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Performance of Jatropha (*Jatropha curcas* L.) under Different Soil and Climatic Conditions in Kenya

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ABSTRACT

As the world's fossil fuel reseverves is shown to be out of oil supply in a few years from now, efforts to finding an alternative, environmentally friendly and sustainable sources of fuel have been heightened towards on-farm biodiesel production and industrial processing of bioethanol. Jatropha (*Jatropha curcas* L.) has been selected among other biodiesel feedstocks targeted for this on-farm biodiesel production with intensive production witnessed in India. In Kenya, however, smallholder farmers are found growing Jatropha despite the limited knowledge about its agro-ecological adaptability. The study hypothesis was that regions for biofuel production have not been properly identified in Kenya. Therefore, the objective of this research was to study the performance of Jatropha under different soil and climatic conditions within the smallholder farms in Kenya. A quantitative baseline survey was conducted from July to August, 2010 in 140 randomly selected farms in Lamu, Kibwezi, Nyando and Bondo districts of Kenya (35 per district). A qualitative in-depth study of 5 farms chosen randomly from each region was also done to verify the information obtained. Results showed that performance of Jatropha was positively linked to humid conditions, well distributed annual rainfall of 500-750 mm, moderately sandy to loam soils, neutral pH and good level of management. It was concluded that good crop management together with climatic and soil suitability are important for successful Jatropha production. Furthermore, it was evident that not all regions where Jatropha is promoted for production in Kenya, though, with suitable climate and soils, support the crop without proper crop management practices.

Key words: Adaptability, biofuel, *Jatropha curcas*, soils, climatic conditions

INTRODUCTION

Jatropha (*Jatropha curcas* L.) has been described as a multi-purpose shrub belonging to the Euphobiaceae family. It is the most commonly grown species of the Jatropha tree whose production has spread both to tropical and sub-tropical countries (Suriharn *et al*., 2011). As peak models for the availability of the oil and natural gas indicate that shortages are likely to occur in the near future combined with extreme weather changes (Campbell, 2006; Greene *et al*., 2006; Brandt, 2007), countries are hurriedly adopting or developing Jatropha production technologies which are considered to be simple, less expensive and having significant potentials of reducing pollution and creating economic benefits to smallholder farmers (Francis *et al*., 2005;

El-Diwani *et al*., 2012). While these simple production technologies are still underway, campaigns have been heated up by the Governments of various countries and private organizations promoting Jatropha as the most suitable candidate for biofuel production in the dry areas (Sujatha *et al*., 2008; Suriharn *et al*., 2011). Some research targeting on-farm smallholder Jatropha production has been carried out generating promising results. For instance, Suriharn *et al*. (2011) while working on pruning levels and fertilizer rates on Jatropha in Thailand reported that pruning at 90 cm above the ground is possible and not at 50 cm while it is recommended to apply NPK fertilizer not exceeding 312.5 kg ha^{-1} to a three year old Jatropha trees under rain fed conditions. Moreover, Mohapatra and Panda (2011) while studying on fertilizer experiment on Jatropha in India reported that 50 kg N ha^{-1}, 100 kg P_2O_5 ha^{-1} and 60 kg K_2O ha^{-1} gave higher yield of seed oil. Furthermore, Brittaine and Lutaladio (2010) have documented successful intercropping of Jatropha with groundnuts in India.

In Kenya, however, it is observed that smallholder farmers still lack information on the ideal agro-climatic and edaphic suitability of *Jatropha curcas*. Common scenarios witnessed in Kenya are existing Jatropha plantations under hot and dry areas to high rainfall potential areas and on sandy to clay loam soils. The objective of this research was therefore to study the performance of Jatropha (*Jatropha curcas*) under different soils and climatic conditions in smallholder farms in Kenya. It was hypothesized that regions for biofuel production have not been properly identified in Kenya.

MATERIALS AND METHODS

Description of the regions: Lamu District is on latitude 2.08°S, longitude 40.75°E, at altitude 0 m above sea level with an average range of temperature of 22-34°C and annual rainfall of 950 mm per annum; Kibwezi District on latitude 2.0°S, longitude 37°E, at altitude between 1500-2160 m above sea level with an average range of temperature of 20-35°C and annual rainfall range of 200-700 mm per annum, Rarieda District on latitude 0.2°S, longitude 34.33°E, with average range of temperature of 25.5-33.0°C and annual rainfall of 1400 mm per annum and Nyando District on latitude 0.11°S, longitude 34.9°E, at altitude 1150 m above sea level with average range of temperature of 20-35°C and annual rainfall range of 1200-1300 mm per annum representing typical Jatropha regions in Kenya with existing Jatropha plantations.

Household survey: A quantitative baseline survey was conducted from July to August, 2010 in 140 (35 per district) randomly selected farms in Lamu, Kibwezi, Rarieda and Nyando Districts. This following a pretest and mending of the survey instrument which was done within Nakuru District in April, 2010. Farmers were asked questions ranging from Jatropha agronomy, planting date, management practices (fertilizing and manuring, irrigation, pruning, harvesting and harvesting frequency), cropping challenges (pests, diseases, drought, seed establishment, time to first harvest) were asked. A qualitative in-depth study of 5 farms in each region chosen randomly was performed to verify the information obtained. This taken into account soil and leaf sampling for laboratory analysis.

Height of plant, circumference of stem and canopy diameter: Plant height (cm), the circumference (cm) of the stem at the widest part and canopy diameter was taken from 5 Jatropha plants randomly selected within the smallholders' farmers field from five farmers each region using a tape measure starting from the ground level to the tallest point of the plant on the main stem and recording the means of the longest and shortest canopy diagonals.

A No. of auxiliary stems, total branches, leaves/branch, no. of clusters/branch, no. of seeds/cluster and no. of seeds/nut: Physical counting was done to establish the number of these parameters for the five plants randomly selected within the farmer's field from five farmers each region.

Size of largest and smallest leaves: This was determined by taking the length and width of the leaf on five leaves (in each case) randomly chosen for the plant among the five plants already randomly selected from the five farmers each region. The size was arrived at after using a correction factor of 0.667.

Percent plant biomass: Five leaves were selected randomly from each of the five plants. Their fresh weights were taken and oven dried for 24 h at 55°C. Percent biomass were then determined as a function of the fresh weights.

Soil sampling: Soil samples were taken from the five farmer's fields in each region using the zig-zag technique by auguring the soil at two different soil depths (0-15 and 15-30 cm); in cases of uneven uniformity of the land additional soil samples were taken. The soil samples from the same depth and at different points of each of the selected farms were mixed thoroughly to make a composite sample from which 100 g of soil sample was withdrawn for further laboratory analysis.

Soil pH: Soil pH was determined using the pH meter on for air dry soils weighed at the ratio of 1:2.5 soils: water w/w basis.

Soil texture: The hygrometer method was used by weighing 50 g of air dry soil transferred into a buffer cup mixed with 50 mL of Calgon solution filled 3:4 with distilled water. This was stirred for 1 h and 1st and 2nd readings for temperature and hygrometer taken after 30 sec and 2 h, respectively.

Soil total N: The soil total Nitrogen (N) was done by the Kjeldahl method given by Okalebo *et al.* (2002).

Percent organic carbon: About 0.3 g of air dry soil was weighed and places in 200 mL bottles after which 10 mL of 1 N KCr_2O_7 was added and swirled. About 15 mL of conc. H_2SO_4 was then added and contents swirled in a fume hood. Lastly 150 mL of distilled water was again added and the solution was titrated against 0.5 N Ferrous Sulphate until the color changed from dark blue to green.

Bulk density and moisture content: From the soil samples obtained through coring taken from the each of the randomly chosen farms, fresh weights were obtained followed by oven drying the soil at 105°C for 24 h. The corings were removed and dry weight recorded. The standard volume of the coring against the weight of the soil was used to determine the bulk density.

Data analysis: Correlation analysis was done using SPSS 15.1 for windows and means arrived at through the Analysis of Variance (ANOVA) table.

RESULTS

This study found out that Kenyan smallholder farmers grow Jatropha in regions with different climatic conditions ranging from humid coastal areas (Lamu District) to the cool highland regions (Nyando District). It was also evident that the dry areas (Rarieda and Kibwezi Districts) were not left out in this development as shown by the existence of Jatropha plantations in these regions (Table 1). These regions were shown to be significantly different from each others in terms of relative humidity and annual precipitation but interms of annual temperature and evaporation rate, Lamu district is significantly different from the Kibwezi and Nyando, while Kibwezi and Nyando were shown to be significantly different.

Regional Jatropha performance in terms of plant height (Table 2) showed that Rarieda Distrit is statically different from Kibwezi and Lamu Districts; with high plant height readings recorded for Lamu District with a mean of 68.5 between these regions. This could be attributed to the high rate of plant growth associated with humid coastal areas. When the leaf area index data and percent leaf biomass accumulation were subjected to analyses of variance (Table 3, 4); Kibwezi District showed significant statistical differences from Rarieda and Nyando Districts with high leaf area and leaf biomass accumulation recorded for Kibwezi District at 5% level of significance. This confirms reports that Jatropha is best suited to hot and dry areas such as Kibwezi District.

Moreover results on soil moisture (Table 5) showed that Nyando district is statistically different from the three regions with Nyando district with a mean of 11.9 between the

Table 1: Climatic characteristics of the Jatropha growing areas

		Annual temp. (°C)	Annual evaporation rate	Annual relative humidity	Annual precipitation
Kibwezi	Nyando	0.6	0.7	0	0
	Lamu	0	0	0	0
Nyando	Kibwezi	0.6	0.7	0	0
	Lamu	0	0	0	0
Lamu	Kibwezi	0	0	0	0
	Nyando	0	0	0	0

*The mean difference is significant at the p = 0.05 level

Table 2: Jatropha performance in height between the regions studied

Dependent variable	(I) District	(J) District	Mean Difference (I-J)	Significance
Height	Rarieda	Kibwezi	-64.8	0.000
		Nyando	-52.8	0.003
		Lamu	-68.5	0.000
	Kibwezi	Rarieda	64.8	0.000
		Nyando	12.1	0.503
		Lamu	-3.7	0.835
	Nyando	Rarieda	52.8	0.003
		Kibwezi	-12.1	0.503
		Lamu	-15.8	0.382
	Lamu	Rarieda	68.5	0.000
		Kibwezi	3.7	0.835
		Nyando	15.8	0.382

*The mean difference is significant at the p = 0.05 level

Table 3: Leaf area index of Jatropha

Dependent variable	(I) District	(J) District	Mean difference (I-J)	Significance
Leaf area index	Rarieda	Kibwezi	-28566.4	0.000
		Nyando	3169.8	0.665
		Lamu	-8188.6	0.259
	Kibwezi	Rarieda	28566.4	0.000
		Nyando	31736.2	0.000
		Lamu	20377.8	0.007
	Nyando	Rarieda	-3169.8	0.665
		Kibwezi	-31736.2	0.000
		Lamu	-11358.4	0.132
	Lamu	Rarieda	8188.6	0.259
		Kibwezi	-20377.8	0.007
		Nyando	11358.4	0.132

*The mean difference is significant at the p = 0.05 level

Table 4: Performance of Jatropha in terms of biomass on dry weight basis

Dependent variable	(I) District	(J) District	Mean Difference (I-J)	Significance
Biomass	Rarieda	Kibwezi	-3226.5	0.000
		Nyando	115.6	0.849
		Lamu	9.4	0.987
	Kibwezi	Rarieda	3226.5	0.000
		Nyando	3342.1	0.000
		Lamu	3236.0	0.000
	Nyando	Rarieda	-115.6	0.849
		Kibwezi	-3342.1	0.000
		Lamu	-106.2	0.864
	Lamu	Rarieda	-9.4	0.987
		Kibwezi	-3236.0	0.000
		Nyando	106.2	0.864

*The mean difference is significant at the p = 0.05 level

Table 5: Percentage of soil moisture from different Jatropha regions

Dependent variable	(I) District	(J) District	Mean Difference (I-J)	Significance
Soil moisture	Rarieda	Kibwezi	-1.5	0.177
		Nyando	-11.8	0.000
		Lamu	0.1	0.948
	Kibwezi	Rarieda	1.5	0.177
		Nyando	-10.3	0.000
		Lamu	1.6	0.163
	Nyando	Rarieda	11.8	0.000
		Kibwezi	10.3	0.000
		Lamu	11.9	0.000
	Lamu	Rarieda	-0.1	0.948
		Kibwezi	-1.6	0.163
		Nyando	-11.9	0.000

*The mean difference is significant at the p = 0.05 level

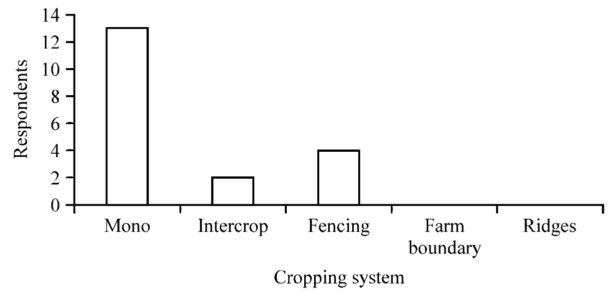

Fig. 1: Jatropha cropping systems

regions recording high percent soil moisture which could be attributed to a lot of rains within this region and the type of soil, which is the clay soils with high moisture retention found within the region. While Fig. 1 showed that mono-cropping was the most preferred cropping systems used for Jatropha. This was mostly influenced by the recommendations of the local Jatropha community organizations and private companies.

From the Table 1 above, annual temperature for Lamu district is significantly different to those of Kibwezi and Nyando with Lamu showing the highest temperature of the three regions. The rate of evaporation for Lamu district is shown to be significantly different to those of Kibwezi and Nyando with Kibwezi experiencing the greatest rate of evaporation. In terms of relative humidity, Lamu is statistically different from Kibwezi with Kibwezi having the highest relative humidity. Lastly the annual precipitation is shown to be unique for each region with Nyando district recording the highest rainfall figures.

Regional Jatropha performance in height (Table 2) shows that Rarieda Distrit is statically different from Kibwezi and Lamu Districts with high plant height figures recorded for Lamu. This could be attributed to the high rate of plant growth associated with humid coastal areas.

When the leaf area index data were analyzed (Table 3); Kibwezi is significantly different from Rarieda and Nyando districts with high figures recorded for Kibwezi.

The biomass production (Table 4) for each region Kibwezi is significantly unique from Rarieda, Nyando and Lamu.

Lastly results on table 5 on percent soil moisture shows that Nyando district is statistically different from the three regions with Nyando district recording high percent soil moisture.

Figure 1 above shows that the most preferred cropping systems used for Jatropha was mono-cropping followed by live fencing and lastly intercropping.

DISCUSSION

The rapid attainment of growth in terms of plant height (Table 2) could be attributed to the high humid conditions in Lamu district as compared to the other three regions surveyed. Plants have been observed to obtain faster growth rate when the surrounding air is humid (Yawson *et al*., 2011). The leaf area index (Table 3) and the means of leaves analyzed (Table 4) show a considerable high leaf growth and biomass production for Kibwezi, followed by Rarieda, Lamu and Nyando this could be due to the optimum enzymatic activity leading to effective photosynthesis with strong sink-source relationship. This coincides with reports that Jatropha leaves are well adapted to high radiation intensities in dry areas (Baumgart, 2007). The remarks of which are synonymous with those made by Achten *et al*. (2008); that Jatropha has adaptability to dry areas.

Table 5 (percent soil moisture) shows that Nyando district is statistically different from Kibwezi, Lamu and Rarieda with Nyando district recording high percent soil moisture. This correlates with the high precipitation figures and the soil type for Nyando district which were clay loams. These soils are known to have good water holding capacity (Gill *et al.*, 2004). Jatropha has also been reported to grow under rainfall of above 2500 mm but under well drained soils (Foidl *et al.*, 1996). Furthermore soil analysis results also showed that Kibwezi and Rarieda districts had sandy loams while those from Lamu were sandy soils. These soils have been observed to be suitable for Jatropha production (Heller, 1996). Furthermore, Kumar and Sharma (2008) reported Jatropha seed yield of up to 3 t ha^{-1} year within the marginal semi-arid areas pointing to the directions that dry and marginal areas could still be resourceful for Jatropha production in Kenya.

In terms of total soil nitrogen and organic carbon levels these soils had low-to-moderate levels of these elements which hints to soil conditions found on marginal areas suitable for expansion of Jatropha industry to dry areas (Heller, 1996). Phosphorus and potassium levels were found to be high while soil pH ranged from 5.5-6.5 which represented similar soil condition used for most Jatropha production in dry areas (Suriharn *et al.*, 2011). With results showing that in terms of biomass production, Kibwezi and Rarieda districts which are found within the arid and semi arid areas of Kenya confirms that the Jatropha does better in dry areas (Makkar *et al.*, 1997; Openshaw, 2000; Achten *et al.*, 2008). It was also evident that farmers established Jatropha seeds directly into the field without pre-planting treatment. Intercropping with food crops was practiced by the smallholder farmers but extensive mono-cropping of Jatropha was mostly common. Brittaine and Lutaladio (2010) have reported successful intercropping of Jatropha with groundnuts in India during the dry periods when Jatropha has shed all the leaves. Manure was considered more appropriate by farmers than inorganic fertilizers while pests and disease incidences were reported to be common during the dry season with pronounced flower shed.

CONCLUSION

Dry areas are still important for the expansion of Jatropha industry if any reasonable yield is to be achieved using simple crop production technologies. Therefore, the Kenyan government, Non-Governmental Organization, Private Developers, Community Based Organization should target the dry and marginal areas of Kenya in their campaigns and any investments in the Jatropha industry. However, good crop management practices together with climatic and soil suitability should be sand-witch for any successful Jatropha production. This study recommends further on-farm research into the dynamics an economically smallholder Jatropha production approach within the dry areas.

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