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Feasibility of a *guayule* commodity chain in the Mediterranean region

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ABSTRACT

Natural rubber demand was 11 million tons in 2014 and is expected to reach 16 million tons by 2025 according to the International Rubber Study Group (IRSG). The expected limitation of natural rubber from *Hevea* induced an interest for the development of alternative sources of natural rubber. *Guayule* (*Parthenium argentatum* Gray L.), being native to the Mexican Chihuahua desert, is a perennial crop of semi-arid area, with the potential of growing in the Mediterranean area. To assess the potential of *guayule* cultivation, CIRAD (France) and Wageningen University (The Netherlands) have conducted some on-farm *guayule* trials in southern Europe in partnership within the European based production and exploitation of alternative rubber and latex sources project (EU-PEARLS). Promising agronomic results have led to assess the profitability of a *guayule* commodity chain in the Mediterranean Europe area. Data on farming practices, biorefinery, costs of inputs were collected from the trials conducted in Spain and France, and from farmers and farmers' organizations in both countries. At farm level, different cost scenarios were tested, with *guayule* biomass being the sole output, with annual or biennial harvests. Our results showed that, based on a nine-year field cultivation, the farmer's breakeven point can be reached at a sale price of €147 ton^{-1} of dry biomass (at 12 ton ha^{-1}). At factory level, the biorefiner needs to sell water-extracted rubber as latex. By adding solvent extraction, it is possible to extract the remaining percentage of total rubber and the resin. In such case, the biorefiner's profits rises to €691 ton^{-1} of extracted rubber, making *guayule* cultivation profitable. Bagasse sale for electricity production or wood pellets is a bonus to be considered too. Our results showed that, in these conditions, a *guayule* value chain in Europe could be profitable.

We extrapolated the results from our experiments to other Mediterranean countrie's culture conditions. Our results showed that *guayule* cultivation would probably be more beneficial in the Southern Mediterranean countries, including Spain, than in the Northern countries (South of France). Introduction of *guayule* production in the Mediterranean region could contribute to improved sustainability in rural development projects, allow a new economic development of the regions, and contribute to provide a new sustainable crop alternative against the impacts of climate change such as longer and more severe drought stress.

1. Introduction

Today, the only commercial source of natural rubber (NR) is from *Hevea* (*Hevea Brasiliensis* Müll.Arg.). Asia produces 93% of the total world NR supply. The tire industry uses 70% of the world NR production. Demand from emerging countries, mainly from China and India, is expected to increase and to reach 16 million tons of NR by 2025, while it was of 11 million tons in 2014. New alternative sources of NR will be needed in a near future to satisfy NR future demand. In the near future, *guayule* and Kazakh dandelion (*Taraxacum kok saghyz* L.E. Rodin) have the potential to develop in Europe and North America as long as they demonstrate they can become a profitable commodity of NR raw material (van Beilen and Poirier, 2007). Presently, *guayule* NR is grown at a commercial scale only in the USA, by the Yulex Company in Arizona (Yulex, 2014). In 2012, Yulex has built a commercial plant located at Chandler, near Phoenix AZ. The largest tire rubber company, Bridgestone, has inaugurated in 2015, a research center and an extraction plant for raw *guayule* rubber production in Arizona, USA.

Commercial *guayule* production does not yet exist in Europe and in Mediterranean area. Some developments were attempted in the 1950s in Spain, and in the 1980s in Morocco (Wright et al., 1991;

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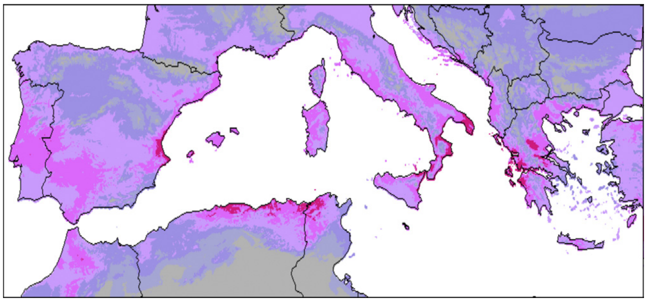

Fig. 1. Main Mediterranean areas suitable for *guayule*. Suitable areas are in pink. The color gradient indicates the correspondence with the area of origin. More color is darker, the more the area is close to the original.

Muller, 1946; Ramos, 1960; Serier, 1981; CSIRO, 1986). *Guayule* development in Spain was in the Huelva and Sevilla area, near the Guadalquivir River. A national project aimed at planting up to 60,000 ha of *guayule* in this area, today part of the Donana parc, and to set an extraction plant to produce up to 16 tons of *guayule* rubber per year. In Morocco, the Institut de Recherches sur le CAoutchouc (IRCA) introduced *guayule* experimentations near Meknes and Marrakech. *Guayule* varieties 226 and 234 grew well in Morocco with 11.2% rubber in the stems and 796 g of stem dry weight (Palu and Chapuset, 2011), but the project was abandoned as there was no funding to set an extraction plant to process the few hectares of biomass.

From 2008 to 2012, the feasibility of *guayule* growth in two Mediterranean countries (France and Spain) *guayule* had undergone within the framework of the EU-Pearls project (Snoeck et al., 2011; van Loo et al., 2012). Besides, Yulex and Versalis reported recently to have signed an agreement to develop *guayule* in southern Italy. Different extraction processes were tested to develop latex and crude rubber extraction adapted to the European context (Palu et al., 2013). Based on the EU-Pearls project results, agronomic and technical feasibility of a *guayule* commodity chain was assessed in the Mediterranean region (Sfeir et al., 2012).

This paper demonstrates the technical and economic aspects of *guayule* cultivation feasibility in the Mediterranean region in order to give information to farmers and biorefiners that would be interested to develop this crop. Our approach emphasizes on the necessity for a *guayule* commercial development, to implement the bio-refinery concept for the extraction process to valorize most of the *guayule* bio-products for specific market such as, non-allergenic latex for medical gloves, raw technically specified rubber grade for tires, fractions of the resins for paint, bio-pesticides, pharmaceutical biomolecules, and the large quantities of remaining bagasse for electricity, bio-carburant, and wood particle panel.

2. Materials and methods

The suitable zones for *guayule* cultivation were determined based on the ecological suitability of this particular crop. The feasibility of growing *guayule* was assessed from GIS suitability mapping using software such as DIVA-GIS, WORLDCLIM and ECOCROP, that helped us determine areas that do not require much water (250–600 mm yr^{-1}), with a range of temperature (−10 °C to +40 °C), suitable for *guayule* cultivation crops (Domonhedo et al., 2013).

The farmer's account was based on actual cultivation data obtained from the *guayule* field trials planted in 2008 in France and Spain within the EU-Pearls project (Snoeck et al., 2011; van Loo et al., 2012). Climatic data of both trial sites are given in Fig. 1.

Based on the trial results, farming practices used for simulations are:

a) Planting density: 50,000 plants ha^{-1}; seedling are grown in nursery and planted in the field in October on ridges (double-rows of 0.35 m × 0.40 m separated by 0.65 m).
b) Planted vegetal material: AZ2, which performed well in the trials.
c) Management with irrigation and fertilization.

Costs were obtained from various surveys (Sfeir et al., 2012) obtained from agricultural experts in the South of France (Van Kempen and Pérès, 2010) and Spain (García García et al., 2012). The costs were used to build our model since *guayule* cultivation does not exist in the region for commercial production. They include:

- Nursery (for production of seedlings), irrigation equipment.
- Land preparation (plowing, ridging, plastic mulching) and planting.
- Land rental.
- Drip irrigation, fertilization, pesticides, use of irrigation water, maintenance of irrigation material.
- Labor over a 10- year growing cycle.

The biorefiner's account was based on the pilot plant developed at the Cirad laboratory (Palu et al., 2013). Rubber, resin content in the fresh and remaining bagasse (fibrous matter left after the branches were crushed) were measured by Automatic Solvent Extraction (ASE/Dionex) analysis at laboratory level (Suchat et al., 2013). Latex content was controlled using an aqueous process on fresh harvested biomass stored less than a week, and at pilot scale (100 kg day^{-1} dry biomass) to set a pilot extraction processes model by Cirad laboratory in Montpellier (France).

3. Results and discussion

The suitable zones for *guayule* cultivation in the Mediterranean area were calculated from the climatic data (Domonhedo et al., 2013). Areas with rainfall and temperatures not different from the Chihuahua conditions were colored in pink, with the pink gradient showing the similarity degree with the area of origin (Fig. 1). More color is darker; the more the area is close to the original.

The advantages of the Southern Mediterranean regions are that:

- Climatic conditions of the Mediterranean are not very different from those of the Mexican desert (Fig. 2).
- Lower European land rental value in semi-arid regions.
- Land available for *guayule* cultivation is less than 5 ha for most farmers.
- Lower labor costs (at least 20% lower in Southern Europe than in Northern Europe).

Particularly, the climatic conditions of Montpellier and Cartagena (Fig. 2a,b) are within a range of temperatures and rainfall acceptable for *guayule* cultivation, even though not as dry as the climatic data reported for Chihuahua desert (Fig. 2c). They are closer to those encountered in Arizona (Fig. 2d); particularly for the south of Spain which has a dry climate and low rainfall (300 mm of rainfall). Montpellier area in southern France has a cooler climate in the winter (up to −12 °C).

The concerned Mediterranean countries were selected to grow *guayule* for the following reasons:

- Even though southern Mediterranean countries suffer with dryness as water is a limiting factor, there is groundwater availability to be used for irrigation.
- The climatic change needs to develop new crops such as *guayule* suitable for semi-arid land development and sustainable farming in the Mediterranean area.