

Jatropha Farm: A Circular Economy Proposal for the Non-Toxic Physic Nut Crop in Mexico [†]

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Abstract: *Jatropha curcas* (physic nut) is a promising crop in tropical countries because its seeds have a high oil content that can be easily transformed into biodiesel. The oil can also serve to obtain other bioproducts. However, several obstacles hinder the extensive application of the crop, for example, the relative low prices of petroleum and oil, the toxicity of the seeds, low crop yields and rusticity of the plant. We propose a model in which several biotechnological strategies are applied to increase the crop value of *Jatropha*, while maintaining the fertility characteristics of the soil, and reducing its carbon and water footprints.

Keywords: *Jatropha*; oil; biodiesel; bioproducts; biofertilizers; recycling



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1. Introduction

Jatropha curcas L. (physic nut) is an emergent crop with potential utilization for biofuel synthesis. Specifically, its oil can be easily converted into biodiesel through transesterification. Glycerin is a secondary product of the process [1]. Several characteristics make this plant a future ally in the world's decarbonization efforts. The plant develops well in dry places, with poor soils, and has good resistance to pests [2]. Despite that, some concerns have arisen regarding the ecological costs of soil conversion for the *Jatropha* crop [3]. Currently, more than 1 million hectares of *Jatropha* are planted around the world. A study found that 40% of the utilized surface was previously cleared from vegetation resulting of logging, not related to *Jatropha*, 34% was defined as unused and the remainder areas were from animal husbandry or other crops [3]. In Mexico, a recognized center of origin of the plant, the agricultural surface occupied by *Jatropha* is very small [4]. The high and medium yield crop potentials in the states of Gulf of Mexico and those in the Pacific coasts are well known. The best altitudes for the crop are at sea level, with a limit at 1000 m [5].

The toxicity of the plant and seeds are factors preventing a wider use. The presence of phorbol esters in the seeds, as also curcins, is responsible for seed toxicity [6]. After oil extraction, a significant proportion of the biomass (up to 50%), known as seed cake, must be carefully treated and discarded. As a way to achieve a more complete utilization of the seeds, a project in the National University of Mexico developed years ago, led by Dr. Ivonne Toledo, consisted in the search and selection of non-toxic *Jatropha* lines across the country. Many accessions were tested and some of them were found with undetectable levels of phorbol esters (Toledo et al., unpublished results). A line named Tlaxcala-2, with such a characteristic, was selected to be included in a pilot project. A total of 30 fields scattered in the south of the Morelos state (in central Mexico, 1000 m a.s.l. altitude on average, moderate-to-low rain precipitations) were established in 2015, covering around 30 hectares, with around 20 thousand plants of the Tlaxcala-2 type. The plants are now five

years of age. In this project, we propose the application of five biotechnological approaches in order to increase the economic value of the non-toxic *Jatropha* crop, while maintaining the natural fertility and biodiversity of soils.

2. The *Jatropha* Farm Model

We propose a circular economy approach for the non-toxic *Jatropha* crop in order to increase the economic value of the seeds, reuse their residues, conserve the natural fertility of the soils and reduce the ecological impact of the crop. The proposed model is shown in Figure 1.

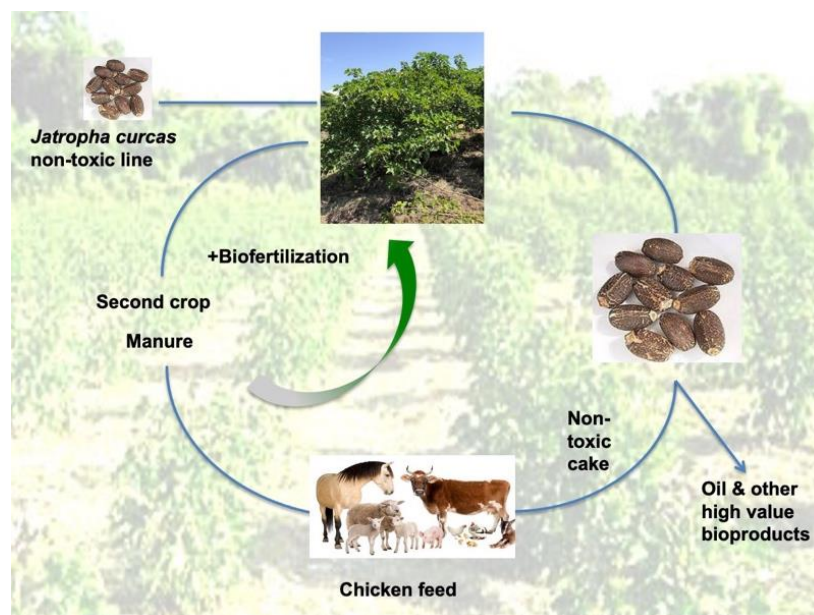


Figure 1. Circular economy proposal of the *Jatropha* Farm.

The non-toxic *Jatropha* variety was used to establish the parcels. The plants are biofertilized with bacteria and mycorrhizal fungi to increase yield, nutrient solubility and organic matter. Upon harvest, the seeds are transported and used for oil extraction. The oil is useful to convert into biodiesel, but also other bioproducts of high value, such as medicines, cosmetics, paints and specialty oils. The residual cake is used to formulate feed for farm animals, such as pigs, cattle or chickens. Their excreta are returned to the *Jatropha* plantation to maintain fertility levels. A secondary crop is established in the plantation for maximal use of land surface and additional economic benefits. The remains of secondary crop plants stay in the field to convert into compost for the next season, increasing nutrients and organic matter. The first part of the proposal consists of the *Jatropha* field experiment; the second part consists of the chicken farm.

3. Preliminary Results

The first part of the *Jatropha* Farm model was established in Xochitepec, Morelos, Mexico, in a plot property of the KSH Innovación Automotriz, a company with which we have a collaboration agreement. The exact location is 18°43'31.3'' N, 99°14'46.6'' W (Figure 2).



Figure 2. Satellite photograph of the *Jatropha* Farm model plot (at left). Xochitepec, Morelos, Mexico. Source: Google Maps.

The parcel covers about 1 ha with 800 plants, in 40 rows of 20 plants each, direction North–South. The non-toxic *Jatropha* plants are 5 years old, healthy, of about 2.5 m height. In the West limit of the parcel, the soil changes visibly to being sandier and the plants are smaller, possibly due to reduced nutrients (Figure 3a). The plots contain 10 plants each. In this part of the field, five treatments with two random-generated repetitions were applied (10 plots). The treatments were as follows:

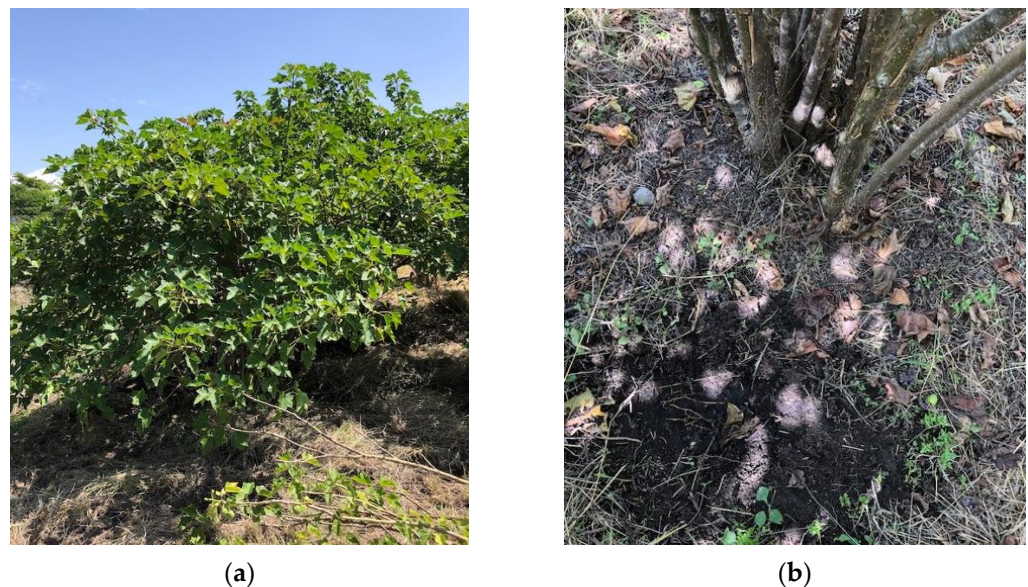


Figure 3. (a) *Jatropha* plant in the model parcel; (b) Application of biofertilizers and manure.

- T1: Control—untreated plots;
- T2: Biofertilized plots. Five grams of Biofabrica Siglo XXI (Cuautla, Morelos, Mexico) combo product, containing *Azospirillum brasilense* and *Rhizopagus irregularis*, were applied at a 0.5 m distance from each plant stem (Figure 3b). Chicken manure was also applied (100 g per plant). The cost of this treatment was USD 0.34 per plant (USD 3.40 per plot);
- T3: Secondary crop. Common bean (*Phaseolus vulgaris*), variety Negro Queretaro, was sown in 2 rows between *Jatropha* plants, 2 plants per hole, 20 plants per row, 80 plants per plot. The seeds were inoculated with specific nitrogen-fixing rhizobial symbiont,

Rhizobium phaseoli CIAT652 strain, prepared in the laboratory (Figure 4a; emerged bean plants, Figure 4b). The cost of this treatment was USD 0.02 per bean plant (USD 1.6 per plot);

- T4: Biofertilized plots plus secondary crop. The combined assay of the two previous treatments. The cost was USD 0.34 per *Jatropha* plant plus USD 0.02 per bean plant. The cost by plot was USD 5.0;
- T5: Fertilized plants. Chemical fertilizer was bought (formula 18-46-00) and applied at the lower recommended rate of 50 Kg N/ha. The doses were applied as halves, one month apart from each other. The cost per *Jatropha* plant was USD 0.145 (USD 1.45 per plot).



Figure 4. (a) Preparation of common bean seed inoculant; (b) emerged bean plants.

4. Conclusions

The second part of the proposal (the chicken farm) will be performed with the cake from seeds harvested in this season. Thus, the five proposed biotechnological approaches of the *Jatropha* Farm will be complete: the use of a non-toxic *Jatropha* line, the application of biofertilizers, establishing secondary crops, recycling the seed cake, and the reuse of chicken manure. At the end of the season (approximately next October), the economic study will consider the costs and benefits of these strategies. The effect on the soil will be studied, assessing bacterial populations and the content of organic matter. The ecological effect of the mentioned strategies will be studied through carbon and water footprints. The entire experiment will run for two additional seasons, finishing in 2023. Meanwhile, the proposal and the preliminary results will be divulged in specialized fora, and also in workshops with the general public and the farmers of the Morelos state, who own non-toxic *Jatropha* parcels. Additionally, we are exploring the conversion of *Jatropha* oil into high value bioproducts, such as dermatological creams and dielectric oils. We are in the process of obtaining the genome sequence of the non-toxic *Jatropha curcas* line; it will allow finding differences in comparison with the genomes of toxic *Jatropha* varieties.

The fundamentals of the project allow for it to be extended to other places and crops. We are collaborating with *Jatropha* researchers in Ecuador, who are interested in the applications of the model, and also with oil palm producers in Colombia. Additionally, we will research the possible rebound effects on promoting this crop instead of others that are traditionally produced, acknowledging a life cycle approach and a decarbonization scenario relying on electric vehicles in medium to long term, such that claims on the circular economy can be made from a resource perspective.

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