SYNGENTA FOUNDATION FOR SUSTAINABLE AGRICULTURE

Project Report

Evaluating the Jatropha curcas – Biodiesel Value Chain as a Potential Driver for Rural Development in Mesoamerica

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Executive Summary

In 2008, the Syngenta Foundation for Sustainable Agriculture initiated a project with Zamorano University to investigate the potential of biodiesel production from *Jatropha curcas* as a possible source of income for smallholder farmers in Central America. The original project duration of five years was extended by one year, with project completion at the end of 2014. During the project, the global Jatropha industry encountered several difficulties which severely restricted the economic viability of Jatropha production. These included yield limitations with current Jatropha varieties, poor agronomic knowledge, emerging diseases and pests, and unrealistic financial expectations. Given these constraints, we cannot yet unreservedly promote Jatropha as an income source for smallholders in Central America, or in the rest of the world.

However, we hope the work carried out by this project will help address the challenges ahead and contribute to a better understanding of *Jatropha curcas* as a crop. The work included:

- agronomic trials to identify the most suitable crop planting and management schemes
- collection, maintenance and characterization of more than 150 Jatropha accessions from Central and South America
- research into the most suitable propagation methods to avoid phenotypic plasticity
- research into biodiesel production and quality standards
- genetic analysis of collected Jatropha varieties.

Since the project began, its findings have been presented at international conferences and workshops, and the submission of several publications is expected at a later date. In addition, Zamorano University has been fully integrated into the Pan-American Jatropha research community and has gained an outstanding reputation in Jatropha research and biofuel quality analytics.

Finally, the project helped Zamorano University to create a highly popular teaching module for undergraduate students, educating young agronomists from all regions of Latin America in

relevant aspects of biofuel production. More than 30 B.Sc. theses have been submitted as a result of the project.

Project Background

Jatropha curcas (physic nut) is a perennial shrub which grows in semi-arid areas of tropical and subtropical regions. It has been the subject of increased attention from the scientific community in recent years, as its seeds are a promising source of vegetable oil for biodiesel conversion. Jatropha's ability to grow on marginal land and under semi-arid conditions has promoted its reputation as a "clean" biofuel source, as it does not compete with valuable ecosystems (e.g. tropical rainforests) or use land dedicated to food production. Although now grown throughout the world (particularly in Northern India, semi-arid SSA, Mesoamerica and Brazil), Jatropha originates from Central America. Consequently, this is also where the greatest genetic diversity is found.

Apart from its location near the genetic epicenter of Jatropha, several other factors support Honduras as an ideal region to investigate Jatropha's potential as an income source for smallholders:

- Honduras is one of the poorest countries in Mesoamerica, with a weak infrastructure and a high emigration rate from rural to urban areas and abroad (mostly to the U.S.)
- Agriculture – mainly by smallholders – is by far the most important economic sector. Honduras is regarded as having great agricultural potential: 70% of its arable (but partly marginal) land is still underutilized, allowing new crops adapted to marginal conditions to be introduced
- Biodiesel production could make Honduras less dependent on fossil fuel imports, which in 2008 were equivalent to 67% of the country's export earnings (Moers, 2010)

Against this background, in 2008 the Syngenta Foundation for Sustainable Agriculture (SFSA) and the Escuela Agricola Panamericana (Zamorano University) initiated a joint project to investigate the use of *Jatropha curcas* for biodiesel production as a potential income source for smallholders in Mesoamerica. It was scheduled to run for 5 years, and received SFSA funding to a total of US$ 500,000. The project was entitled "*Evaluating the Jatropha – Biodiesel Value Chain as a Potential Driver for Rural Development in Mesoamerica",* and was divided into 6 separate components:

1. evaluation of the productivity and key agronomic and agro-ecological aspects of *Jatropha curcas* cultivation
2. collection and characterization of regional Jatropha strains and creation of a germplasm bank at Zamorano University
3. initial development of a value chain for Jatropha seeds and byproducts in Honduras
4. interaction and cooperation with other Jatropha research initiatives
5. research into oil extraction and biodiesel production
6. inclusion of biofuels production in the Zamorano University curriculum

The following chapters describe the main results and achievements of these components.

Evaluation of Jatropha Productivity

As Jatropha has only been cultivated for a relatively short time, several relevant agronomic aspects have yet to be investigated. These include the effect of watering, fertilizer and pruning regimes, the influence of different varieties and cropping densities on yields, and the disease susceptibility of Jatropha cultures. To address these issues, Zamorano University devoted several plots (7 ha in total) to investigate the following specific agronomic aspects:

a) productivity of different Jatropha varieties/accessions
b) impact of cropping density on Jatropha growth, seed yield and disease susceptibility
c) potential of mixed cropping schemes (e.g. with trees or nitrogen-fixing groundnuts)

Further aspects, such as irrigation regime, fertilizer management, and pruning have recently been added to these agronomical trials. However, as Jatropha plants only reach their full yield potential after 4-5 years (and remain productive for 20-25 years), most of the results are not yet available. Nevertheless, initial results are promising and several varieties with yields of up to 11 t seeds/ha have been identified (average literature values: 4-7 t/ha). As Jatropha seeds have an average oil content of 28-30% (Kandpal et al 1995), this is equivalent to 3-4 t of biodiesel/ha.

Establishment of Local Jatropha Germplasm Stock

Jatropha lacks a suitable stock of germplasm for propagation, again as a result of its relatively short cultivation history. Until now, mostly only one variety of Jatropha has been cultivated throughout the world: *Cabo Verde* (not a Cape Verde islands native, it was introduced there from Mesoamerica in the late 1700s). To introduce more diversity, Zamorano University used over 150 accessions from throughout Central America to establish a germplasm stock of locally adapted Jatropha varieties. This stock forms the basis for propagation experiments to increase yield, reduce disease, improve pest resistance and remove toxins (which would allow byproducts to be processed into protein-rich animal feed). Plants of these accessions are currently growing on the campus, and are being assessed for characteristics such as seed yield, plant growth and branching capacity. In addition, a selection of about 100 varieties is currently undergoing genetic analysis in collaboration with the Biorenewables Development Center of York University. This genotyping analysis should reveal the phylogenetic relationship of the accessions collected, and may also allow important traits such as yield capacity to be mapped to genetic markers. The results are expected in September 2014, with later publication in a relevant journal. The future development of this project component includes finding partners to further identify and characterize relevant genetic traits, and using the germplasm stock to create improved Jatropha varieties. In addition to germplasm collection and characterization, this project component also investigated the production of clean and reliable planting material. This investigation was prompted by the high degree of genetic variability in growth, seed yield and oil content generated by sexual seed propagation (as commonly performed in Jatropha farming). Moreover, Jatropha seeds are believed to be vectors for many yield-limiting seed-borne diseases (Machado and Pereira 2013). Using tissue culture techniques, Zamorano University established a protocol to produce pluripotent callus (“plant stem cells”) from Jatropha leaf tissue. Despite promising initial results, a reliable protocol for the re-differentiation of callus tissue to

plants has not yet been fully established. Plans for collaborative work with research groups in Bolivia and Switzerland are in preparation.

Establishment of a Local Value Chain for Jatropha Seeds

Apart from SFSA's engagement with Zamorano University, several foreign aid funded initiatives have been launched in recent years to help establish a Jatropha industry in Honduras. GotaVerde, a mainly EU-funded initiative, was recently visited by SFSA and Zamorano staff. The original objective of the GotaVerde project was to create decentralized biodiesel processing facilities to produce fuel from Jatropha seeds supplied by local smallholder communities. Additional supplies to maintain production levels were foreseen from larger Jatropha plantations on marginal land close to the processing facilities.

Our recent visit to the GotaVerde project sites revealed that all the plantations established 3-5 years ago were abandoned, and some have been cut down (Fig. 1A). Similar observations were reported for other plantations across the country. The main reason is that Jatropha farming is not economically viable: no plantation met the original yield predictions, with some only reaching 5-10% of anticipated quantities. We also observed that most of the plants were showing symptoms of stem canker-like disease, potentially caused by the fungal pathogen *Lasiodiplodia theobromae* (Fig. 1B). This disease severely restricts yields and eventually kills the plant. According to recent literature, this problem is currently being encountered in Jatropha plantations across the world (Latha et al. 2009, Pereira et al. 2009). It was also determined that most plantations on marginal soil and/or with limited water supplies displayed particularly low yields and high disease prevalence, contradicting the expected result of good performance by Jatropha under these conditions. Literature research revealed that all these findings were shared by a recent report on the GotaVerde project (Prakash 2012).

As most of the biodiesel production facilities established by the GotaVerde project were still operational (but lacking a supply of Jatropha seeds), alternative farming methods to low-yield and disease-prone Jatropha monocultures were considered. One promising approach was to plant Jatropha shrubs as hedges to fence off farmland (reportedly a common practice), and to use the seeds as a source of additional income. SFSA subsequently met with Prof. Albrecht Ehrensperger of Bern University, who has investigated similar systems in East Africa. He indicated that given the low yields of current Jatropha varieties, the economic viability of these hedge systems is still limited and the manpower required (particularly for harvesting) might be better applied to other farm activities (Ehrensperger et al. 2013).

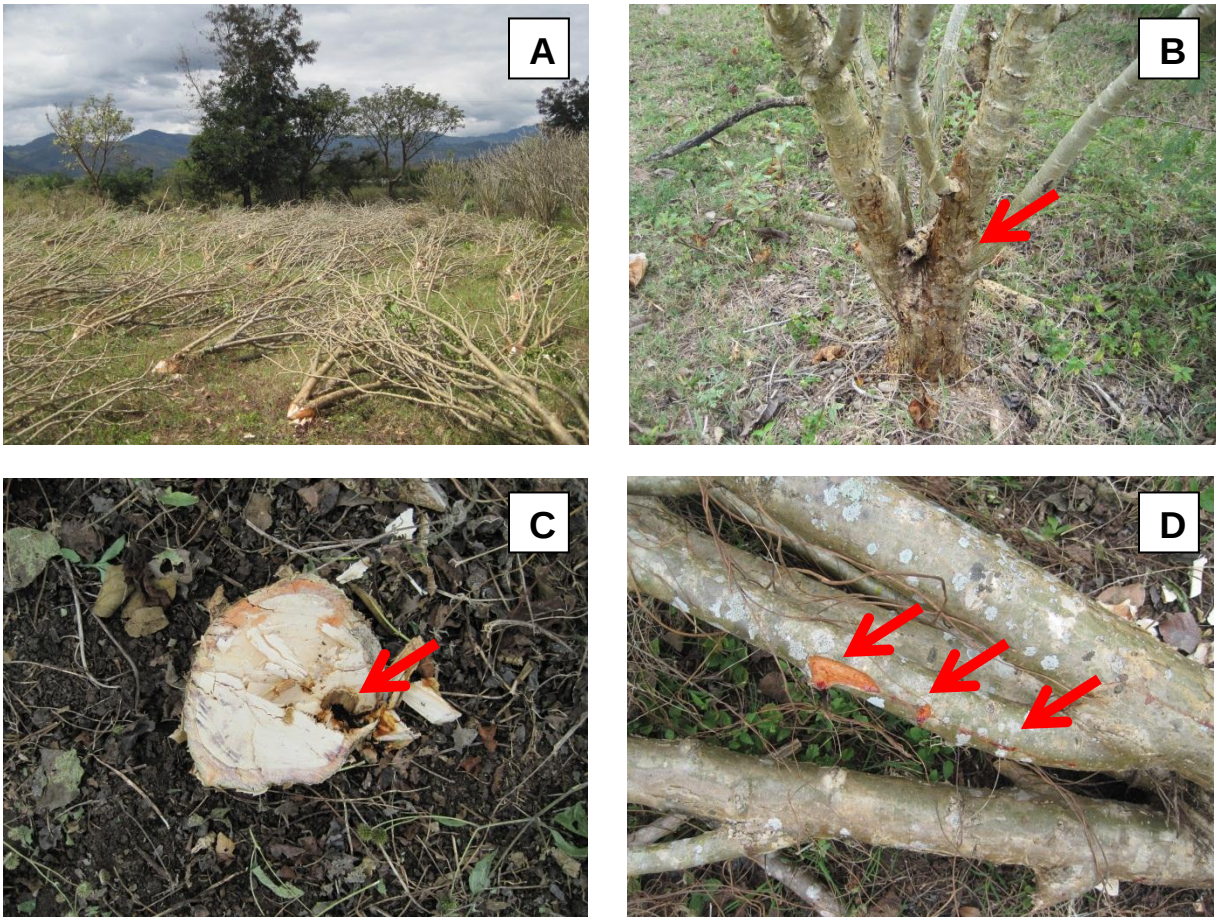

Figure 1: Observations on GotaVerde Plantations

A) Several of the plantations visited are currently being cut down, as expected yields have not been achieved
B) Most of the plants display stem canker-like disease symptoms, potentially caused by the fungal pathogen Lasiodiplodia theobromae
C) Cut stem of a diseased plant showing fungal rot
D) Red stem exudates as potential indicators of infection

Another way to increase the income from Jatropha cultivation may be to identify alternative income sources to biodiesel. For example, value can be extracted from the non-lipid parts of the seeds, which comprise roughly 70% of the seed biomass. The seed cake (Jatropha seed husk after oil extraction) has a high protein content (up to 60%, Makkar & Becker 2009) and could thus be used as livestock feed. However, as Jatropha seed cake and leaves contain a mixture of toxic compounds (phorbol esters, Li et al. 2010), non-toxic varieties would need to be identified or new extraction protocols established before such a dual-use system could be promoted.

Overall, the project findings suggest that further research into the above-mentioned issues must be carried out before a functioning Jatropha value chain can be established in Mesoamerica. The results obtained by the SFSA-Zamorano University joint project, especially in gathering agronomical know-how, collecting and characterizing Jatropha germplasm and defining suitable agricultural practices in Jatropha farming, could represent a very promising contribution to the goal of making Jatropha a viable crop for smallholders in Mesoamerica.

Promotion of a Regional and International Network for Jatropha Research

During the project, Zamorano University engaged in cooperative activities with several academic partners, such as the Biorenewables Center of York University (UK) and the Campina Grande University (Brazil). It has also helped to found a network of regional Jatropha stakeholders in Latin America – the Latin American and Caribbean Jatropha Curcas Network – and has contributed to most workshops of this organization. Zamorano staff have also presented project results at several conferences and workshops, including the 2010 Tropentag at ETH Zürich and the annual meetings of the American Oil Chemists' Society. In addition, manuscripts relating to several components of the project such as agronomic trials, germplasm collection & analysis, and biodiesel quality analytics are currently in preparation and are expected to be published in peer-reviewed scientific journals.

The major findings of the project will be presented to local and regional stakeholders in the Jatropha industry at a workshop held at Zamorano University at the end of this year.

Oil Extraction and Biodiesel Production from Jatropha

As an additional part of the project, several aspects of biodiesel production and quality research have been investigated. A fully functional biodiesel extraction plant was established on the Zamorano campus to evaluate the advantages and disadvantages of several methods of biodiesel production. The raw material for this extraction plant is not restricted to Jatropha seeds: other sources such as oil palm, castor beans, *Acrocomia*, etc. can also be processed into biodiesel.

An analytics facility has been established to assess biodiesel quality – the only one of its kind in Mesoamerica. Both the extraction plant and the analytics facility now operate in complete compliance with ASTM D6751 quality standards. Consequently they have already attracted external clients for biodiesel quality analytics, such as SGB Biofuels (http://www.sgbiofuels.com/), a US company promoting Jatropha as a biofuel.

The results of this project component were presented at the recent annual meeting of the American Oil Chemists' Society. The two poster contributions were "Quality analytics on enzymatically produced biodiesel from *Jatropha curcas"* and "Quantification of toxic phorbol esters in the seed cake of Jatropha seeds", and concerned component activities and the analytics facilities established by the joint project. Two publications relating to these topics are expected to appear in the "Journal of the American Oil Chemists' Society" at a later date.

Local Education in Biofuels Production

Zamorano University is one of the leading agricultural education centers in Latin America, with over 1,000 students originating from Chile to Mexico on its campus. It is famous for its "hands-on" approach to education, with many projects linking theory to applied research. Consequently, all the project components relating to the Jatropha value chain were included in Zamorano's "learning-by-doing" modules, providing students an insight into all aspects of this research. As a part of the joint project with SFSA, Zamorano established a highly popular teaching and project module for senior bachelor students: an in-depth study of the entire Jatropha-Biodiesel value chain, from seedling propagation to biodiesel extraction and quality analysis. So far more than 30 bachelor theses have been submitted as a result of the joint project.

To emphasize the importance of this component, we at SFSA believe that agronomists with a thorough knowledge of biodiesel production – and its opportunities and constraints – will be essential to the development of biofuel value-chains in Mesoamerica. Extensive agronomic and economic know-how will be needed to overcome the challenges presented by the successful integration of *Jatropha curcas* into cropping systems in Central America.

Summary and Outlook

As several project targets are about to be reached, it has been decided to extend the scheduled duration of the project until the end of 2014 (without additional funding from SFSA). By then, the major aspects of this project are expected to be complete and the results compiled. These include:

- final evaluation of optimal Jatropha plantation density and variety performance
  → *publication of these findings in a relevant journal is anticipated*
- completion of the Jatropha germplasm bank and the phenotypic and genotypic analysis of the most promising varieties
  → *publication of these findings in a relevant journal is anticipated*
- establishment of a Jatropha tissue culture propagation protocol
- organization of a Zamorano Jatropha workshop to present the main project findings to regional and international stakeholders by the end of 2014

It is also planned to identify and contact potential private and public partners to continue research into Jatropha cropping systems at Zamorano University, focusing in particular on Jatropha disease resistance, biodiesel extraction & quality research, and Jatropha agronomy.

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