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Technical options for optimization of production of *Jatropha* as a biofuel feedstock in arid and semi-arid areas of Zimbabwe

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ABSTRACT

Biofuels are being promoted as sustainable alternatives to fossil fuels both from energy supply perspective as well as a technical option to respond to climate change. Various crops are grown throughout the world to supply feedstocks for the production of biofuels. In sub-Saharan Africa, *Jatropha curcas* is considered to be the most suitable feedstock for production of biodiesel. Zimbabwe is a tropical country with suitable growth conditions for *Jatropha*. Since 2005, the production of *Jatropha* has gathered momentum in the country. The plan for production of *Jatropha* has concentrated on boosting production areas. Not much attention has been given to technical issues that are important in optimizing the yield and quality norms of *Jatropha* seed. This paper discusses technical interventions at two levels of the value chain that are required to optimize production of *Jatropha* in the country as a commercially viable energy crop. Emphasis is placed on the need to supply elite planting materials to optimize seed yield and seed quality as well as consider suitable agro-techniques required to establish the *Jatropha* plantations. Given that the longevity of *Jatropha* trees is 50 years, the objective is to establish plantations based on improved germplasm rather than rely on wild type germplasm.

1. Introduction

Production of biofuels has become part of the global sustainable development agenda. Bioethanol and biodiesel are the most important liquid biofuels in use today. Biofuels are derived mainly from agricultural crops such sugarcane and corn (bioethanol) and oilseeds (biodiesel). Production of suitable feedstocks is an important dynamic in the biofuels industry. *Jatropha curcas* has been promoted extensively as an energy crop for production of biodiesel in the tropics [1]. In sub-Saharan Africa *Jatropha* is considered to be the most suitable crop for biodiesel production. This is due to its adaptation to tropical conditions.

Jatropha is an oil tree that belongs to the family Euphorbiaceae. It is extensively described in literature as a hardy tree that grows in a wide range of physiographic and climatic conditions [2]. It is a vigorous, drought- and pest tolerant plant that can grow on barren, eroded lands under harsh climatic conditions [3–5]. *Jatropha* is still largely a wild plant. It is largely promoted as a crop grown on marginal and wastelands. Seed yields of *Jatropha* reported in literature have ranged from 0.2 t ha^{-1} to 12 t ha^{-1} depending on production conditions [3]. It has a high content of non-edible oil ranging from 30 to 48% [6]. The yield of biodiesel is about 92% of the initial weight of the *Jatropha* oil [7].

Zimbabwe has shown interest in the production of *Jatropha* as the main feedstock for its biodiesel program. Since 2005 the production of *Jatropha* has gathered momentum in the country. The target is to produce at least 365 kt of *Jatropha* seed per year [8]. The plan for production of *Jatropha* in Zimbabwe

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has mainly concentrated on boosting production hectarages. Not much attention has been given to technical issues that are important in optimizing yield and quality norms of *Jatropha* seed. The planting materials that are being used have not been selected for quality. In addition, *Jatropha* is mainly relegated to marginal land crop status, secluding it from appropriate agro-technological interventions. The success of *Jatropha* production will depend on its viability as a commercial crop. There is need for the development of a package of practice for optimization of commercial cultivation of *Jatropha* in Zimbabwe. This paper discusses technical interventions at two levels of the value chain that are required to optimize the production of *Jatropha* in the country as a commercially viable crop.

2. Supply of quality plant germplasm

2.1. Quality of planting materials

The quality of planting materials is very important in determining the performance characteristics of crops [3,9]. Unlike with other commercial agricultural crops which have planting materials certified according to performance characteristics, there is currently no certified planting material for *Jatropha* [9]. *Jatropha* is propagated from seed or vegetatively from stem cuttings. *Jatropha* is still largely a wild plant and has not yet undergone much selection and improvement for agricultural use [3,9]. It exhibits great variability in productivity between individual plants. Seed yields vary from as low as 200 g to over 2 kg per plant and oil content of 30–48% has been reported [3,6]. The yield dynamics of *Jatropha* are mainly caused by variation due to cross-pollination [6]. Propagation through seeds does not give population true to the parental stock due to cross-pollination. The wide variation in performance characteristics of *Jatropha* makes selection very important in order to optimize its yield and quality norms.

In Zimbabwe *Jatropha* planting materials are collected in areas where the plant is used as a live fence. These areas are geographically spread out over the country. More recently, planting materials are becoming available from commercial plantations that have been established all over the country. The planting materials consist of seed, seedlings and stem cuttings. There is no selection or plant improvement programs to supply elite planting materials. *Jatropha* has longevity of up to 50 years. This makes it less flexible than annual crops, and without plant improvement programs there is a high possibility of establishing plantations that are based on inferior planting materials. Thus, there is need to set up programs for the production of improved *Jatropha* germplasm in the country. Traits of economic importance include seed yield and seed quality. Naturally *Jatropha* is drought and pest tolerant.

2.2. Improvement of quality of planting materials

The supply of elite planting materials is not without precedence in agriculture. Technology has been widely used to improve the performance characteristics of many agricultural crops. The plant improvement program for *Jatropha* should mainly focus on three traits. These are improving seed yield, oil content and oil quality [4,10]. Morphometric traits associated with seed yield such as number of branches and number of fruits per branch are expected to improve concurrently with yield increments. There are several strategies that can be used to improve these traits. These include cross breeding, mutation breeding and genetic engineering [11].

2.2.1. Improving seed yield

Plants with seed yields above 2 kg per tree are ideal [5]. This translates to about 4.5 t ha^{-1}. Seed yields of above 5 t ha^{-1} cited in conventional literature seem to be biological potential that can only be achieved with high quality planting materials. Several techniques are available for improvement of seed yield of *Jatropha*. The first step is gene mapping to establish an elite population with desirable characteristics that breeds true. The elite mapping population data could then be used to screen germplasm of *Jatropha* to identify DNA markers or major quantitative trait loci associated with high yield and the information used to start genetic improvement for yield characteristics [10]. In cases where there is little variation for economically important traits, inter-specific and inter-generic crossing is needed. *Jatropha* is a morphologically diverse genus with over 170 species [6]. Examples of inter-specific hybridization in *Jatropha* have been reported in India [6]. These have been between different accessions and species of *Jatropha*. The hybridization improved vegetative, flowering and fruiting traits of *Jatropha* [6]. Techniques in tissue culture such as *in vitro* fertilization, somatic hybridization and gene transfer can be used to facilitate such crosses [10].

Seed yield improvements in *Jatropha* have also been studied using mutation breeding techniques [10]. Induced mutation can be used to improve the quality of *Jatropha* in terms of seed production, oil content and days to maturity [11]. Mutation breeding is reported to be more efficient and cheaper [11]. Induced mutation of *Jatropha* by irradiation of cuttings has been reported to increase genetic variation [11]. Gamma radiation doses of 10–15 Gy have been used with cuttings, and created genetic variation which led to early maturity and increased 100 seeds weight [11]. Three types of mutants have been considered. These are; morphological, physiological and biochemical mutants [10]. Work in these areas is still in progress.

Jatropha is propagated both sexually and asexually. Vegetative propagation of Jatropha is not difficult. Stem cuttings maintain the purity of the parental stocks due to clonal propagation [6]. The success of clonal propagation depends on availability of superior clones and clonal multiplication rate. Stem cuttings are widely used in Zimbabwe for propagation of Jatropha. Only cuttings from plants with desirable traits need to be used to establish Jatropha plantations. There is need for availability of sufficient cuttings for clonal planting on a commercial scale.

2.2.2. Improving oil content and quality

Oil is the chemical constituent of *Jatropha* seed that is used for the production of biodiesel. There is wide variation in the oil content of *Jatropha* seed. Oil content has been reported to vary from 31 to 37% [10], 30–48% [6], 35–58% in seed and 40–60% in kernel [11]. It is important to breed plants with oil yields on the upper limits of the given ranges. Efforts of National Oilseed and Vegetable Oil Development Board of India have resulted