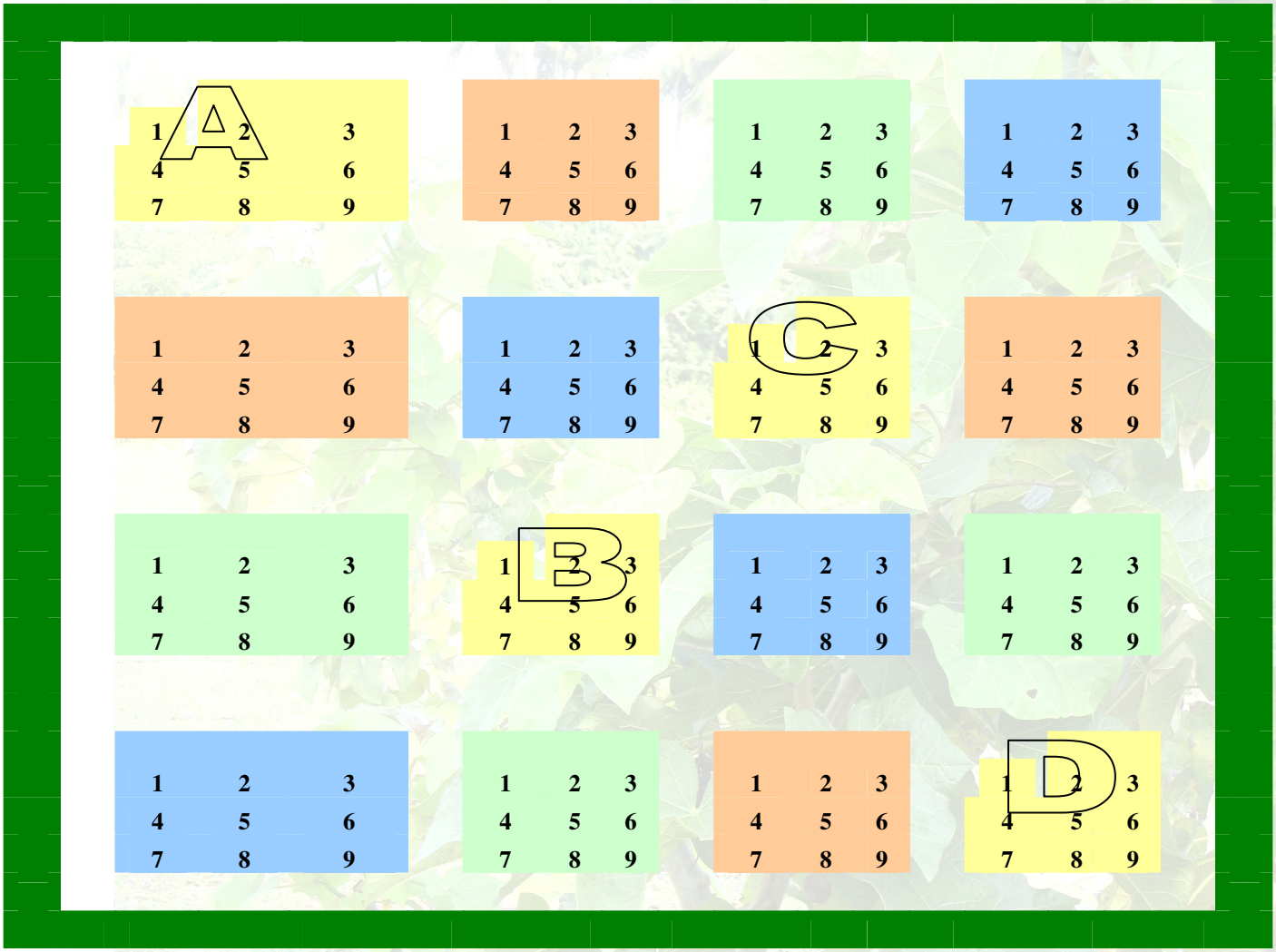
Trial numbers

A/B/C/D = repetition
1-9= plant numbers. 9 plants should be labelled individually

Observations on 9 marked individual plants from each block
1. Nr. of branches per month
2. Height per month
3. First flowers (date)
4. Nr. fruits per bunch
5. Yield per month

Duration of the trial: 2-3 years

Selection trial layout



Borderplants

A B C D

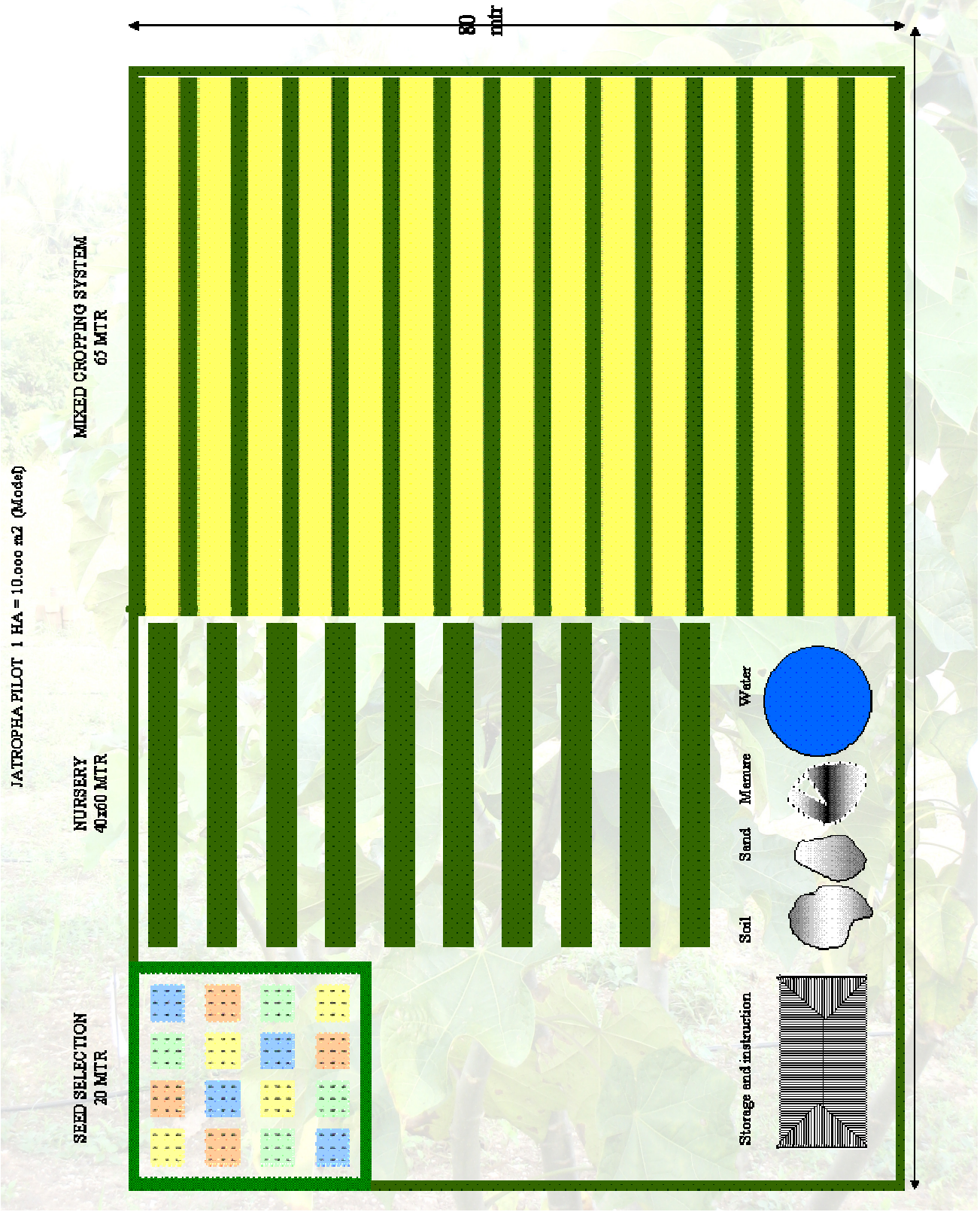
repetitions

selection 1
selection 2
selection 3
selection 4

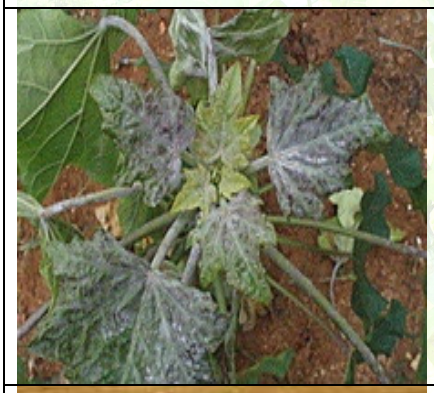
Planting distance 2x2 meters

e-mail: info@jatropha.pro, web www.jatropha.pro

Annex 3. Pilot project



Annex 4.. Diseases

	Name	Symptoms	treatment
	Polyphagotarsonemus latus mites	Young plants get very thick and sturdy leaves with veins almost on top of the leaf service. Growing points will dry and the plant stops growing until a new flush starts, provoked by rain or irrigation. It is a typical disease of nursery plants and recently planted plantations.	If single plants are being attacked, cut the infested part and burn it. Larger area's can be treated with: Dicofol 18.5% EC @ 3ml/lt Vertimec 1.9 EC @ 0.5ml/lt
	Oidium spp Powdery mildew	White powdery fungus mainly on younger leaves and stems. Most Jatropha,s get this disease in area's with low average temperatures, especially during night time and relatively high humidity.	Products based on dithiocarbamate (Zineb, Dithane, Manzate etc.)
	Fusarium Wilt	Young and fully grown plants collapse in a very short time as if they do not get water. Indeed they do not get water, because the vascular system blocked by the fungus. The disease spreads from one plant to another , sometimes trough flood and open channel irrigation.	Soil fumigation or drenching
	Macrophomia spp Collar rot	Usually caused by over irrigating or high water table. The plant tries to recover by making new roots in the rotted area. Farmers use to cover these area's with soil, in order to stimulate secondary root growth	Improve growing conditions

	Chrysocoris spp Scutalarid bug (picture D1)	Sucks on fruits , diminishing yield	Cypermethrin. Do not use during flowering, because it is highly toxic to bees.
	Ferrisia virgata Mealy bug	ucks the sap from leaves and stems, sometimes from fruits if heavily infested and causes crinkling leaves, dry stems and reduced reproductive parts.	Chlorpyrifos or Mercaptothion, Dimethoate. Malathion 50%
	Slugs and snails	Feed on leaves and stem, mainlyin the nursery	Course sand around the nursery beds keeps them out.
	Leaf Webber	Physical damage, mainly on leaves	*Bacillus thuringiensis sub sp. Kurstaki*
	Stomphosistis thraustica Leaf miner	Physical damage, mainly on leaves	*Bacillus thuringiensis sub sp. Kurstaki*