

Performance of maize and beans under castor based intercropping system

ABSTRACT

Castor (*Ricinus communis* L.) has attracted a lot of attention all over the world as a potential crop targeting on-farm biofuel production. In Kenya smallholder farmers are already growing castor with maize (*Zea mays* L.) and beans (*Phaseolus vulgaris* L.) under an intercrop system in spite of the limited knowledge that such a system would have on growth and yield. The aim of this research was to investigate the possible effect of castor-based intercropping systems on the performance of maize and beans. A $3 \times 3 \times 2$ factorial experiment randomized in complete block design with three levels of crops, three levels of cropping system and two levels of spacing was laid-out at the Organic Farm-Egerton University, Njoro campus; for three seasons in 2010 to 2012. Results at 0.1% level of significance indicated high seed yield for castor monocrops ranging from 2.0 - 3.0 tons seeds $\text{ha}^{-1} \text{yr}^{-1}$ while castor with beans intercrop were shown as the best intercrop combination with resultant yields levels reported in the range of 1.63 - 2.43 and 0.3 - 0.83 tons seeds $\text{ha}^{-1} \text{yr}^{-1}$ respectively. In contrast, castor with maize intercrop gave low maize grain yield of between 0.0 – 1.1 tons $\text{ha}^{-1} \text{yr}^{-1}$. It was concluded that castor could be grown successfully with beans without straining food crop production. In addition an intercrop of castor with maize and beans would not have a significant affect the yield performance of castor.

Keywords: *biofuel; cropping system; productivity; seed yield; smallholder farmer; spacing*

1. INTRODUCTION

Castor (*Ricinus communis* L.) is a wild shrub from the Euphorbiaceae family and has been shown to appear in many farming systems of the world [1,2]. This crop grows widely and wildly from high, medium to low rainfall areas with reports indicating that arable sites under high altitude areas recording higher seed yield per tree [3]. The oil is the most important product of this plant and has been reported to have several industrial applications varying from aviation lubricant, biofuel and medicinal properties; moreover, there have been reports that ricin, a poisonous protein from the seeds of castor, **having for terrorism and suicide attacks** [4]. **Currently** castor is under investigation as a potential biofuel crop with records showing seed yield of 1.2 tons ha⁻¹ yr⁻¹ but can reach up to 1.8 tons ha⁻¹ under irrigation [5,6]. The seed oil content has been documented to be between 36.6 - 53.85% with potentials of up to 3.0 tons oil ha⁻¹ yr⁻¹ under good management. The crop has been described as a high yielding biodiesel plant as compared to either croton (*Croton megalocarpus* L.) or jatropha (*Jatropha curcas* L.). For instance reports show that croton yield's up to 3.6 tons seeds ha⁻¹ yr⁻¹ with seed oil content of 30 - 32% contributing to about 1.2 tons oil ha⁻¹ yr⁻¹ while jatropha has been documented to have seed oil content of between 35 - 40% giving about 0.404 ton oil ha⁻¹ yr⁻¹.

In tackling the endeavor issue of food situation and energy crisis in several parts of the world most research is currently focused on biofuel-based cropping system. It is worth noting that cereal-legume intercropping has been shown to play a significant role in the smallholder farmers subsistence food production in both developing and developed countries [7,8]; therefore by integrating non edible biofuel crops into these cropping systems it would be imperatively significant not to impact negatively on the productivity of these food crops whose yields have also been shown to be on the decline. For instance, in India, castor has been grown with crops such as cluster bean, pigeon pea, Indian bean, cucumber, Calliandra, cassia, chick pea, finger millet with the objective of increasing the productivity of the land and provision of food and fodder [9]. In Kenya, however, castor had been grown commercially since 1910 but witnessed a major decline in 1980s due to poor **marketing, Wegoro [10]**. The country had placed low priority on researching on castor a condition which contributed to the low and varied yield of this crop and other biofuel crops [11]. It is, however, noted that with the current campaigns smallholder farmers are rapidly embracing on-farm biofuel production against limited information on the resultant crop yields. Therefore it was worth investigating the possible effect of castor-based intercropping system. The objective of this study was to determine the effect of intercropping castor with maize and beans on growth and yield. It was hypothesized that intercropping castor with maize and beans had no significant effect on growth and yield.

2. MATERIAL AND METHODS

2.1 Site description

Egerton University-Organic farm is at an elevation of 2238 m above sea level and located on latitude 0°23'S and longitude 35°56'E. It receives an average rainfall of 1012 mm annually with 60% reliability of 908 mm. The site has a mean temperature of 14.7°C with minimum and maximum temperatures of 8.5°C of 21.0°C respectively. The area is under the Agro-ecological zone of LH3 which is described as wheat and barley zone. The soils are well drained, silty clay to clay with humic top soil (Mollic Andosols) with pH of 5.5 - 6.5 [12].

2.2 Description of materials

Materials were seeds for castor (*Ricinus communis* cv. Zanzi palm), maize (*Zea mays* cv. H513D) and beans (*Phaseolus vulgaris* cv. Rose Coco) respectively. Di-Ammonium Phosphate (DAP) (18:46) and Calcium Ammonium Nitrate (CAN) (26% N) fertilizers, SC-1 leaf porometer for stomatal conductance, leaf chlorophyll meter (CCM-200), Stanton weighing balance for weight determination and a tape measure for plant height determination.

2.3 Treatment description

A 3 × 3 × 2 factorial experiment consisting of three levels of crops (castor, maize and beans), three levels cropping systems (sole cropping for all crops, intercrop combinations of any crops and intercrop combinations of the three crops); and two levels of spacing for each crop i.e. high and low levels, for “low” level of spacing 1.5 m × 1.0 m, 0.5 m × 2.0 m and 0.75 m × 0.3 m while 1.8 m × 1.0 m, 0.6 m × 0.2 m and 0.9 m × 0.3 m were used as the “high” spacing for castor, beans and maize respectively. The experiment was laid in a randomized complete block design (RCBD) replicated three times in plots of 9 x 4 m for three seasons beginning May, 2009 to December 2012.

2.4 Cultural practices

The experimental field received an initial disc plough followed by a disc harrow and manual raking and removal of the grass. Castor seedlings were transplanted from the nursery at a height of 0.15 m in May, 2009. Maize and beans were then sown into already established castor plants at two seeds per hole which were later thinned to one seedling per hill at 14 DAS (days after sowing). 33 kg N ha⁻¹ and 84.3 kg P ha⁻¹ was applied at planting followed by a top dress with 188 kg CAN (26% N) ha⁻¹ to maize at knee high. Two manual weeding was done at 21 and 45 DAS. Data on plant height, stomatal conductance, leaf chlorophyll content was determined at 21, 42, 63 and 84 DAS while number of cobs, nuts and pods per



plant were recorded at harvesting for maize, castor and beans respectively. Harvesting and threshing were done manually and seed weight determined through an electronic weigh balance (Stanton).

2.5 Data analysis

The data was subjected to analysis of variance (ANOVA) by SAS/STAT in release 9.2 for windows and means separated through Duncan's Multiple Range Test (DMRT).

3. RESULTS AND DISCUSSION

3.1 Rainfall (mm)

During the three year period of the experiment the area received an average monthly rainfall of 107.13 mm month⁻¹ with much of the rains experienced in 2010 and 2012 as compared to 2009 and 2011. Results further indicated that the year 2010 and 2012 recorded 1599.2 mm against 972 mm for 2009 and 2011 on combined averages respectively with 2009 recording the lowest total annual rainfall of 663.7. Most rains were received between March and September with the wettest months shown as between May and August (Fig. 1). Generally it was concluded that the region experienced a bimodal pattern of rainfall with March to September notably as the main cropping season.

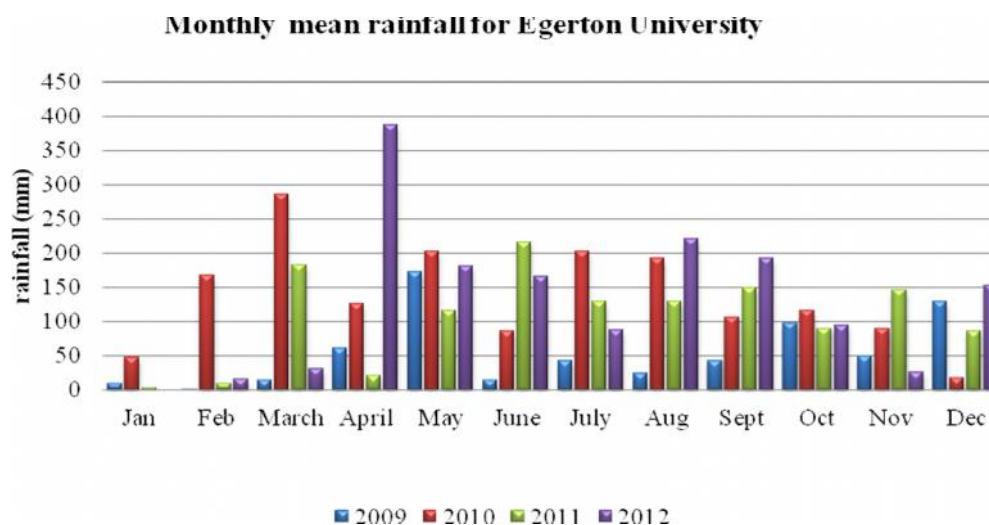


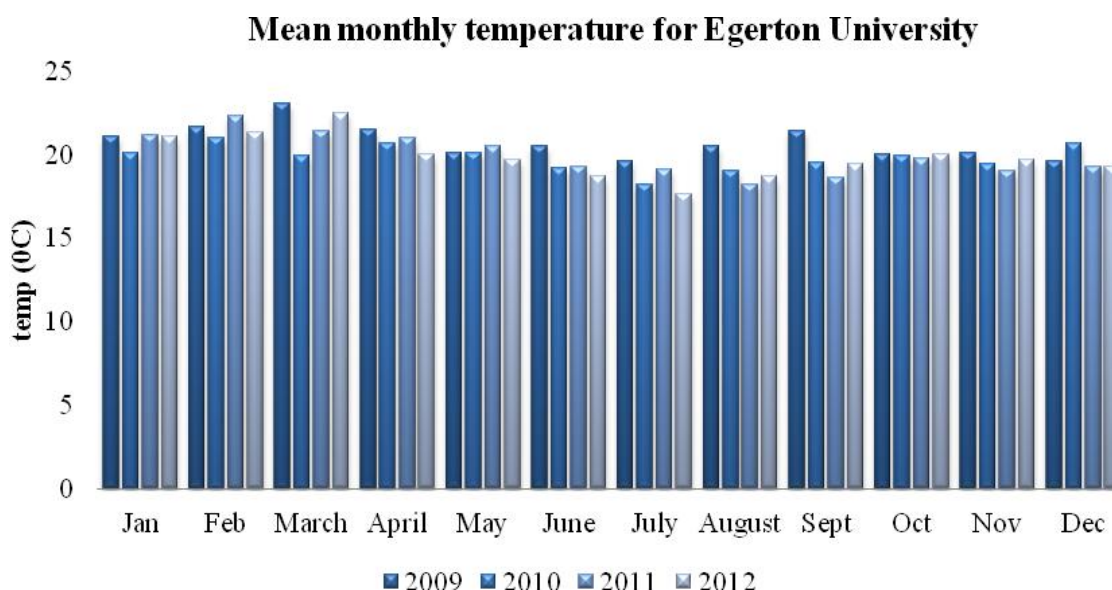
Fig. 1. Monthly mean rainfall figures for 2009 to 2012

^a Data collected from Egerton University weather station No. 9035092 Lat 00° 23'S Long 35° 55'E

for 2009-2012

3.2 Temperature (°C)

Mean monthly temperature ranged from 17.6°C to 23.1°C with reports indicating 2009 as the hottest year. Temperature means above 20°C were recorded between January and May while June to September showed temperature below 20°C (Fig. 2).



^b

Fig. 2. Mean monthly temperature for Egerton University weather station for 2009 - 2012

The information on rainfall and temperature is imperatively important considering timely planting and choice of adapted cultivars. Time of planting which generally corresponds to the onset of the rains especially for rainfed agricultural has been found to significantly influence crop yield [13]. Therefore is it important that within this region planting be done around mid April, however, as a result of the prolonged rains that persisted until September some losses were incurred in beans. The reduction in ambient temperature recorded during the critical growth period of these crops accounted for the long growing season witnessed especially in the maize. However castor remained unaffected by these factors. The crop shaded most of the leaves during the dry spells between January to March with resumption of active growth and nut production the rainy season.

^b Data collected from Egerton University weather station No. 9035092 Lat 00° 23'S Long 35° 55'E
for 2009-2012

3.3 Plant height (cm)

Results on plant height (table 1) indicated significant differences between seasons, treatments and crops at $P < .0001$ level of probability. It was observed that individual monocrops of castor, maize and beans recorded heights of 0.406 m, 0.137 m and 0.042 m respectively while castor with maize intercrop reported taller plants in the range of 0.300 – 0.311 m and 0.35 – 0.60 m respectively. This could be attributed to the influence of a strong castor canopy that shaded most of the maize crop from accessing the light. Furthermore none of the companion crop had a significant effect on the attainment of height in castor; which was reported to be between of 0.387 – 0.424 m. The significantly tall plants as seen under castor hampered harvesting of the nuts and home-made ladders had to be used for this purpose.

3.4 Stomatal conductance ($\text{mmol m}^{-2} \text{s}^{-1}$)

Leaf stomatal conductance (table 1) was shown to be unique for seasons, treatments and crops at 0.01% level of significance. These results indicated an intercrop of castor at 1.5 m $\times$ 1 m with beans at 0.6 m $\times$ 0.2 m as having high values for stomatal conductance at the range of 108.6 – 111.1 and 65 – 70 $\text{mmol m}^{-2} \text{s}^{-1}$ respectively. Further on maize grown under castor showed low levels of stomatal conductance of in the range of 37 – 50 $\text{mmol m}^{-2} \text{s}^{-1}$. It has been reported that high stomatal conductance under unlimited moisture supply correlates to high photosynthetic rate and the resultant high crop yield this could support the resultant low yields gained from the maize which had been exposed to radiation stress under castor. Miko [14] noted that high stomatal conductance could be advantageous in allowing a faster induction and higher carbon gain during sun flecks or under strong canopies thereby maintaining a higher quantum yield because of the greater intercellular partial pressures of CO_2 . This was observed on beans planted under castor that had no significant yield from the corresponding monocrops.

3.5 Chlorophyll fluorescence

Results on leaf chlorophyll fluorescence (table 1) were in line with those recorded for carbon (IV) oxide assimilation (table 1). Seasons, treatments and crops showed significant differences at $P < 0.0001$ level of probability; with castor recording higher values of the three crops. Maize grown under castor had low chlorophyll fluorescence which negatively influenced the capacity of electron transport and carbon assimilations resulting into reduced crops photosynthetic capacity thus low yields. Leaf chlorophyll fluoresces has also been linked to the expansion of the leaf mass area [15]. Marini and Sowers [16] also showed that shaded leaves usually have low net photosynthetic rate prompting that the two factors noted above may have had an effect on the general productivity maize.

3.6 Mean seed weight (gm)

A hundred seed mean weight analyzed indicated unique differences in the productivity of the cropping





147 systems at 0.01% level of significance. An intercrop of castor at 1.5 m × 1 m with beans showed the best
 148 cropping system. This system gave 2.43 and 0.831 tons seeds ha⁻¹ yr⁻¹ for castor and beans respectively
 149 with a land equivalent ratio of 3.1. This concurs with earlier research assertions that castor and legumes
 150 provide best intercrop combination. For instance, higher castor equivalent yield it has been shown under
 151 paired row intercrop system with cluster bean, which had increased productivity and net profit, results
 152 which supported earlier findings [17]. Castor had however showed similar performance across all the
 153 treatments with the castor monocrops at 1.5 m × 1.0 m and 1.8 m × 1.0 m spacing giving seed yields in
 154 the range of 1.85 – 3.5 tons ha⁻¹ yr⁻¹ respectively. Moreover results showed that individual crop yields
 155 were significantly different, with those of castor reporting higher seed yield compared to maize and beans.
 156 However an intercrop of castor with maize showed significantly low grains yields of maize in the range of
 157 0 – 1.1 tons seeds ha⁻¹ yr⁻¹ under a strong castor canopy with significant gains obtained in the second
 158 season of up to 3.48 tons seeds ha⁻¹ yr⁻¹. These findings corresponds to those made earlier by with
 159 reports indicating higher seed yield of castor under intercropping with legumes as compared to non
 160 legumes [18].



161 Table 1. Means squares of physiological and agronomic parameters of castor, maize and beans

Source of variation	df	Plant height (cm)	Stomatal conductance (mmol m ⁻² s ⁻¹)	Chlorophyll fluorescence	100 seed weight (gm)
Season	1	1.148 × 10 ^{5**}	6.039 × 10 ^{4**}	4.269 × 10 ^{2**}	1.896 × 10 ^{3**}
Block	2	9.615 × 10	1.564 × 10 ²	0.3106 × 10	1.479 × 10 ^{2**}
Treatment	23	6.661 × 10 ^{5**}	2.819 × 10 ^{3**}	4.386 × 10 ^{2**}	3.197 × 10 ^{2**}
Crop	2	2.573 × 10 ^{6**}	1.965 × 10 ^{4**}	1.618 × 10 ^{4**}	7.271 × 10 ^{3**}
Spacing	3	2.488 × 10 ²	5.076 × 10 ²	1.807 × 10	4.268 × 10
Season × Treatment	23	1.661 × 10 ^{3**}	7.587 × 10 ^{2**}	3.841 × 10	2.518 × 10
Season × Crop	2	7.634 × 10 ^{3**}	4.059 × 10 ^{3**}	1.444 × 10 ^{3**}	1.081 × 10 ^{3* *}
Treatment × Crop	19	7.460 × 10 ^{2**}	4.550 × 10 ²	9.115 × 10	2.099 × 10

162 **Means highly significant at $P = .0001$ level of probability

163 4. CONCLUSION

164 This study finds out that castor could be intercropped productively with beans therefore smallholder
 165 farmers could successfully embrace castor based intercropping system with beans without straining on
 166 food crop production. In addition intercropping castor with maize and beans may not have significant
 167 effect on the seed yield of castor. However an intercrop of castor with maize would aggravate the already

worsening food situation to smallholder farmers. This study recommends further trials with dwarf castor varieties and/or at wider spacing.

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176 **Abbreviations:**

177 ANOVA – Analysis of variance

178 CAN – Calcium ammonium nitrate

179 DAP – Di-ammonium phosphate

180 DAS – Days after sowing

181 DMRT – Duncan multiple range test

182 LER – Land equivalent ratio

183 LH3 – Lower highland zone II

184 RCBD – Randomized complete block design

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