Attempted Cultivation of *Jatropha curcas* L. in the Lower Senegal River Valley: Story of a Failure

Marieke Terren[1,2*], S. Saverys[1], P. Jacquet de Haveskercke[1], S. Winandy[2] & G. Mergeai[2,3]

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Summary

With the objective of determining whether it would be possible to sustainably produce Jatropha curcas *L. seeds on the marginal land situated close to the Senegal River, a 6-hectare pilot plantation was cultivated under drip irrigation between September 2007-November 2011, close to the village of Bokhol (Lat. 16°31'N, Long. 15°23'W). A series of tests were conducted on this plot, in order to identify the best cultivation methods for the area (date, density and method of planting, appropriate type of pruning, fertilisers to be applied, irrigation method, etc.). The average yields obtained at this site, after four years of cultivation (less than 500 kg.ha^{-1} of dry seed), using the best known production techniques, are significantly lower than anticipated, compared to the available figures for the irrigated cultivation of* Jatropha *in other parts of the world. The main causes of this failure are the plant's limited useful vegetation period of six months per year, instead of twelve, and the scale of attacks by a soil-borne vascular disease, which destroyed over 60% of the plantation within four years.*

Résumé

Tentative de culture de *Jatropha curcas* L. dans la basse vallée du fleuve Sénégal: histoire d'un échec

Dans le but de déterminer s'il était possible de produire durablement des graines de Jatropha curcas *L. sur des terres marginales situées à proximité du fleuve Sénégal, une plantation pilote de 6 ha a été installée sous irrigation goutte à goutte et exploitée entre septembre 2007 et novembre 2011 à proximité du village de Bokhol (Lat. 16°31'N, Long. 15°23'W). Une série d'essais ont été réalisés sur cette parcelle en vue d'identifier les meilleures modalités de culture de celui-ci (date, densité et mode de plantation, type de taille à réaliser, fertilisation à appliquer, mode d'irrigation, etc.). Les rendements moyens obtenus sur ce site après quatre ans de culture (moins de 500 kg.ha^{-1} de graines sèches) pour les meilleurs itinéraires techniques identifiés sont nettement inférieurs à ceux attendus sur base des chiffres avancés pour la culture irriguée du Jatropha dans d'autres régions du monde. Les principales causes de cet échec sont la limitation de la période de végétation utile des plantes à six mois par an au lieu de douze et l'importance des attaques d'une maladie fongique vasculaire transmise par le sol qui a détruit plus de 60% de la plantation en quatre ans.*

Introduction

Jatropha curcas L. (which we will call simply Jatropha) is a rustic shrub that originated in Central America, which is cultivated on a large scale in the world's tropical regions, because of its many claimed and proven qualities (2, 3, 4, 5, 7, 10, 17, 20). Its oil-rich seeds represent a high quality feedstock for the production of agrofuels. Its large-scale production represents a possible solution to the energy crisis that threatens the world, following structural increases in hydrocarbon prices. This explains the current enthusiasm for Jatropha cultivation shown by many stakeholders in the energy sector (governments, private investors, NGOs, farmer organisations, etc.), despite the fact that the viability of developing production and processing chains, for the use of this plant, has not yet been properly assessed. Most of the available data on the costs and revenue from this type of enterprise are invariably based on simple hypotheses or incorrect extrapolations (8, 11, 14, 22, 24). In order to determine whether it would be possible to sustainably cultivate Jatropha on a large scale on the marginal land situated close to the Senegal River, a pilot project was launched in September 2007 in the rural community of Bokhol (Dagana Département, Saint-Louis Region). The results obtained by this research and development project, after four years, are here presented and discussed, in order to provide information for anyone wishing to set up business producing Jatropha in this region or other areas characterised by similar cultivation conditions.

1. Durabilis Foundation, Kortrijksesteenweg 930, B-9000 Gent, Belgium.
2. Gembloux Agro-Bio Tech (ULg), Passage des Déportés 2, B-5030 Gembloux, Belgium.
3. Aide au Développement Gembloux (NGO) asbl, Passage des Déportés 2, B-5030 Gembloux, Belgium.
*Author's e-mail: m.terren@doct.ulg.ac.be Tel.: (+221) 773 394912.

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Equipment and methods

Area studied and source of data analysed

The data here presented was collected as part of the project focusing on Jatropha cultivation, which was conducted in Senegal by the Durabilis SAFS, with scientific support from the Tropical Crop husbandry and Horticulture Unit of the Faculty of Gembloux Agro-Bio Tech of the University of Liege.

Observations were made at the 6-hectare pilot experiment site used for the drip irrigated cultivation of Jatropha, which was set up by the Durabilis SAFS 1.5 km south-east of the village of Bokhol (Lat. 16°31'N, Long. 15°23'W.) and 1.5 km from the Senegal River. This site is characteristic of the agro-ecological zone of the Senegal River (21). The climate is of the BWh type (Sahelian climate) according to the classification of Köppen. The annual rainfall in this area ranges from 180-300 mm, distributed over three months in the rainy season (late June - late September). The average annual daily temperature is above 18 °C, with an average annual minimum temperature of 23 °C and an average annual maximum temperature of 37 °C. Temperatures can fall to below 10 °C at night between late December – late February and exceed 41 °C during the very hot periods seen in May. The terrain is completely flat and the plantation was established on sandy soils (*Dieri* type). The 6 hectares covered by the plantation were divided into twelve half-hectare plots, where a series of tests were conducted.

Method used to produce the Jatropha analysed

Based on the natural and socio-economic characteristics of the areas, in which Jatropha is cultivated, the latter can be included in a wide range of different cropping systems. When it comes to perennial plants, these cropping systems can be identified mainly by the crop combinations and the cultivation techniques used.

In the Senegal River zone, the environmental conditions are such that it is only possible to cultivate Jatropha by providing additional water. The cultivation method analysed in this region involves cultivating Jatropha in pure stand under drip irrigation. This irrigation system was adopted because it was the most economical in terms of water use.

In the case of the Bokhol site, the water is drawn from the Senegal River and conveyed to the Jatropha plots using an electric centrifugal pump of the Ebara brand (35 $m^3.h^{-1}$), which is powered by an 8 kVA electric generator of the ANTOR AL 8000 TS brand (Lombardini). In areas located further away from the river, the use of drill holes of varying depths is necessary in order to irrigate the plots.

Tests conducted at the Bokhol site

The tests conducted at the pilot plantation aimed to identify the best cultivation methods for *J. curcas*. These trials focused on: the planting method (direct sowing, planting of bareroot and containerized seedlings produced in nurseries), plant spacing (2 x 2 m, 3 x 1.33 m, 3 x 2 m, 3 x 3 m et 3 x 4 m), high and low shape pruning on 1-year old plants, fertilisation with various doses of mineral and organic fertilisers.

Methods used to analyse technical-economic performances of cultivation systems

Evaluating the technical and economic performances of Jatropha cultivation involved calculating the net income $hectare^{-1}$. $year^{-1}$. This income was calculated by subtracting the value of intermediate inputs (all goods and services consumed as an integral part of the production process within the same year) and the cost of the labour required for the production process from the gross product (i.e. the value of the yield produced during the relevant year).

Results and discussion

Climatic constraints

Contrary to expectations when the plantation was set up, climatic conditions in the region are not suitable for continuous Jatropha production throughout the year. Between mid-December and mid-March, low temperatures at night cause all plants of all the ecotypes cultivated, which are older than one year, to lose all their foliage. From mid-March until late June (when the rainy season begins), the leaves reappear on the trees, but the inflorescences are fully dried out by the dry and warm wind, which blows across the region from the Sahara. In the absence of effective wind-breaks (which were not erected due to lack of time), the period, during which Jatropha fruits can be produced, is ultimately limited to only 6 months of the year (from mid-June to mid-December) in the area. The effectiveness of wind-breaks created using *Eucalyptus camadulensis*, which are recommended in the area, in order to promote the development of annual and perennial crops, was not evaluated due to lack of time (12). It appears, however, unlikely that the latter would have significantly improved the situation.

The loss of foliage, which helps the plant to survive periods that are not conducive to growth, is a common reaction in Jatropha. Water stress is often the cause of this phenomenon (2). The prevalence of excessively cold temperatures in winter, even if it is possible to cover the plant's need for water, also causes it to lose all its leaves. This type of behaviour limits the potential to cultivate Jatropha in the area studied and certainly represents a constraint, in terms of extending its cultivation to areas situated further north than the Senegal River (North Africa, Egypt).

Edaphic constraints

The soils at the Bokhol site contain, on average, over 90% sand (fine and coarse) in the arable horizon and

are slightly richer in clay at lower levels. Their organic matter content is very low (< 1%) and they present a very low chemical fertility (CEC between 2-3 meq/100 g soil). Based on previous findings, due to their loose texture and good drainage characteristics, they do not present unfavourable physical properties for Jatropha cultivation. This was demonstrated by the plants' very high initial growth, which was observed when the plantation was set up. Effectively managing the irrigation and fertilisation of this type of soil should make it possible to produce almost any kind of crops, except for rice. The soil characteristics therefore do not seem to be considered, in order to explain the serious problems affecting the growth of Jatropha plants at the experimental site.

Phytosanitary constraints

At the start of the dry season in the second year after the plantation was set up, the Jatropha plants suffered strong attacks from leaf miners of the *Stomphastis thraustica* species (Lepidoptera, *Gracillariidae*). This type of attack recurred more occasionally in subsequent years. Several far more sporadic attacks of *Calidea panaethiopica* bug (Heteropteran, *Scutelleridae*) on maturing capsules and stem miners of the *Pempelia morosalis* species (Lepidoptera, *Pyralidae*) have also been observed in Bokhol. The cost of the inputs necessary to control pests on Jatropha in the Bokhol area is estimated at 50 EUR ha^{-1}. $year^{-1}$.

In addition to attacks by pests, the Jatropha plants suffered from very serious attacks of a vascular disease, from the second year of cultivation, which killed approx. 65% of the Jatropha on the plantation within three years (Photo 1). This disease is characterised by a withering and decolouration of the foliage (Photo 2) followed by the loss of all leaves, all of which was accompanied by collar rot. Once the leaves have fallen onto the ground, the plants suffer from opportunistic attacks by termites, which cut through the trunks and cause them to fall to the ground. The disease has spread from a number of infection sites. Various chemical treatments (sulphur, thiophanate-methyl, oxychloride and benomyl) were used, in an attempt to control this disease, but without success. Similarly, the decrease of the frequency of irrigation did not permit to limit the losses.

The importance of soil-borne vascular diseases on Jatropha plants cultivated under irrigation is not well documented. According to Ab van Peer (13, 23), these problems are common in many irrigated plantations, but very few scientific publications refer to this type of attack. Kaushik *et al.* describe attacks by *Fusarium moniliforme* in India (15). Other soil fungi (*Nectria haematococca*, *Lasiodiplodia theobromae*) are examined by Wu *et al.* (25) and Pereira *et al.* (18) in cases of root and collar rot in China and Brazil.

As no other Jatropha cultivation attempts have been made at large-scale in other parts of the Senegal River valley, it is not possible to confirm that all the soils present the same level of infection as that found in Bokhol. It must be noted, however, that fungal attacks, which cause damage similar to that recorded in Bokhol, have been observed at other plantations in the north of Senegal.

Main results of the tests

Following major attacks by a soil-borne vascular disease and climatic conditions that were not conducive to cultivation, most of the results obtained from the different tests are limited to the first two years of cultivation.

Table 1
Comparison of expected and actual yields of dry Jatropha seeds

Year	Expected yield per hectare (tonne. ha^{-1}) under irrigation and the least favourable conditions	Yield obtained at Bokhol (tonne. ha^{-1})
Year 1	0.75	0.13
Year 2	1.00	0.35
Year 3	4.25	0.50
Year 4	5.25	0.50

Photo 1: Aerial view of the plantation in Bokhol (September 2010).

Photo 2: *Jatropha* plant showing symptoms of the soil-borne vascular disease.

The main results from the tests show that the planting method influences the development of plants. Plants grown in nurseries after being sown in plastic containers show stronger growth. The addition of organic and mineral fertilisers can be beneficial to the development and growth of Jatropha. The best response was obtained from a 1 kg dose of organic fertiliser and 40 g NPK per plant for irrigated crops. Pruning makes it possible to increase the number of ramifications. The spacing out of plants promotes their agronomic performance, particularly in terms of productivity.

The average yields obtained at the site after four years of cultivation (less than 500 kg. ha^{-1} of dry seeds), using the best known techniques of production, are significantly lower than anticipated, compared to the available figures for irrigated Jatropha crops in other parts of the world. The seeds are often small and poorly filled. The weight of 1000 seeds rarely exceeds 500 g and their average oil content (23%) is less than the 35% frequently quoted in the literature (2).

Profitability of Jatropha production

In the north of Senegal, the need for water increases rapidly after planting and, once the vegetative cover of the Jatropha has closed, reaches a value directly linked to that of the potential evaporation, which varies between 4.26 to 8.33 mm. day^{-1} within the same year in this area (9). Under the climatic and soil conditions in Bokhol, with its drip irrigation system, the total volume of water to be added per hectare/year rises to 11,314 m^3 (26). Based on an average cost estimated at 40 Fcfa. m^{-3} (water has to be brought up from the Senegal River, using a motor pump to a height of 1.5 m over a distance of 1.5 km), this results in a total cost of 452,560 Fcfa or 691 EUR ha^{-1}. $year^{-1}$.

Despite the possibility of irrigating throughout the year, the combination of problems caused by fusarium/pest attacks and the limited annual growth period of Jatropha resulted in an average yield of under 500 kg. ha^{-1} dry seed for the plantation in its 4th year, instead of the 5.25 tonnes anticipated for the soil type at the experimental site (13). Table 1 compares the actual performance of the Bokhol site with the anticipated result, based on the yields quoted for irrigated Jatropha crops by different sources (13, 16, 19).

Very little data has been published on yields produced by irrigated Jatropha crops. The majority of available references (16) are based on studies conducted by different organizations (19), which base their estimates on second hand data. In a test conducted at the National Water Research Centre at Sharkiya in Egypt, Abdrabbo *et al.* (1) produced yields ranging from 90-200 kg.ha^{-1} of seed at a plantation that was over two years old, depending on the quantity of water applied (between 50%-125% of the PET). These yields are very far from those described by some advocates of Jatropha cultivation (13).

Due to the low yields obtained, the attempt to grow Jatropha in the Bokhol area resulted in complete failure (Table 2). In view of the average price of 65 FCFA (0.10 EUR). kg^{-1} offered to Senegal in 2011 for the purchase of dry Jatropha seeds, an average gross product of 50 EUR.ha^{-1} is obtained. Under these conditions, the GVA generated during the third year after the plantation was established is largely negative (around – 690 EUR.ha^{-1}, taking into account 690 EUR. ha^{-1} for the required water and 50 EUR.ha^{-1} for the cost of other inputs).

This means that, based on the conditions for purchasing Jatropha seeds at the end of 2011 in Senegal and for the system set up at Bokhol, it would have been necessary to produce at least 7,000 kg dry seed ha^{-1}. $year^{-1}$, in order to cover the cost of intermediate inputs. This fails to take into account the depreciation of the irrigation system and equipment, as well as the cost of labour required during harvesting. Considering the even higher cost of obtaining irrigation water from deep boreholes (actual cost= 120 Fcfa.m^{-3}) compared to water pumped from the river (6), the setting up of irrigated Jatropha crop plantations is certainly not profitable under the cultivation conditions that prevail in the north of Senegal.

Conclusions

The results obtained from the Jatropha cultivation tests conducted on marginal soils in Bokhol contradict some of the statements still found on the Internet concerning the potential of this crop (13). According to these allegations, Jatropha is hardly sensitive to

Table 2
Economic performance of Jatropha curcas cultivation at the pilot site

Year	Yield kg.ha^{-1}	Gross profit (EUR.ha^{-1})	Cost of inputs (EUR.ha-1)	Labour costs (EUR.ha^{-1})	Irrigation costs (EUR.ha^{-1})	Net profit (EUR.ha^{-1})
Year 1	130	13	70	300	300	- 600
Year 2	350	35	100	500	310	- 875
Year 3	500	50	100	750	690	- 1490
Year 4	500	50	100	750	690	- 1490

attacks by pests and diseases, able to grow in all soil types, except hydromorphic soils, and, provided it is irrigated, can be cultivated at low altitudes in all tropical regions. On the contrary, our results clearly show that climatic constraints (low temperatures during the winter months and warm, dry winds during the hot, dry season) and phytosanitary constraints (massive attacks by a soil-borne vascular disease) meant that Jatropha cultivation was not economically viable at our experimental site. These constraints resulted in the failure of the large-scale Jatropha plantation project on marginal land in the lower Senegal River valley. We felt that it was important to share this unfortunate experience with anyone wishing to explore this avenue, so that they do not repeat our mistakes and go into this type of business with their eyes open.

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M. Terren, Belgian, PhD student, Department of Tropical Plant Husbandry and Horticulture, University of Liège/ Gembloux Agro-Bio Tech (Belgium).
S. Savery, Belgian, CEO and Chairman, Durabilis NV, Gent (Belgium).
P. Jacquet de Haveskercke, Belgian, CEO and Director, Durabilis NV, Gent (Belgium).
S. Winandy, Belgian, Master in Agricultural Bioengineering, University of Liège/ Gembloux Agro-Bio Tech (Belgium).
G. Mergeai, Belgian, Professor at the Department of Tropical Plant Husbandry and Horticulture, University of Liège/ Gembloux Agro-Bio Tech (Belgium).