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Experiences with *Jatropha* cultivation in sub-Saharan Africa: Lessons for the next phase of development

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Jatropha curcas L. has emerged in recent times as a leading energy crop in sub-Saharan Africa with over 32 countries in the region involved in its production. The establishment of *Jatropha* has not been without challenges and has arguably been driven by crop-suitability factors that have been put to test in the last decade. The objective of this paper is to provide an analysis of the performance of *Jatropha* as an energy crop, benchmarking on the plant's acclaimed attributes. The paper analyses information originating from sub-Saharan Africa and examines the performance of the crop. The results show that current agronomic practices and performance levels of *Jatropha* in terms of seed yield (< 1 t/ha^{-1}) are inadequate and unlikely to lead to production of sufficient quantities of seed for biodiesel production. Not enough has been done in the region in terms of research and use of information extrapolated from other environments has not been adequate. The conclusion is that much work still needs to be done in terms of developing suitable germplasm and agronomic practices for *Jatropha*.

Keywords: agronomic practices, crop performance, seed yield, *Jatropha*, seed yield, sub-Saharan Africa

JEL classification: O13, O30, O33, O55, N50, N57

Introduction

Sub-Saharan Africa (SSA) is made up of 49 countries that lie south of the Sahara. Thirty-two countries in this region are investing in production of *Jatropha curcas* L. as an energy crop for production of biodiesel and other products. Total land area in SSA under *Jatropha* cultivation was 119 000 ha by 2008 and projected to rise to about 2 million ha by 2015 (GEXSI 2008). The region in SSA suitable for *Jatropha* cultivation (known as the 'Jatropha belt') is delimited by the tropics of Cancer and Capricorn (Basili and Fontini 2010). Parsons (2005) postulated that prime land suitable for cultivation of *Jatropha* in SSA stretches for over 10.8 million square kilometers or one billion ha.

Commercial production of *Jatropha* in SSA is a relatively new industry that is still burgeoning and expected to witness both spatial and temporal transformation. Cultivation of *Jatropha* in SSA has mainly been influenced by the acclaimed attributes of the plant. These include that it is a high yielding oil crop that is drought tolerant and has low nutrient, water, and management requirements and is well adapted to grow on marginal lands (Sale and Dewes 2009, Achten et al. 2010). Seed yield is the most important economic trait in the cultivation of *Jatropha*. Benchmark figures for seed yield indicate that with optimum rainfall of 900–1 200 mm, yields can be up to 5 t/ha^{-1} (Maes et al. 2009). Jongschaap et al., (2007) calculated a theoretical optimum seed yield of 7.8 t/ha^{-1} for mature plantations after three to four years of growth.

The major problem is that most of the data used to substantiate claims on the attributes of *Jatropha* have been extrapolated from outside SSA. In addition, these claims have not been adequately corroborated by local systematic research. However, there is now substantial experience in SSA in terms of commercial cultivation of *Jatropha* as an energy crop. Substantial data and information are now available in the region in terms of the performance of *Jatropha.* This paper analyses these data and information. The objective is to set a development agenda for *Jatropha* based on empirical evidence derived *in situ* under local conditions.

Experiences with *Jatropha* cultivation

Experiences with the commercial cultivation of *Jatropha* will be described by considering four important factors. These are:

- Agronomic practices;
- Pests and diseases;
- Seed yield; and
- Economic viability.

Agronomic practices

Establishment and management

Jatropha is propagated both sexually and asexually in SSA. This is consistent with practices elsewhere. Cuttings used for propagation are derived mainly from existing *Jatropha* hedgerows. In 2008, the total length of *Jatropha* hedges in Africa was estimated at 75 000 km (Muok and Källbäck 2008). Where *Jatropha* is propagated from seed, both direct seeding and transplanting from nurseries are practiced (GEXSI 2008). It is clear that there is very little or no certified planting material in SSA (JA and UNAC 2009). Thus, the quality of planting material is an issue in the region.

Other agronomic practices such as plant spacing and pruning are very variable. Plant spacing ranges from 2 × 2 m (2 500 plants/ha) to 3 × 3 m (1 111 plants/ha) in most of the plantations (Wahl et al. 2009). Pit geometry is variable but on average is about 0.5 × 0.5 × 0.5 m (FACT 2006). Pruning regimes are indiscriminate and experience in Mozambique shows that after 2–3 years of growth, most plants had 18 to 30 branches (JA and UNAC 2009).

Irrigation and fertiliser application

Ability to withstand drought conditions is a major attraction for *Jatropha* cultivation in SSA given the arid and semi-arid conditions prevalent in the region. Farmers in SSA ventured into *Jatropha* cultivation expecting a crop that would have low water requirements (JA and UNAC 2009). Most of the plantations in SSA are under rain-fed conditions. The GEXSI report (2008) showed that 49% of the plantations in the world were under irrigation. However, the report indicated that irrigation was less developed in SSA.

The annual precipitation range suitable for *Jatropha* cultivation is 250–1 500 mm, with an optimum range of 900–1 500 mm (Benge 2006, Trabucco et al. 2010). This is hardly the case in SSA. Hence, irrigation is quite common in *Jatropha* cultivation. For example, in order to achieve good stand establishments, farmers in Mozambique applied 5–7 litres of water per day per plant to supplement rainfall in the early phases of growth of *Jatropha* (JA and UNAC 2009). Data from Kenya also showed that at least 40% of *Jatropha* farmers practiced irrigation (GTZ 2009).

Jatropha is claimed to thrive on marginal land. One of the characteristics of marginal lands is low soil fertility. Limitations of soil fertility are known to hamper crop development (Jongschaap et al. 2007). Where *Jatropha* has been grown on marginal lands without application of fertilisers, seed yields have been as low as 0.4 t/ha^{-1} (Openshaw 2000). Use of fertilisers, especially organic types is quite common in SSA. In Kenya, 50% of farmers used organic fertilisers in *Jatropha* production (GTZ 2009). In Tanzania, no farmers were observed to apply fertilisers or any other inputs (Brittaine and Lutaladio 2010). Types of organic fertilisers used include *Jatropha* seedcake.

Jatropha seems to respond to both organic and inorganic fertiliser application. For example, in India, treatment of *Jatropha* plantations with 3 t/ha^{-1} of *Jatropha* seedcake increased seed yield by 120% and 93% at different plant densities of 833 (4 × 3 m) and 1 667 (3 × 2 m) plants ha^{-1}, respectively (Ghosh et al. 2007). In Burkina Faso, addition of organic matter to *Jatropha* on degraded soils was shown to significantly enhance the growth rate of seedlings (Kagamebga et al. 2011).

Pests and diseases

It is known that pests and diseases are deleterious to crop production. One of the claimed attributes of *Jatropha* is tolerance or resistance to pests and diseases (Jongschaap et al. 2007). Experiences in many countries in SSA suggest that *Jatropha* is vulnerable to several diseases and pests. Contrary to the belief that toxicity and insecticidal properties naturally protect *Jatropha* from pests and diseases, several pests and diseases have been reported to attack the plant. There is an increase in the risk for pests and diseases especially in areas where *Jatropha* is cultivated in large scale monocultures (Grass 2009). Some of the diseases and pests are shown in Table 1. Although information in Table 1 does not provide evidence on the severity of the identified pests and diseases, it does indicate the susceptibility of *Jatropha* to pests and diseases.

Seed yield

Seed yield is one of the most important economic traits in commercial production of *Jatropha*. Most plantations established in the late 1980s to the 1990s were abandoned due mainly to low productivity and/or high labour costs (Jongschaap et al. 2007). Reasons given for not recommending *Jatropha* cultivation, for example by JA and UNAC (2009) in Mozambique and Wahl et al. (2009) in Tanzania, are all centred on poor seed yields and poor viability.

There is little empirical information that has been collected regarding actual seed yields of *Jatropha* in SSA. The information that is available is highly variable, not standardised and difficult to verify. Seed yields that have been reported include 1.65 t/ha^{-1} in Tanzania (Brittaine and

Table 1: Pests and diseases of Jatropha reported in the sub-Saharan Africa region

Country	Pest/Disease	Reference
Mozambique	Leaf spot, collar rot, root rot	JA & UNAC 2009
Kenya	Golden flea beetle (*Aphtona* sp.), leaf spotting, powdery mildew (*Oidium* sp.)	GTZ 2009
Zimbabwe	Stem borer (*Ostrinia furnacalis* or *Xyleborus* sp.), golden flea beetle, fungus of *Cercospora* species (frogeye)	FACT 2006
Tanzania	Scutellarid bug (*Scutellera nobilis*), golden flea beetle, stem borer, powdery mildew	Wahl et al. 2009

Lutaladio 2010), less than 1 kg per tree in Mozambique (JA and UNAC 2009), 0.63 t/ha^{-1} in Mali (FACT 2006) and up to 0.86 kg per tree in Kenya (GTZ 2009).

The data given above are accompanied by little or no information on variables such as genetic provenance, age of plantations, propagation method used, canopy management regime, rainfall, tree densities, soil types and soil fertility management (Brittaine and Lutaladio 2010). This makes it very difficult to relate the yields to any parameters. However, these yields can be contrasted with benchmark figures which show that with optimum rainfall of 900–1 200 mm, yields can be up to 5 t/ha^{-1} (Maes et al. 2009).

Seed yield given per tree should be treated with caution. Henning (2008) showed that there is too much variation among individual trees in terms of seed yield. The results showed that annual yield variation of 19 trees ranged from 0 to 850 g dry seed per tree. Thus, according to Achten et al. (2008), expectations that *Jatropha* will yield up to 12 t/ha^{-1} of dry seeds result from illegitimate extrapolation from individual plants.

It is clear from emerging information that harvesting of *Jatropha* seeds is labour-intensive. This is ascribed to lack of mechanisation and the heterogeneous or asynchronous fruiting of the plants. This is problematic in smallholder farming situations where family labour is reported to be overstretched in most instances.

Economic viability

Economic dimensions of *Jatropha* cultivation include diversifying income opportunities for farmers, opportunities arising from the value chain (production, transportation and processing) and income from clean development mechanism (CDM) and carbon credits.

Studies in Tanzania (Wahl et al. 2009) and Kenya (GTZ 2009) showed that *Jatropha* cultivation was not a viable enterprise under conditions that prevailed at the time. Reasons given for the poor viability included the following:

- High requirement for labour;
- High opportunity cost when grown on fertile land;
- Low producer prices; and
- Low seed yields.

Evidence from Zimbabwe also shows that the *Jatropha* project which was initiated by the Plant Oil Producers' Association in 1992 was abandoned after it was realised that the profit margins were not as big as originally expected (Henning 2003b). The indication is that commercial viability of *Jatropha* cultivation needs to be improved.

Lessons for development

The true potential of *Jatropha* as a cash crop depends on the successful domestication of this semi-wild plant as well as the creation of a market that ensures reasonable prices (GTZ 2009). Generally, *Jatropha* in SSA is subjected to harsh climatic conditions, marginal soils and poor agronomic practices that do not promote good yields. Farmers in SSA who ventured into *Jatropha* cultivation expecting a crop that would thrive on marginal soils and with low maintenance requirements (JA and UNAC 2009) have been disappointed.

Focus areas

Experiences with *Jatropha* cultivation in SSA provide a reality check that helps set an agenda for enhancing the status of *Jatropha* as a viable energy crop. The major issue is to improve seed yields. Perhaps it is reasonable to acknowledge that the low seed yields are consistent with a plant still under domestication and will improve in the course of time. There are five critical areas that need attention. These are:

- Improvement of quality of planting materials;
- Establishment of good crop management protocols;
- Determination of appropriate fertiliser regimes ;
- Determination of water requirements and development of irrigation; and
- Development of competitive markets for *Jatropha* seeds.

Development framework

Crop productivity depends on the effects of environmental conditions which can be mitigated or amplified by technical practices (Trabucco et al. 2010). There is need for a systematic framework that will guide development of appropriate technical interventions that will improve the performance of *Jatropha*. The underpinning principle is that of best practice. Best practices are required in order to establish efficient production systems. From an agronomic or silvicultural perspective, development of production packages is a fundamental issue and these packages need to be in place to guide farmers.

The proposed framework is based on a series of questions which will help to develop solutions to knowledge gaps in the production of *Jatropha*. The important questions are given in Table 2. The range of issues includes selection of planting material, propagation methods, watering regimes, fertiliser use, canopy management, and pest and disease control. Development of best practices for these issues will mitigate specific environmental constraints.

Development strategies

The supply of elite planting material is the single most important step in the transformation of *Jatropha* into a viable energy crop. This is not without precedence in agriculture. Technology has been widely used to improve the performance characteristics of many agricultural crops. The plant improvement programme for *Jatropha* should mainly focus on three traits. These are improving seed yield, oil content and oil quality.

Many strategies are currently available to produce improved varieties with desirable traits for specific growing conditions of a cross-pollinated *Jatropha* crop. Genetic improvement methods applied to exploit genetic variation in *Jatropha* include mass selection, recurrent selection, heterosis breeding, mutation breeding and inter-specific hybridisation (Divakara et al. 2010). These need to be optimally used in *Jatropha* breeding programmes. Many countries in SSA have well developed infrastructure for plant breeding. Juxtaposition of *Jatropha* into these programmes is a requirement.

Coordinated research is required for agronomic issues such as optimum soil texture, macro- and micronutrients required, intercropping, amounts of water and irrigation requirements, pruning intensity, and evaluation and propagation methods. Countries in SSA can leverage their crop research infrastructures in formulation and implementation of research programmes for *Jatropha*. It will be good practice if research endeavours for *Jatropha* are supported by enabling policies.

The issue of markets for *Jatropha* is a critical success factor for *Jatropha* cultivation. Often farmers in SSA have found themselves without reliable markets. This is an issue that requires state intervention at policy level. Unless farmers are guaranteed a reliable market, there will be little motivation for cultivation of *Jatropha*.

Table 3 provides more information for each of the five areas that require attention in the development of *Jatropha* production programmes in SSA.

Conclusion

The need for appropriate technical interventions to support *Jatropha* cultivation in SSA is without doubt. It is also clear that development of production packages for use by farmers is a critical success factor for *Jatropha* production. Evidence herein presented shows that *Jatropha* is a crop undergoing domestication. Attainment of most of its acclaimed attributes can only be achieved through best practices. This is premised on the formulation and implementation of research programmes that are informed by evidence in vogue. This paper provides some insights that can inform development of research programmes for *Jatropha* in SSA.

Table 2: Some important questions regarding Jatropha cultivation

	Important questions
Best establishment practices	What is the quality of available planting material?
	What is the appropriate planting method?
	What is the appropriate plant spacing for different agro-climatic conditions?
Best fertilisation practices	What types of fertilizers need to be applied?
	In what quantity, frequency, and on which soil types?
Water requirements	What are the water requirements?
	What is the water use efficiency?
Canopy management	What is the appropriate pruning regime?
	What is the optimum number of branches per tree?
	What are common pests and diseases?
	How are they managed?

Table 3: Focus areas for improvement of Jatropha cultivation in Sub-Saharan Africa

Focus area	Intervention descriptors
Improvement of quality of planting materials	Development of national breeding programmes
	Mapping of existing germplasm
	Development of gene banks
	Application of current plant breeding technologies
	Breeding trials
Establishment of good crop management protocols	Development of appropriate plant establishment practices
	Determination of canopy management strategies
	Identification of pests and diseases and their management regimes
	Development of harvesting and storage strategies
Determination of appropriate fertiliser regimes	Determination of micro- and macro-nutrient requirements
	Measurement of response to nutrients
	Development of fertiliser application regimes
Determination of water requirements and development of irrigation	Measurement of water requirements for sexually and asexually propagated plants
	Development of watering regimes
Development of competitive markets for *Jatropha* seeds	Setting up competitive markets
	Development of farmer-support services
	Development of pricing models

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