Australian Journal of Crop Science AJCS
AJCS 7(7):917-922 (2013) ISSN:1835-2707

Performance and challenges of biofuel cropping systems in Kenyan smallholder farming systems: A case study on castor (*Ricinus communis* L.), jatropha (*Jatropha curcas* L.) and croton (*Croton megalocarpus* L.)

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Abstract

The world's availability of fossil fuel has shown limited supply in the near future; consequently, efforts towards finding alternative and sustainable sources of fuel have been heightened targeting on-farm biofuel production and industrial processing of bioethanol. In Kenya, smallholder farmers grow castor (*Ricinus communis* L.), croton (*Croton megalocarpus* L.) and jatropha (*Jatropha curcas* L.) as the main biofuel feedstocks despite limited knowledge on their agronomic practices. They are grown either as monocrops, intercrops or as boundary crops with their seeds pressed locally or sold to the local biodiesel processors. The overall research question of this study was to evaluate the performance of these cropping systems with detailed investigation on the existing biofuel cropping systems, their yields, associated cropping challenges and possible solutions. A household survey was conducted in 210 smallholder farmers selected randomly from three regions: namely Laikipia, Nyeri and Lamu Districts, with seventy farmers per region. Farmers were asked questions on the general crop husbandry. The data was analyzed using SPSS version 17.1. Results showed that farmers practiced monocropping, intercropping, live fencing and boundary cropping systems with biofuel feedstocks and that their yields exhibited a lot of variability in the range of a few to 900 kg $ha^{-1}yr^{-1}$. Moreover, market availability and rainfall reliability presented the most cropping challenges while organized market, availability of adapted clones and irrigation were cited as the best possible solutions. It was concluded that the biofuel yield variability and the cropping systems used were as a result of the poor knowledge of agronomic practices.

Keywords: agronomic practices; biodiesel; energy; feedstocks; sustainable; yield variability.
Abbreviations: EAC – East Africa Commission, EBB – European Biodiesel Board, GoK – Government of Kenya, GTZ – Germany Technical Cooperation, ICRAF – World Agroforestry Centre, IEA – International Energy Agency, KARI – Kenya Agricultural Research Institute, KEFRI – Kenya Forestry Research Institute, NGOs – Non-Governmental Organizations. USA – United States of America, WEC – World Energy Council.

Introduction

The current world's demand for fossil fuel stands at 84 million barrels per day (bpd) and is projected to increase to 116 million bpd by 2030. Against this demand, peak models for the availability of the fossil oil and natural gas indicate that shortages could occur in the near future (Campell, 2006). Green et al. (2006), Brandt (2007) and Guseo et al. (2007) argue that the peak for fossil oil supplies may be limited before 2030. With this reality, Governments, Non-Governmental Organizations and Private Organizations worldwide are busy lobbying for a shift to sustainable and renewable sources of energy: the biofuel feedstock. These energy sources are deemed environmentally-friendly than the combustion of fossil fuels which contributes to the global green house gas emissions and associated climatic change. In terms of world's production of biodiesel, European Biodiesel Board (EBB) (2006) noted that the overall biodiesel production in Europe increased from 3.2 million tons in 2005 to nearly 4.9 million tons in 2006 while World Energy Commission (WEC) (2009) reported that the annual rate of ethanol production in the USA increased by 25% with the amount produced in 2005 standing at 16.2 million tons. Meanwhile in the Indian state of Gujarat, a total of 0.2 million tones of castor oil was produced (Patel and Fatten, 2005). Bracken and Inslee (2007) noted that Brazil is the world's largest biofuel economy with production mainly from sugarcane. Even though currently the production of such biofuel crops cannot replace crude oil, Jeff (2006) argued that they are worth producing. In Kenya, biofuel production was witnessed in the mid eighties (1983) when it started with bioethanol, which provided a 10% alcohol and gasoline blends. However this was discontinued in 1993 due to pricing and mismanagement (Wachira, 2007 and Wegoro, 2003). Currently the Kenyan Government and NGOs have identified the potential of non food biofuels in reducing the

Table 1. Description of the research regions selected on the basis of the presence of the biofuel plantation.

Region	Biofuel Crop	Latitude	Longitude	Altitude (m above sea level)	Rainfall (mm) per annum	Temperature (°C)
Lamu	Jatropha	2.08°S	40.75°E	0 m	950 mm	22°C - 34°C
Laikipia	Castor	0.4166°S	36.75°E	1700 - 2600 m	400 mm - 750 mm	16°C - 26°C
Nyeri	Croton	0.5°S	36.96°E	1759 m	200 - 1600 mm	7°C - 28°C[a]

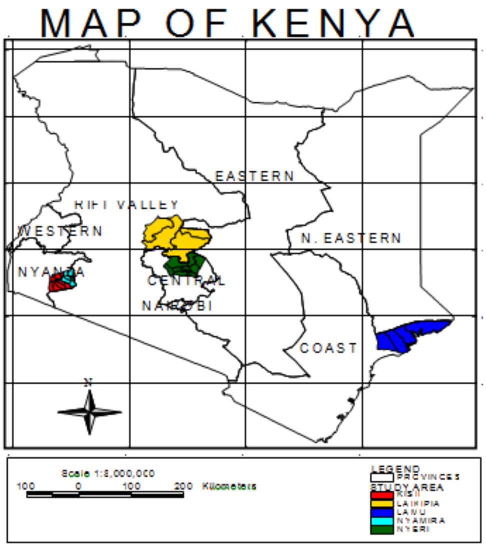

Fig 1. Map of Kenya showing the study regions.

reliance on foreign oil and in improving rural economy and livelihoods. The priority crops targeted for this on-farm biofuel production are castor beans (*Ricinus communis* L.), croton (*Croton megalocarpus* L.) and jatropha (*Jatropha curcas* L.). High emphasis has been placed on smallholder farmers who have responded positively to growing these crops despite lack of knowledge of their agronomic practices. The common practices at the farmers' fields are sole cropping, intercropping, hedgerows, boundary or live fences cropping systems for these crops. The objective of this study was to answer the following questions: What are the existing cropping systems associated with these biofuel crops: what are their yield levels: and what are the cropping challenges and their possible solution? It was hypothesized that cropping systems and their yields for biofuel crops in Kenya are still heterogeneous.

Results and Discussion

Farmers with and without the biofuel crop

Results from interviewing the 210 farmers indicated that 30% were either non-seed collectors or non growers of biofuel feedstock while 70% represented seed collectors and farmers with existing plantations. The disparity was due to the choice of the research area which was based on the existing biofuel feedstock on the farmer's fields. Among the farmers interviewed with the biofuel feedstock there were castor (29%), croton (35%) and jatropha (36%) farmers respectively. Farmers embracing castor farming were low as compared to croton or jatropha; this could have been caused by lack of ready market and promotion for castor (Wegoro, 2008) and the low priority placed on the crop by the Kenyan Government (Nderitu, 1997). In the case for croton, the region visited had a local biodiesel factory which was purchasing seeds from farmers; and in turn processing into biodiesel oil which was consumed locally by the "Matatu" business operators. On the other hand jatropha had received intensive lobbying from the Government and Non-Governmental Organizations in Kenya (Muok et al., 2008). Furthermore this biofuel feedstock was being pressed locally and farmers were already seeing its benefits.

Biofuel Establishment

Biofuel planting was shown to have picked up from 2007 – 2009 but slowed down in 2010 (Fig. 2). The high adoption rate could have been on jatropha caused by the intensive lobbying efforts through campaigns led by the Government, Non-Governmental Organization, Kenya Forestry Research Institute (KEFRI) and the World Agro forestry Centre (ICRAF) (Endelevu Energy, 2009; Githunguri, 2012). In addition jatropha seeds were reported to be given free of charge to any willing farmer for planting. Furthermore local and regional markets were opening up for this crop. Rejila and Vijayakumar (2011) noted that jatropha is an attractive crop in that it can be able to augment the income for famers. However the slow pace witnessed by 2010 could have been due to the marketing, pricing dynamics and later diminishing support for biofuels on grounds of social and environmental concerns (Hunsberger, 2010). Furthermore before 2000 some plantations were recorded. This was the period when castor was being grown in Kenya but ran down in late 1980s due to pricing and mismanagement (Wegoro, 2008). Jatropha had been established during the same period but not as a biofuel feedstock (Endelevu, 2009).

Propagation materials for biofuel feedstock

Jatropha was mostly sown from seedlings while both seeds and seedlings were preferred for croton however for castor; seeds were the most acceptable planting material (Fig. 3). The seedlings preference for jatropha is due to their rapid establishment, genetic uniformity and early maturity

Table 2. Biofuel cropping challenges with marketing presenting the most challenge on biofuel feedstock surveyed

	Market Availability	Pests	Diseases	Rainfall Reliability	Cost of inputs	Lack of capital	drought	Wildlife menace
Jatropha	22	4	7	15	5	4	5	4
Castor	17	5	7	12	3	4	4	3
Croton	20	5	11	17	4	2	4	5
Total	59	14	25	44	12	10	13	12[h]

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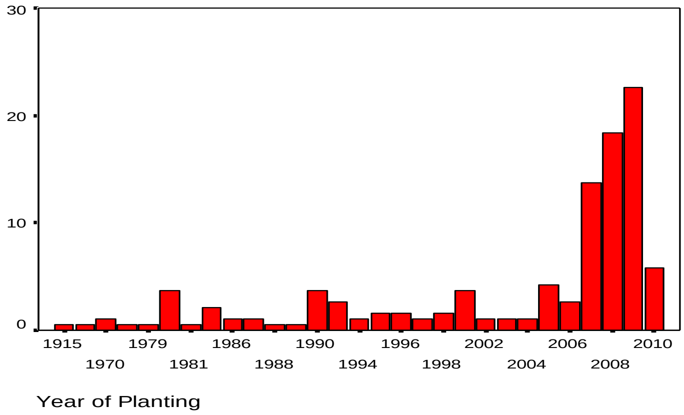

Fig 2. Years of biofuel establishment.

exhibited by such plantations; even though such plants have shorter lifespan (Brittaine and Lutaladio, 2010; Githunguri, 2012). It has also been reported that seeds from high yielding jatropha plants, in most cases, are unavailable (Brittaine and Lutaladio, 2010).

Sources for the propagation materials

Non-Governmental Organizations (NGOs) and sourcing from other farmers were the most preferred sources of planting materials for these biofuel crops (Fig. 4). The source of planting material impacts on the quality of planting material. It was not clear whether the biofuel clones grown by the farmers were one variety, or their quality aspects (disease and pest resistance, agro-ecological adaptability, yield and oil content)? The source of planting material also influences the information passed down to farmers on the type of cropping practices.

Biofuel cropping systems

Monocropping stood out as the most preferred cropping system for these biofuel crops however farmers still practiced intercropping with food crops; while fence and boundary cropping systems were unique to castor and croton (Fig. 5). However monocropping system may prove environmentally unsustainable in terms of soil and biodiversity degradation. It is argued that intercropping of biofuels may proof profitable to smallholder farmers by augmenting their incomes (Rejila and Vijayakumar 2011). On the other hand the same intercropping may impact negatively on the growth and yield to both biofuels and the companion food crops aggravating further the rural food insecurity situation for instance, Dapaah et al. (2004) reported reduced yield of soybean and cowpea in an intercrop with cassava. These phenomena leave the boundary and hedgerow cropping systems to be explored but may soon prove unsupportive in terms of enhanced seed delivery to the factory for biodiesel production. Abugre et al. (2011) observed that jatropha could be grown with maize under hedgerow systems comfortably at a spacing of 2 m from the hedgerow. They also noted that within the first year of jatropha establishment planting close to the hedgerow could improve the yield of maize through enhanced plant density.

Biofuel companion crops

Most farmers preferred growing jatropha together with maize, cowpea, common beans and green grams while castor was grown together with maize, beans and Irish potatoes. As for croton Irish potatoes was the most preferred intercrop and to a lesser extent maize (Fig. 6). Jatropha has been successfully intercropped with groundnuts in India during the dry periods when jatropha has shed all the leaves (Brittaine and Lutaladio, 2010). Rejila and Vijayakumar (2011) also reported on intercropping of jatropha with sesame, green chilli, green gram and sunflower where they found out that jatropha - sesame intercrop was a success. In fact the common scenario is intercropping jatropha within the first few years before jatropha attains a full canopy (Brittaine and Lutaladio, 2010). Furthermore jatropha-maize hedgerow has also been shown to give higher yields of maize Abugre et al. (2011).

Fertilizer use on biofuel feedstocks

Fertilizer use showed that 83% of the farmers interviewed were not applying fertilizers to the biofuel crops. However of the farmers that were applying fertilizer to biofuel crops, jatropha accounted for 59% while castor and croton were 22% and 19% respectively. Furthermore farmers (68%) preferred applying manure to jatropha while castor and croton was each at 16%. The use of manure could be due to its ease of availability and low cost implication. Furthermore most jatropha agencies promoted manure use of biofuels crops. Mohapatra and Panda (2011) while working 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} gives higher yield of seed oil and that growth and development is improved under tropical agro-climatic conditions. Suriharn et al. (2011) also stated that a three year old jatropha plantation should receive NPK fertilizerat a rate not exceeding 312.5 kg ha^{-1}.

Table 3. The possible solution to the biofuel production challenges.

	Govt. Support	Electric fencing	Irrigation	Subsidized Inputs	Market	Adapted Clone	Herbicide	Pesticide
Jatropha	4.0	5.0	15.0	7.0	12.0	13.0	4.0	6.0
Castor	2.0	6.0	12.0	6.0	10.0	8.0	5.0	6.0
Croton	4.0	5.0	16.0	7.0	11.0	13.0	5.0	7.0
Total	10.0	16.0	43.0	20.0	33.0	34.0	14.0	19.0

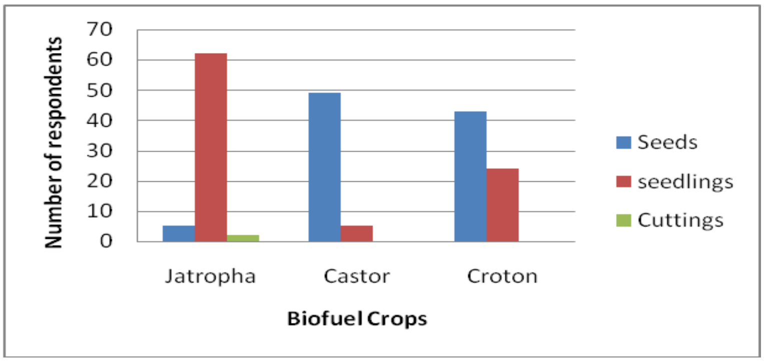

Fig 3. Preferred Propagation materials for the different biofuel feedstocks.

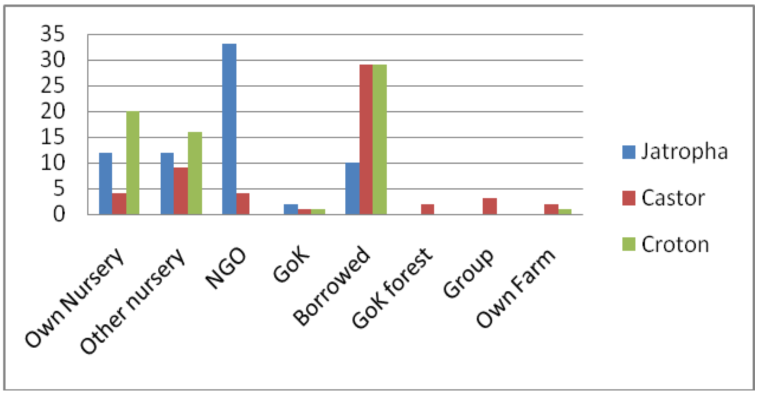

Fig 4. The most preferred sources of biofuel planting materials.

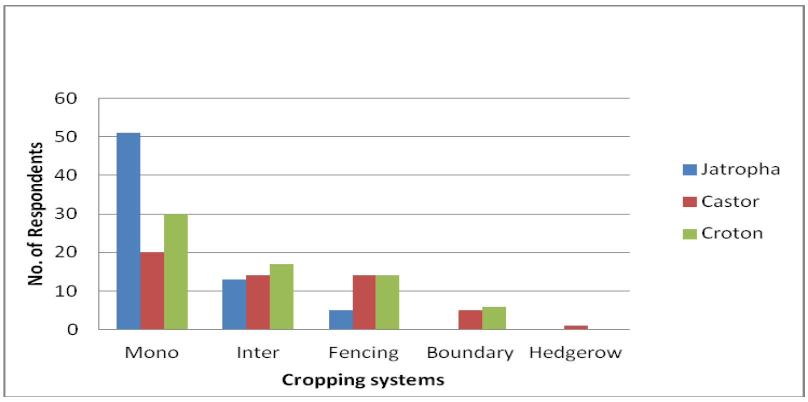

Fig 5. Biofuel cropping systems

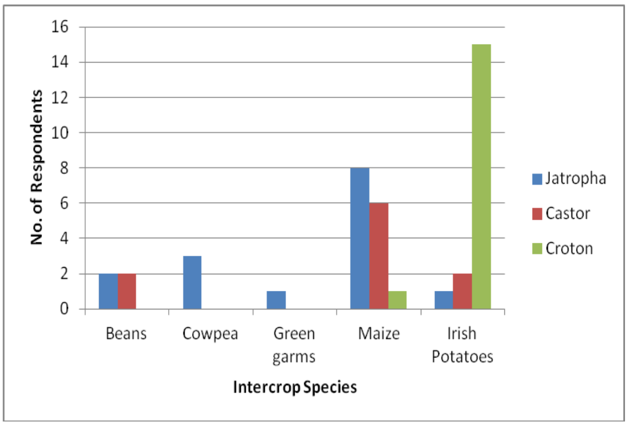

Fig 6. Food crops grown with biofuel feedstocks.

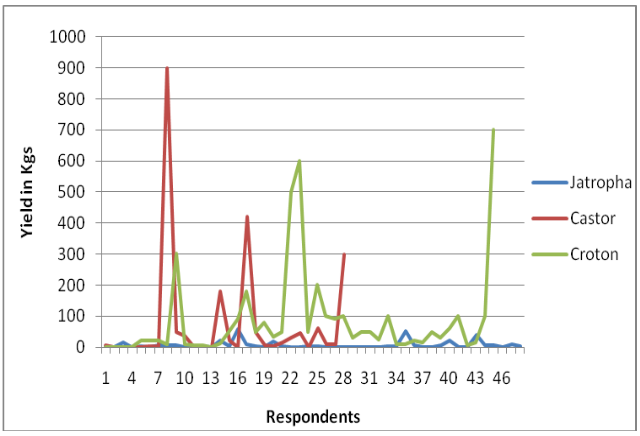

Fig 7. Yield curves for castor, croton and jatropha.

Yield Levels

The yields were very variable and unpredictable. The yield curve generated indicated jatropha yield disparity range from 1 - 57 $kgyr^{-1}$ while castor showed 4 – 900 $kgyr^{-1}$ with 10 – 700 $kgyr^{-1}$ for croton. The yield curves had several peaks but were dominated by unpredictably low levels (Fig. 7). This yield variability could have been caused by the wide variation in cropping practices, the type of biofuel feedstock, the existing clones for the various biofuel crops and agro-ecological adaptability. Tomomatsu and Brent (2007) reports an annual estimated seed yield range from 200 gm to more than 2 kg per tree. Brittaine and Lutaladio (2010) argue that most yield figures are accompanied by little or no genetic information and the lack of documentation on the associated crop husbandry practices used.

Cropping Challenges and their Possible Solutions

The highly cited cropping challenges that affected on-farm biofuel production were; market availability, rainfall reliability and crop diseases (Table 2.). There existed middlemen that linked some farmers to the local biodiesel processor but farmers complained of their over exploitation. However a number of possible solutions were suggested by farmers, among them, provision of irrigation, adapted biofuel clones and organized markets were most preferred (Table 3.).

Materials and methods

Description of Research Regions

This research was carried out in three major regions in Kenya: Lamu, Laikipia and Nyeri Districts (Fig 1). These regions exhibited different climatic characteristics; Lamu, for instance a humid climate but with moderate rainfall. Laikipia and Nyeri had higher altitude with dry to moist conditions (Table 1). Jatropha is shown to be grown mostly under humid conditions with moderate rainfall (950 mm) annually. However castor and croton were preferably grown in dry to moist conditions with varying degree of altitude range of 1700 – 2600 meters above sea level.

Methodology

A quantitative baseline survey was carried out from July to October, 2010 in 210 smallholder farmer's (seventy farmers per region) chosen randomly through a purposive sampling on the basis of existing biofuel plantation. This was done after a pretest and modification of the questionnaire in April, 2010. During the survey a structured questionnaire was presented to these farmers with questions on land preparation, propagation materials, and source of planting materials, nursery or direct field establishment, date of plant establishment, fertilizing, irrigation, weeding, harvesting and seed collection, yields, production challenges and their solutions and marketing.

Conclusion

It was concluded that monocropping of biofuel feedstocks could be environmentally unsustainable due to potential soil and biodiversity degradation while intercropping with food crops may aggravate the rural food insecurity situation. Furthermore, live fence and boundary cropping systems may prove industrially unsupportive due to the need for intensive processing. Moreover, the yield variability and the cropping systems used were as a result of the poor knowledge of agronomic practices and the underdeveloped biofuel market. Hence, further research is required to investigate in detail the dynamics of these cropping systems.

Acknowledgements

The authors wish to thank Egerton University, BOKU University Vienna, ERAARD, Szeged University - Hungary and KARI – Njoro, Kenya; for funding this work.

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