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Research Paper

Productivity Indices of Bambranut as Determined by Intra-row Spacing when Intercropped with Maize

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Experiments were conducted to evaluate productivity indices and their response to varying spacing of bambaranuts (*Vigna subterranea* L. Verdec) intercropped with maize. The indices were land equivalent ratio (LER), area time equivalent ratio (ATER), relative yield (RY), system productivity index (SPI), monetary advantage (MA) and income equivalent ratio (IER). Three crop planting systems were used as factors: sole bambaranut, bambaranut intercropped with maize, and sole maize. Bambaranut seeds were sown in 1:1 alternate rows of maize and at various spacing on plots measuring 4.5 × 3.5 m. There were three factors in different levels: (1) sole bambaranut sown at intra-row spacing of (i) 45 cm, (ii) 35 cm, (iii) 30 cm, (iv) 25 cm, and (v) 15 cm; (2) sole maize; (3) intercropped maize-bambaranut in: (i) 45 cm, (ii) 35 cm, (iii) 30 cm, (iv) 25 cm, and (v) 15 cm. A medium maturing maize variety Hybrid H513 was sown at the constant intra- and inter-row spacing of 75 × 30 cm at the population density of 45714 plants/ha for all plots. Bambaranut landrace KK204 was used for the study. The experiment was repeated for three growing seasons (2006/2007, 2007/2008 and 2008/2009). Significant ($p<0.05$) differences for both mono- and intercropped bambaranuts for weight of pods/plant; pod and grain yield, IER, MA and SPI for 2006/2007, 2007/2008 and 2008/09 growing seasons; shelling %, LER and ATER for 2006/2007 and 2007/2008 growing seasons; relative yield (RY) for 2007/2008 and 2008/2009. Maize showed significant ($p<0.05$) differences for both mono-and those intercropped with bambaranuts for shelling %, grain yield/ha for 2006/2007 and 2007/2009 growing seasons, RY and IER for 2006/2007 and 2007/2008 growing seasons.

Key words: Cropping system and productivity indices.

INTRODUCTION

Intercropping involves the production of two or more crops simultaneously on the same piece of land and at the same time under the same management conditions (Stokskof, 1981). Intercropping is the most common cropping system in developing countries (Francis, 1986; Enyi, 1973). The checklist of crops grown in association especially in fields around the homestead can be high if fruit trees are included (Igboziruke, 1977). The diversity of species grown in association is an indicator of stability since complex systems are more stable (Gomez and Gomez, 1983). Intercropping is important among smallholder farmers in developing countries where population growth is high and land under production is becoming scarce and this helps them to meet their dietary demand, spread of family labour and resources. Under such systems cropping in pure stand is of limited use because of limited availability of production resources. The crop combination involves years of natural selection based on several criteria including morphology, growth vigour, ability to compete well with associated crop species and weeds. It is also important in increasing relative resistance to diseases, possession of high level of genetic variability, good performance under low inputs and spread of utilization of family labour (Mutsaers et al., 1997). Other systems such as mixed cropping enables farmers evade risks of total crop failure since when one crop fails there is an associated crop, which would compensate for the loss (Mutsaers et al., 1997).

Furthermore, Okigbo (1973) stated that mixed cropping increases efficiency in the utilization of environmental factors, labour, leads to higher gross returns, protects the soil against erosion while improving water infiltration and reduces the incidence of pests and diseases. Omolo and Ogango, (1999) demonstrated the effectiveness of varietal intercropping against pest infestations in sorghum and cowpea. These advantages are not achieved by costly inputs but by simply growing crops together thus benefitting the resource poor farmers. Willey, (1979a) reported adverse effects of intercrops which can reduce yield such as diseases, competition between various mixtures and allelopathic effects. As a result, one needs to identify those situations which are beneficial and those which are not. A number of intercropping systems exist based on spatial arrangement which leads to inter- as opposed to the intra-crop competition that exists in monoculture. According to Willey (1979b), yield advantage in intercropping systems should be categorized into three: where combined intercrop yield must exceed the yield of the higher yielding sole crop, where intercropping must give full yield of main crop plus some additional yield of a second crop and where the combined intercrop yield must exceed a total sole crop yield.

Many methods are used to measure yield advantage of intercrops such as land equivalent ratio (LER), staple land equivalent ratio (SLER), area time equivalent ratio (ATER), aggressive ratio (AR), and partial land equivalent ratio (PLER). Other approaches include use of relative yield (RY), relative crowding coefficient (RCC), reciprocity, competition index (CI), system productivity index (SPI) crop compensation ratio (CCR) and monetary advantage (MA) (Willey, 1979a). In Kenya complex combinations exist such as cereal/cereal intercrops e.g. sorghum/ sugarcane, sorghum/ maize, maize/ sugarcane, other combinations are maize/ pyrethrum, and legume/ legume. Others are legumes/ potato intercrops and a more complex three-way intercropping e.g. maize/ sorghum/ groundnuts or maize/ sorghum/ beans (Obura, 2005). This is because the cereal in most cases is the main food source and its yield is much higher than that of the legume (Nnko and Doto, 1980).

Land equivalent ratio >1 shows that the requisite monocultures used more land than the intercrop to provide equal quantities of the various products. The implication is that the magnitude of LER quantifies the increase in biological efficiency achieved by intercropping (Hiesbisch and McCollum, 1987). Land equivalent ratios of up to 1.73 have been reported in bambara nut/ maize intercrops (Karikari et al., 1999). An aggressive ratio (AR) of zero in inter-cropping systems indicates that the component species are equally competitive. The greater the numerical value the bigger the difference in competitive abilities and the difference between actual and expected yields (Willey, 1979b). If a species has an RCC of less than, equal to, or greater than one it means it has produced less, the same or more yield than expected, respectively. The component crop with the higher coefficient is the dominant one (Willey, 1979b). Competitive index (CI) less than one means the intercrop is more competitive on plant-for-plant basis than the other species indicating an advantage of intercropping (Willey, 1979b). A study on groundnut-maize intercrop in Vietnam showed that the highest area time equivalent ratio (ATER) of 1.36 was observed at closer spacing (30 cm) of the component crop (http://www.grad.cmu.ac.th/1998). Monetary advantage (MA) expresses the relative advantage indicated by the LER as an absolute monetary advantage. Thus, LER of 1.25 indicates not only a relative yield increase of 25% but also a monetary increase of 25% (Willey, 1979b).

The associated intercropping systems practiced by farmers in most crops could either be mixed, strip or relay intercropping or a combination of two or more of the above in the same field and at the same time (Edje, 1980). Since their introduction to the East African Coast bambaranut has evolved and been adapted to different farming systems. Bambaranuts have been reported to be grown on flat, ridge, raised bed, furrow and mound seedbed types (Mkandawire, 1996). Regardless of seedbed system adopted, bambaranut can be sole, mixed and strip or relay intercropped, with maize, groundnuts, beans, cassava and sorghum among other crops. In West Africa, bambaranut is grown as a sole crop in rotation with maize, cowpeas, cassava or yam (Okigbo, 1973). In a series of intercropping trials in Ghana, Karikari and Doku (1976) evaluated bambaranut and cassava intercropping system and found that a 50:50 population combination gave a yield advantage with a land equivalent ratio (LER) of 1:5. In Malawi bambaranut are intercropped with maize on the same ridge and spaced 45 × 15 cm with four to five hills in between maize with one seed per hill (Malawi Government, 1994). Studies on population density and types of seedbed during the short and long rainy seasons in Morogoro, Tanzania showed higher yields for bambaranut planted in furrows at 30 × 25 and on the flat at 30 × 15 cm, respectively (Mkandawire, 1996). Furthermore, in Dodoma, Tanzania it is very common for bambaranut to be sown as a monocrop and or alternating strips of groundnuts (Rachier, Personal Communication, 2000).

Although an evaluation of yield in intercropped bambaranut has been done elsewhere, very little has been done to evaluate bambaranut-intercropping systems under Kenyan conditions. Despite evidence that the combined yields of intercrops exceed the sole crop yield, experiences on bambaranut intercrop production in Kenya is not well documented. Hence the need to study the influence of productivity indices such as land equivalent ratio (LER), and area time equivalent ratio (ATER). Other indices were relative yield for maize and bambaranut (RY M and B), shelling percentage (SP), systems productivity index (SPI) and monetary advantage (MA) in bambaranut and maize intercropping systems. Productivity indices provide a reliable means of estimating dimensions of plant growth (http://aob.oxfordjournals.org, 2000). These relationships change from time to time during the period of plant growth. It is against this background information that this study sought to determine productivity indices and their response to varying spacing of bambaranut intercropped with maize.

MATERIALS AND METHODS

The study was conducted at the Kenya Agricultural and Livestock Research Organization (KALRO), Kakamega in western Kenya. The KALRO - Kakamega is located in Agro-ecological Zone (AEZ) UM_1 at latitude 0°16' North, longitude 34° 45' East and the altitude is 1585 m.a.s.l. The area experiences about 1800 mm of bimodal rainfall attributed to its proximity to Lake Victoria, the Equator and the Kakamega tropical rainforest thus receiving convectional rainfall. The mean annual temperature is 21± 1° C. The soils are well drained *Mollic Nitisols*, deep, dark red, friable clay, and some areas have humic top-soil characterized as Dystric Nitisols (Kenya Ministry of Agriculture, 1987).

Land preparation

The experimental fields were ploughed, harrowed and experimental plots measuring 4.5 m × 3.5 m laid down. Two different composite soil samples from depths of 0-15 cm and 15-30 cm were collected systematically after land preparation from each plot following a zig-zag pattern (Okalebo et al., 2000). These soil samples were air-dried and ground to pass through a 2 - mm mesh sieve for physical and chemical analysis.

Experimental design, treatments and experimentation

The experiment was laid down in a randomized complete block design (RCBD) and replicated three times. Each experimental plot of sole maize, sole bambaranut, and intercropped maize measured 4.5 m × 3.5 m in dimensions. The distance between individual plots within a replicate was 0.5 m and between replicates it was 1 m and the sowing spacing for maize was 75 cm × 30 cm. Based on the plot size in sole and intercropped maize plots there were 5 rows and 14 planting holes there were 70 maize plants/ 15.65 m^2 plot, which was equivalent to 44,728 plants/ha. The spacing of rows of bambaranut was 37.5 cm from each other under sole/pure stand and 37.5 cm between the two rows of maize plants under intercrop. In sole bambaranut there were 9 rows and in intercropped bambaranut the rows were 4. There were 15 treatment combinations from three factors in different levels/treatments: (1) sole bambaranut sown at intra-row spacing of (i) 45 cm, (ii) 35 cm, (iii) 30 cm, (iv) 25 cm, and (v) 15 cm; (2) sole maize; (3) intercropped maize-bambaranut in: (i) 45 cm, (ii) 35 cm, (iii) 30 cm, (iv) 25 cm, and (v) 15 cm of intra-row spacing of bambaranut.

Data collection

During the growing period data on rainfall, minimum and maximum temperatures, wind speed, and radiation were collected from the regional meteorological station at KALRO-Kakamega. Data on yields of bambaranut and maize in each experimental plot were collected and used to compute land equivalent ratio (LER) as described by Radosevich and Holt (1984) and Odo (1984) such that:

$$LER = \frac{Xa}{MA} + \frac{Xb}{MB} \tag{1}$$

Where Xa = yield of maize in intercrop, MA = yield of maize in pure stand, Xb = yield of bambaranut in intercrop, MB = yield of bambaranut in intercrop.

Relative yield (RY) was calculated as the ratio of the yield of bambaranut in intercrop to the yield of bambaranut in sole crop (Radosevich and Holt, 1984).

$$RY = \frac{Yield\ of\ A\ in\ the\ intercrop}{Yield\ of\ A\ in\ monocrop} \tag{2}$$

Shelling percentage (SP) was calculated as grain weight divided by the total pod or cob weight and represented as a percentage (Karikari et al., 1999).

$$SP = \frac{Grain\ yield}{Pod\ (cob) weight} \times\ 100 \tag{3}$$

Area time equivalent ratio (ATER) was calculated as the ratio of area time required in monoculture or pure stand of the crop to area time used by the intercrop in producing the similar quantities of all component crops. It is also the ratio of the number of hectares-days required

Table 1. Details of the 15 treatments and replicates.

TRTS	DESCRIPTION	REP 1	REP 2	REP 3
B45	Sole-cropped bambaranut 45	3	10	14
BM45	Bambaranut + maize 45	13	7	8
M1	Monocropped maize	11	12	3
B35	Sole-cropped bambaranuts 35	1	3	11
BM35	Bambaranut + maize 35	4	1	2
M2	Sole-cropped maize	2	15	4
B30	Sole-cropped bambaranut 30	9	2	12
BM30	Bambaranut + maize 30	10	8	1
M3	Sole-cropped maize	14	6	10
B25	Sole-cropped bambaranuts 25	6	11	7
BM25	Bambaranut + maize 25	7	5	15
M4	Monocropped maize	8	4	13
B15	Sole-cropped bambaranut 15	13	9	5
BM15	Bambaranut + maize 15	5	14	8
M5	Sole-cropped maize	12	13	9

TRTS stands for treatments for various spacing combinations for each bambaranut spacing (i.e 45, 35, 30, 25 and 15 cm were exposed to each of the planting systems Bambaranut, Bambaranut + maize and maize alone).

in monoculture to the number of hectares-days used in the intercrop to produce similar quantities of each of the component crops. This was calculated as described by Hiesbisch and McCollum (1987):

$$ATER = \frac{Y\ (IA)/TI}{Y(SA)/TSA} + \frac{Y\ (IB)/TI}{Y\ (SB)/TSB} \quad (4)$$

Where Y = yield, T = time, IA = intercrop A (say bambaranut), IB = intercrop B (say maize), SA = monocrop A, SB = monocrop B, I = time from initial sowing to final harvest of intercropped plots.System productivity index (SPI) was used to standardize bambaranut grain yield in terms of maize yield and this identifies the combinations that utilized growth resources most effectively and maintained a stable yield performance. This was calculated as described by Odo (1984):

$$SPI = \frac{SA}{LB} X\ (Lb + Sa) \quad (5)$$

Where S_A and L_B are mean yields of maize and bambaranut in monoculture, and S_a and L_b are maize and bambaranut yields in intercrop.

Income equivalent ratio (IER) was calculated by dividing the income from bambaranut and maize in intercrop by income from both crops in their pure stand (Maheshwari et al., 1995).

$$IER = \frac{Income\ from\ both\ crops\ in\ intercropping}{Income\ from\ both\ crops\ in\ monocrop} \quad (6)$$

Monetary advantage (MA) Monetary advantage was calculated by taking the value of the combined yield of bambaranut and maize multiplied by land equivalent ratio minus one divided by land equivalent ratio (Maheshwari *et al.*, 1995).

$$MA = Value\ of\ combined\ intercrop\ yield \times \frac{LER-1}{LER} \quad (7)$$

Where *LER = Land equivalent ratio*

Data analysis

The analysis of variance (ANOVA) was performed for all variables using SAS (2004) computer package. Significant means were separated using Tukey's honest multiple comparison.

RESULTS

Effect of cropping systems and sowing spacing on pod and grain yield

Results of the pod and grain yields for the 2006/07, 2007/08, and 2008/09 cropping seasons are presented in (Tables 1-3). Significant ($p<0.05$) differences were observed on bambaranut pod yield during the 2006/07, 2007/08 and 2008/09 growing seasons for both sole-cropped and intercropped bambaranuts (Table 2). In 2006/07 significantly ($p<0.05$) highest pod yield was recorded at the sowing intra-row spacing of 15 cm. The intra-row spacing of 30 cm gave significantly the lowest pod yield. In 2007/08 growing season bambaranut pod yield was highest at the spacing of 35 cm for both mono- and the intercrop. The lowest pod yield for sole-cropped bambaranuts was realised at the spacing of 30 cm for the intercrop. In 2008/09 growing season, sole bambaranuts recorded significantly highest yield at the spacing of 15 cm

Table 2. Bambaranut pod yield (kg/ha) as influenced by planting system for KALRO Kakamega during 2006/07, 2007/08 and 2008/09 cropping season.

Pop (Spacing)	2006/2007		2007/2008		2008/2009	
	Mono-crop	Inter-crop	Mono-crop	Inter-crop	Mono-crop	Inter-crop
76,190 (45 cm)	558.24b	69.05e	517.39b	498.37bc	519.37d	37.37e
95,235 (35 cm)	503.42bc	104.46d	652.47a	502.34bc	897.54c	56.86e
114,285 (30 cm)	454.90c	68.01e	427.61f	450.40def	888.83c	58.38e
133,333 (25 cm)	549.10b	105.74d	431.99ef	474.54cd	1215.52b	62.76e
222,222 (15 cm)	644.77a	109.47d	425.15cde	467.15cde	1541.58a	50.28e
CV	13.98	13.98	4.37	4.37	19.92	19.92
MSE	42.42	42.42	21.17	21.17	108.18	108.18
LSD	72.77	72.77	36.46	36.46	185.58	85.58

Means within a column followed by the same letter (s) are not significantly different (P≤0.05) according to Tukey's test.

Table 3. Bambaranut grain yield (kg/ha) as influenced by planting system for KALRO Kakamega during 2006/07, 2007/08 and 2008/09 cropping seasons.

Spacing	2006/2007		2007/2008		2008/2009	
	Sole-crop	Inter-crop	Sole-crop	Inter-crop	Sole-crop	Inter-crop
45	273.72 ab	38.80 f	160.15 e	340.37 b	305.22 c	19.31 d
35	263.30 b	68.09 d	250.98 d	358.97 a	527.13 b	34.77 d
30	271.40 ab	44.21 ef	380.64 b	317.17 c	530.08 b	35.85 d
25	310.84 a	74.85 d	321.30 c	365.44 a	636.19 ab	37.09 d
15	187.65 c	72.79 d	476.66 a	345.50 b	742.80a	88.03 d
CV	10.02	10.02	4.76	4.76	24.17	24.17
MSE	15.99	15.99	15.14	15.14	71.47	71.47
LSD	28.23	28.23	28.50	28.50	122.60	122.60

Means within a column followed by the same letter (s) are not significantly (p<0.05) different according to Tukey's test

followed by the spacing of 25 cm. The lowest was recorded at the spacing of 45 cm. In the same growing season intercropped bambaranuts showed no significant differences among the treatments.

Bambaranut grain yields showed significant (p<0.05) differences during 2006/2007, 2007/2008 and 2008/09 growing seasons (Table 3). Sole bambaranuts (2006/2007) had the highest grain yield at the spacing of 25 cm followed by spacing at 35 cm. The lowest grain yield was recorded at the spacing of 15 cm which initially produced the highest unshelled yield in kg/ha. This is attributed to a low shelling percentage as indicated in Table 4 because there was a higher percentage of a pods affected by moth beetle. Bambaranuts intercropped with maize had the highest shelled yield at the spacing of 25 cm and lowest at the spacing of 45 cm. Spacing of 15 cm for the sole-crop produced the highest bambaranut grain yield in 2007/08 growing season. The lowest grain yield was produced at the spacing of 45 cm. In the same growing season bambaranuts intercropped with maize produced highest grain yield at the spacing of 25 and 35 cm. The lowest grain yield was recorded at the spacing of 30 cm.

Sole bambaranuts gave the highest grain yield at the spacing of 15 cm in 2008/09 growing season. The lowest grain yield was recorded at the spacing of 45 cm. Bambaranuts intercropped with maize were not significantly affected by the planting system.

Shelling percentage values during 2006/2007 and 2007/2008 growing seasons were significantly (p<0.05)

Table 4. Shelling percentage for bambaranuts as influenced by planting system for KALRO Kakamega during 2006/07, 2007/08 and 2008/09 growing season.

Spacing (cm)	2006/2007		2007/2008		2008/2009	
	Sole-crop	Inter-crop	Sole-crop	Inter-crop	Sole-crop	Inter-crop
45	49.03 e	56.11 cd	73.79 ab	69.36 b	58.75 a	50.56 a
35	51.17 d	65.21 b	73.11 ab	71.46 ab	59.08 a	58.45 a
30	59.81 c	65.01 b	72.42 ab	70.42 ab	61.33 a	61.87 a
25	56.72 d	70.84 a	70.57 ab	77.01 a	57.60 a	62.06 a
15	30.39 f	66.68 ab	72.19 ab	73.96 ab	48.63 a	59.00 a
C V	4.76	4.76	5.97	5.97	19.46	19.46
MSE	2.73	2.73	4.32	4.32	11.14	11.14
LSD	4.68	4.68	7.45	7.45	19.11	19.11

Means within a column followed by the same letter (s) are not significantly (p<0.05) different by Tukey's test..

Table 5. Land equivalent ratios (LER) as influenced by planting system for KALRO Kakamega during 2006/2007, 2007/2008 and 2008/2009 cropping season.

Spacing (cm)	2006/2007	2007/2008	2008/2009
45	1.30 ab	1.16 b	1.17 a
35	0.94 c	1.43 a	1.11 a
30	1.00 bc	1.02 b	1.12 a
25	1.47 a	1.04 b	1.11 a
15	1.41 a	1.11 b	1.23 a
CV	18.19	7.32	20.85
MSE	0.22	0.08	0.24
LSD	0.42	0.16	0.45

Means within a column followed by the same letter (s) are not significantly (p<0.05) different by Tukey's multiple comparison test

Table 6. Maize relative yield (RY M) as influenced by planting system for KALRO Kakamega site during 2006/2007, 200720/08, 2008/2009 cropping season.

Spacing	2006/2007	2007/2008	2008/2009
(M1)	1.29 a	0.93 b	0.92 a
(M2)	0.64 c	1.13 a	0.95 a
(M3)	0.83 bc	1.01 ab	1.07 a
(M4)	1.23 ab	0.99 ab	1.06 a
(M5)	0.91 abc	1.09 ab	0.90 a
CV	22.16	9.67	24.19
MSE	0.22	0.09	0.25
LSD	0.41	0.19	0.45

Means within a column followed by the same letter (s) are not significantly (p<0.05) different by Tukey's multiple comparison test.
M1 – M5 represents treatments for maize alone for each variation in spacing.

affected by the planting systems (Tables 4). Highest shelling percentage value was realised at the spacing of 25 cm for bambaranuts intercropped with maize during 2006/2007 growing season. During the same growing season sole bambaranuts produced the lowest shelling percentage at the spacing of 15 cm. In 2007/2008 growing season plant spacing of 25 cm produced the highest shelling percentagefor intercropped bambaranuts while spacing at 45 cm recorded the lowest values. Shelling percentage values were not significantly (p<0.05) affected by planting systems during 2008/09 growing season. In general, in 2006/07 increase in plant population density and intercropping with maize increased the shelling percentage. During 2007/2008 shelling percentage values for both sole- and bambaranut intercropped with maize were much higher than those for 2006/07 and 2008/2009 growing seasons while sole bambaranuts had lower values of shelling percentage.

Table 7. Relative yield for bambaranut (RY B) as influenced by planting system for KALRO Kakamega during 2006/2007, 2007/2008 and 2008/2009 cropping season.

Spacing (cm)	2006/2007	2007/2008	2008/2009
45	0.26 a	0.14 a	0.15 b
35	0.06 a	0.16 a	0.21 a
30	0.07 a	0.08 b	0.15 b
25	0.05 a	0.18 a	0.19 a
15	0.10 a	0.19 a	0.18 a
CV	29.05	17.48	10.68
MSE	0.14	0.03	0.02
LSD	0.27	0.05	0.03

Means within a column followed by the same letter (s) are not significantly (p<0.05) different by Tukey's multiple comparison test.

Table 8. Area time equivalent ratios (ATER) as influenced by planting system for KALRO, Kakamega during 2006/2007, 2007/2008 and 2008/2009 growing seasons.

Spacing (cm)	20062007	2007/2008	2008/2009
45	1.41 a	1.17 b	1.17 a
35	0.85 b	1.47 a	1.09 a
30	0.98 b	1.05 b	1.12 a
25	1.39 a	1.07 b	1.11 a
15	1.08 ab	1.14 b	1.23 a
CV	15.95	6.92	21.19
MSE	4.40	0.08	0.24
LSD	0.30	0.15	0.46

Means within a column followed by the same letter (s) are not significantly (p<0.05) different by Tukey's multiple comparison test.

Table 9. Income equivalent ratios (IER) as influenced by planting system for KALRO Kakamega during 2006/07,2007/2008 and 2008/2009 growing season.

Spacing (cm)	2006/2007	2007/2008	2008/2009
45	1.31 b	0.46 a	1.40 a
35	1.19 b	0.40 a	0.67 b
30	1.06 b	0.18 c	0.63 b
25	1.38 b	0.29 b	0.50 b
15	1.99 a	0.29 b	0.61 b
CV	21.47	13.12	33.65
MSE	0.29	0.04	0.26
LSD	0.56	0.08	0.48

Means within a column followed by the same letter (s) are not significantly (p<0.05) different by Tukey's multiple comparison test.

Productivity indices (LER, RY (M), RY (B), ATER, IER, MA and SPI)

Information for productivity indices for 2006/2007, 2007/2008 and 2008/2009 growing seasons is summarized in (Tables 5-11). Land equivalent ratio values in 2006/2007 growing season was highest at spacing of 25, followed by spacing of 15 and 45cm (Table 5). Spacing of 35 cm recorded significantly the lowest LER. Land equivalent ratio of more than 1.00 indicates that intercropping was advantageous especially at the spacing of 25 and 15cm where there was 47% and 41% increase in the overall yield as a result of intercropping, respectively.

In 2007/2008 growing season significant (P≤0.05) differences were reported for LER values for grain yield. Land equivalent ratio was significantly (P≤0.05) highest at the spacing of 35 cm. This is equivalent to an intercropping advantage of 43%. The other LERs were not significantly different for the growing season. In

Table 10. Monetary advantage (MA) as influenced by planting system for KALRO Kakamega site during 2006/07, 2007/08 and 2008/09 cropping season (KSh).

Spacing (cm)	2006/2007	2007/2008	2008/2009
45	20,283.00 ab	2,565.10 bc	17,743.00 ab
35	-5,105.00 b	7,480.80 a	6,706.00 bc
30	- 280.00 b	294.00 c	8,329.00 bc
25	35,411.00 a	2.363.00 bc	12,832.00 b
15	28,827.00 a	3,270.70 b	19,969.00 a
CV	40.72	38.05	39.72
MSE	14,842.00	1,215.64	18,326.18
LSD	27,946.00	2,280.90	34,505.00

Means within a column followed by the same letter (s) are not significantly (p<0.05) different by Tukey's multiple comparison test.

2008/2009 growing season land equivalent ratio values were not significant.

There were significant (p<0.05) differences in relative yield (RY) for maize with respect to spacing during 2006/2007 and 2007/2008 growing seasons (Table 6). In 2006/2007 significant RY (M) values of the maize spacing of M1 and M4. The rest of the treatments were below one unit with M2 producing significantly the lowest RY (M). During 2007/2008 growing seasons, RY (M) values were above one unit at the maize spacing of M2, M5 and M3, respectively with highest RY (M) value produced at M2. Lowest RY (M) was recorded at the maize spacing treatments of M4 and M1, respectively. There were no significant (p<0.05) differences reported for RY (M) in relation to spacing during 2008/2009 growing season.

Spacing did not result into significant (p<0.05) differences in relative yield (RY) (B) values for bambaranuts in 2006/2007 growing season (Table 7). These values if compared to RY (M) in Table 6 show that maize was the main beneficiary in the combination. Significant (p<0.05) differences in RY (B) were, however, recorded in 2007/2008 and 2008/2009 RY (B) although the values were less than a unit for all treatments a clear indication that bambaranuts suffered at the expense of maize in the intercrop.

Area time equivalent ratios for 2006/2007 and 2007/2008 were significantly (p<0.05) affected by spacing (Table 8). Above one unit values for ATER were reported at the spacing of 45, 25 and 15 cm, respectively with the highest achieved at the spacing of 45 cm. Significantly less than one unit values for ATER were recorded at the spacing of 35 and 30 cm, respectively. Significant differences (p<0.05) were detected among the means during 2007/2008 and all ATER values were above one unit. The highest ATER value was recorded at the spacing of cm. The rest did not show any significant differences. Area time equivalent ratios of above one unit indicate that there was time benefit in having two crops on the same piece of land at the same time.

Income equivalent ratio values were significantly (p<0.05) affected by the different spacing during 2006/2007, 2007/2008 and 2008/2009 growing seasons (Table 9). During 2006/2007 growing season spacing at 15 cm resulted into the highest income equivalent ratio (IER) value. Differences in IER values for the rest of the spacing treatments were not significantly different from each other. Generally, IER values for 2006/2007 growing season were much higher than the rest of the seasons. The lowest IER values were recorded in the 2007/2008 growing season. During the same season, spacing at 25 and 15 cm recorded significantly lower figures for IER. The lowest IER values were obtained at the spacing of 30 cm. During 2008/2009 growing season spacing at 45 cm resulted into significantly highest IER value. The rest of the IER values were less than one unit and not significantly different. Generally, 2007/2008 growing season reported the lowest IER values. The main reason why yields were low in 2007/2008 was because the crop succumbed to maize blight despite frantic efforts to save the crop.

Significant (p<0.05) differences were observed for monetary advantage during 2006/2007, 2007/2008 and 2008/2009 growing season (Table 10). In 2006/07 highest monetary advantage values were observed at the spacing of 25 and 15 cm. Spacing of 45cm resulted into third best values of MA. Negative MA values (-5105.00 and -280.00) were reported at the spacing of 35 and 30 cm, respectively.

In 2007/2008 growing season bambaranut spacing of 35 cm resulted into the highest value for MA followed by spacing at 15 cm. Spacing at 25 and 45 cm recorded slightly lower values for monetary advantage. The lowest monetary advantage value was observed at the bambaranut spacing of 30 cm.

During 2008/2009 growing season lowest values for monetary advantage were observed at the spacing of 35 and 30 cm, respectively. Spacing at 15 and 45 cm produced highest values of monetary advantage. Throughout the experimental period during 2006/2007 and 2008/2009, monetary advantage values were depressed at the spacing of 35 and 30 cm, respectively.

Systems productivity index values were significantly (p<0.05) affected by various spacing during 2006/2007, 2007/2008 and 2008/2009 growing seasons (Table 11). In 2006/2007 highest significant values of SPI were observed at the spacing of 45 cm. It was observed that

Table 11. Systems productivity index (SPI) as influenced by planting system for KALRO Kakamega during 2006/2007, 2007/2008 and 2008/2009 cropping season.

Spacing (cm)	2006/2007	2007/2008	2008/2009
45	334.88 a	298.40 b	331.00 b
35	179.83 b	343.75 ab	571.10 ab
30	230.68 b	449.03 ab	548.20 ab
25	335.88 a	328.26 ab	683.30 a
15	199.14 b	530.63 a	832.60 a
CV	15.23	29.74	26.43
MSE	38.98	114.58	156.79
LSD	73.42	219.50	0.46

Means within a column followed by the same letter (s) are not significantly ($p<0.05$) different by Tukey's multiple comparison test.

spacing at 15 cm resulted into the highest values of SPI during 2007/2008 growing season. Lowest values of SPI were observed at the spacing of 45 cm.

During 2008/2009 growing season highest values of SPI were observed at the spacing of 25 and 15 cm. Spacing at 45 cm recorded the lowest systems productivity index. In general, 2008/2009 SPI values were much higher than those recorded for 2006/2007 and 2007/2008 growing seasons.

DISCUSSION

Pod and grain yield as affected by planting system

Pod and grain yields were significantly (($p<0.05$)) higher in mono than in intercropped bambaranuts (Tables 2 and 3). Higher pod and grain yields in the monocrop were attributed to better use of resources as a result of less competition between maize and bambaranuts. Similar results were obtained by Baring *et al*. (2010) who reported higher pod formation, higher pod and grain yield in a bambaranut/ sweetpotato intercrop experiment in Swaziland. On the other hand, Alhassan and Egbe, (2013) reported reduced pod formation per plant and grain yield of intercropped bambaranut landraces as compared to monocrop. This was ascribed to interspecies competition for both above and underground resources (water, nutrients, light and air). Tall maize plants shaded the low canopy legume, thus reducing light availability for optimum photosynthetic activity and subsequently culminating in low yield of bambaranuts. This is also consistent with Trenbath, (1976) who opined that the component of intercropping (maize) with its broad and horizontal leaves held higher in the canopy structure was more advantaged than bambaranut. The only exception in this study was in 2007/2008 growing season when there were no substantial differences in the yield of mono- and intercropped bambaranuts (Table 3). This was as a result of the failure of the maize crop due to an early attack by leaf blight which started as early as 40 DAS and continued up to the end of the growing season. The factors that led to the attack of maize by leaf blight were beyond the researchers control but seed borne resulting into withdrawal by the seed company of the particular batch from the market for further cleaning.

Effect of population density on pod and grain yield

Pod and grain yield was significantly ($p\leq0.05$) higher for mono- than intercropped bambarnuts across all population densities. There was a general tendency of increased pod yield at the population density of 222,222 plants per hectare in 2006/2007 and 2008/2009 this was more pronounced in 2008/09, while there was no specific trend in response to population density for the intercropped bambaranuts. The results suggest a linear relationship between population density and pod yield. These results concur with the findings of Akpalu *et al.* (2012) who in a study in Ghana on the effect of spacing on growth and yield of bambaranut landraces eluded to the fact that crop yield increases in direct proportion to increase in plant density when there is no interplant competition. The findings are also consistent with the previous studies by Kouassi and Zorobi, (2010) who reported that although pod and grain yields plants^{-1} was higher at lower (13,900 plants ha^{-1}) population densities than at higher, the influence of plant density on seed yield was through the production of pods per unit area but not through increased production of pods plants^{-1}. There was, however, compensation on the yield and monitory value because of intercropping. This was evident from land equivalent ratio (LER), area time equivalent ratio (ATER), monitory advantage (MA), income equivalent ratio (IER) and systems productivity index (SPI) (Tables 5, 8, 9. 10 and 11).

LER values were 30, 41 and 47% higher at the spacing of 45, 15 and 25 cm for 2006/2007 growing season, respectively. In 2007/2008 growing season LER values showed higher compensation in yield at the spacing of 35 cm. LER values recorded in this study are consistent with the finding of Karikari *et al.* (1999) who reported LER values at 25, 27, and 30% in a bambaranut/cereal intercropping study in Botswana. The increased efficiency of bambaranut/cereal crop occurred because bambaranuts were able to produce almost the equivalent of a full monocrop yield while growing in only 75:25% ratio. Similar LER values were also reported by Dariush *et al.* (2006), and Alhassan *et al.* (2012). Higher values of LER recorded in this study are a clear indication that intercropping was advantageous to varying degrees with reference to spacing and population densities. ATER values were 39 and 41% higher at the spacing of 45 and 25cm, respectively, for 2006/07 growing season. In 2007/2008 growing season spacing at 35cm recorded the highest (47%) ATER value. ATER advantage ranged from 8-42% for various spacing treatments. Higher ATER values realized in this study could be attributed to efficient utilization of natural (land and light) and added (fertilizer and water) resources. Higher ATER values have also been reported in Cotton + Cowpea (Allen and Obura 1983), in wheat + linseed (Khan and Saeed, 1997), rice + pigeon (Banik and Bagehi (1994), wheat and lentil (Ahmad, 1997), soybeans + sorghum (Aasim *et al*., 2008) and bambaranut + sweetpotatoes (Baring, *et al*., 2010) associations compared with monoculture of their component crops.

IER values varied considerably with above one unit for 2006/07 and below one unit for 2007/2008 and 2008/2009 growing season. IER values above one unit indicate that the intercropping system was beneficial. The results obtained in 2006/2007 are in agreement with the findings of Sarkar *et al*. (2003) in pigeon pea + sunflower intercropping, Rani *et al*. (2006) in carrot and ber – based cropping system and Lakshminarayanan *et al*. (2005) in intercropping vegetables in pruned fields of jasmine. IER values of less than one unit especially for 2007/08 and 2008/09 growing seasons may have arisen because of low relative yield of bambaranut as indicated in Table 7. The lower values of IER could also be attributed to lower shelling % value as a result of attack of pods by an underground beetle. Usually the higher the MA value the more profitable the combination (Odo, 1984). The trends of MA values realized in this study are in agreement with (Ghost, 2004). SPI values as increased as planting seasons progressed from 2006/2007, 2007/2008 and 2008/2009. The SPI values recorded here were lower than those reported by Agegnehu *et al*. (2006) in teff/faba bean mixed cropping system who reported the highest SPI values in the range of 1680 to 2032. Lower values of SPI in this study could have been because of the different types of crops involved in the two studies.

Conclusion

This study has revealed that intercropping bambaranuts and maize is possible and can enable farmers obtain additional bambaranut yield in addition to maize especially in areas where land is a limiting factor of production.The yields of bambaranut obtained in this study indicated that intercropping as a system of crop production can still contribute to food security and improved nutrition especially where cereals form the bulk of the of the staple food. Productivity indices revealed that LER was most profitable ATER values were all above one thus showing that crops utilised the time of production efficiently. This means that land was used efficiently and simultaneously by producing two crops in one season. Income equivalent ratio (IER) values were all above one across all population densities in 2006/2007 but were less than one in 2007/2008 and 2008/2009 growing seasons except at the population density of 76,190 plants/ hectare. System productivity index (SPI) values were highest at the population density of 133,333 plants/ha at the spacing of 25 cm throughout the period of study. The results of this study have shown that the population density at 222,222 plants/ ha at the spacing of 15 cm more pods/ plant and higher yields/ ha.

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AUTHORS` DECLARATION

We declare that this study is an original research by our research team and we agree to publish it in the Journal.

REFERENCES

Aasim M, Karim A (2008). Yield and competition indices of intercropping cotton (*Gossypium hirsutum* L.) using different planting patterns. Tarim Bilimleri Dergisi, Ankara Universitesi Ziraat Fakültesi14 (4):326-333.

Agegnehu G, Ghizaw A, Sinebo W (2006). Crop productivity and land-use efficiency of a teff/faba bean mixed cropping system in a tropical highland environment. Exp. Agric. 42:495-504.

Ahmad N (1997). Agro-economic relationships of the component crops in some wheat-based intercropping systems at different patterns of wheat plantation. *Ph.D. Thesis,* Univ. Agric., Faisalabad–Pakistan.

Akpalu MM, Sarcodie-Addo J, Akpalu SE (2012). Effect of spacing on growth and yield of five bambara groundnut (*Vigna subterranean* (L.) Verdc.) land races. J. Sci. Techn. 32(2):9-19.

Alhassan GA, Kalu BA, Egbe OM (2012). Influence of planting densities on the performance of intercropped bambara groundnut with cowpea in Makurdi, Benue state, Nigeria. Int. J. Dev. Sust. 1(3): 860-879.

Alhassan GA, Egbe MO (2013). Bambara groundnut/maize

intercropping: Effects of planting densities in Southern guinea savanna
of Nigeria. Afr. J. Agric. Res. 9(4): 479-486.
Allen JR, Obura RK (1983). Yield of corn, cowpea and soybean under different intercropping systems. Agron. J. 75:1005-1009.
Banik P, Bagchi DK (1994). Evaluation of rice (*Oryza sativa*) and legume intercropping in Bihar plateau. Indian J. Agric. Sci. 64: 364-368.
Baring SN, Ekpo MO (2010). Effects of jugo bean [*Vigna subterranea* (L.) Verdc.] plant population on physiological growth indices and yields under intercropping with sweetpotato [*Ipomoea batatas* (L.) Lam.]. Adv. Environ. Biol. 4(2): 201-215.
Dariush M, Ahad M, Meysam O (2006) Assessing the land equivalent ratio (LER) of two corn (*Zea mays* L.) varieties intercropped at various nitrogen levels in Karaj Iran. J. Central Eu. Agric. 7(2):359-364.
Edje OT (1980) Comparative development and yield and other agronomic characteristics of maize and groundnut in monoculture and in association. In: Proceedings of second symposium on Intercropping in semi-arid areas, held at Morogoro Tanzania, Pp.4-7.
Enyi BAC (1973**).** The effects of intercropping maize or sorghum with cowpeas, pigeon peas or beans. Exp. Agric. 9:83-90.
Francis CA (1986). *Multiple Cropping Systems*. MacMillan Publishing Company, New York.
Ghost PK (2004). Growth yield, competition and economic of groundnut/cereal fodder intercropping system in the semi-arid tropics of India. Field Crops Res. 88: 227-237.
Gomez AA, Gomez KA (1983). *Multiple Cropping in the Humid Tropics of Asia*. Ottawa, Canada. P. 248.
Hiesbisch CK, McCollum RE (1987). Area-x-time equivalent ratio: A method for evaluating the productivity of intercrops. Agron. J. 79:15-22.
Igboziruke UM (1977). Agriculture at crossroads: A comment on agricultural ecology. University Press, Nigeria. P.116.
Karikari SK, Doku EV (1976). Agronomic significance of intercropping: Bambara groundnuts intercropped with cassava. In: Grain legumes in Ghana. Proceedings of the first University of Ghana/Council for Scientific and Industrial Research (CSIR) Symposium on Grain Legumes. Legon, Ghana 10-12 December, 1976. Doku, E. V. (Ed.). 67-74 pp.
Karikari SK, Chaba DKO, Molosiwa B (1999). Effect of intercropping bambara groundnut on pear millet, sorghum and maize in Botswana. Afr. Crop Sci. J. 7(2):143-152.
Kenya Ministry of Agriculture (1987) Fertilizer Use Recommendation Project (Phase 1). Annex 111 Vol 8, Nandi District.
Khan SA, Saeed M (1997). Competitive relationships of component crops in different wheat – based intercropping systems. J. Animal and Plant Sci. 7:37-39.
Kouassi NJ, Zorro IA (2010). Evaluation of agronomic performance of two landraces of Bambara groundnut (*Vigna subterranea*) in woodland savannahs of Cote d'Ivoire. Afr. J. Agric. Res. 6(21):4852-4856.
Lakshminarayanan M, Haripriya K, Manivannan K, Kamalakannan S (2005). Evaluation of leguminous vegetables as intercrops in pruned fields of jasmine (*Jasminum sam* bac Ait.). J. Spices and Aromatic Crops. 1-1(1):61-64.
Maheshwari SK, Sharma RK, Gangrade SK (1995). Effect of spatial arrangement of performance of *Palmarosa cymbopogon* Martini var Motia - Pigeonpea (*Cajanus cajan*) intercropping on a black cotton soil (vertisol). Indian J. Agron. 40(2): 181-185.
Malawi Government (1994). Guidelines to Agriculture Production in Malawi. *Agricultural Communication Branch*, Lilongwe, Malawi.
Mkandawire FL (1996). Effect of plant density and types of seed bed on the growth and grain yield of bambaranuts (*Vigna subterranea L.* Verdc). MSc Dissertation Sokoine University of Agriculture, Morogoro, Tanzania. P. 136.
Mkandawire FL Sibuga KP (2002). Yield response of bambara groundnut to plant population and seedbed type. Afr. Crop Sci. J. 10(1):39-49.
Mutsaers HJW, Weber GK, Walker P, Fisher NM (1997). *A Field Guide for On- Farm Experimentation.* IITA/CTA/ISNAR.
Nnko EN, Doto AL (1980). Intercropping maize or millet with soybean, with particular reference to planting schedule. Proc. Second Symposium on intercropping in semi-arid areas, held at Morogoro, Tanzania. 33:168.
Odo PE (1984). Evaluation of short and tall sorghum varieties in mixtures with cowpea in the Sudan Savanna of Nigeria: Land equivalent ratio, grain yield and system productivity index. Exp. Agric. 27:435-441.
Obura RK (2005). Personal Communication. Laikipia University, Kenya.
Okalebo JR, Gathua KW and Woomer PL (2000). *Laboratory Methods of Soil and Plant Analysis:* A Working Manual. Second Edition. P.128.
Okigbo BN (1973). Grain legume in the farming systems of the humid lowland tropics. Proc. First IITA Grain Legume Workshop 29 October - 2 November, 1973, IITA, Ibadan, Nigeria. 211-223 pp.
Omolo KO, Ogango KO(1999). Use of varietal intercropping to control pests in sorghum and cowpea. Afr. Crop Sci. J. 4:569-573.
Radosevich SR, Holt J.S. (1984). *Weed Ecology. Implications for vegetative management*. John Wiley and Sons. New York, USA. P. 265.
Rani NS, Syed I, Reddy YN (2006). Effect of cropping situations and integrated nutrient management practices on growth, yield, quality and economics of growing carrot in ber-based cropping system. Indian J. Dryland Agric. Res. Dev. 21: 136–140.
Rachier GO, Personal Communication (2000).Kenya Agricultural and Livestock Research Organization (KALRO).
Sarkar RK, Goswami S, Pal PK (2003). Production potential and economic feasibility of sunflower (*Helianthus annum*) and pigeon pea (*Cajanus cajan*) intercropping system on rain fed upland condition. Indian J. Agron. 48(4):263-266.
SAS (2004). Statistical Analysis System version 9. North Carolina State University.
Stokskof CN (1981). Understanding Crop Produciton, Reston, Inc. Virginia USA.
Trenbath BP (1976). Plant interactions in mixed communities. In: Papendick RI, Sanchez PA and Triplett GB (Eds.). Multiple Cropping, ASA, CSSA and SSSA, Madison, WI. pp.76-102.
Willey RW (1979a) A Scientific Approach to Intercropping research. In: Proc. Second Int. Workshop on intercropping. 10-13 January 1979, Hyderabad, India. pp.4-14.
Willey RW (1979b). Intercropping: Its importance and research needs. Part 1. Competition and yield advantages. Field Crops Abstract, 32:1-10.
http://www.grad.cmu.ac.th/1998
http://aob.oxfordjournals.org, 2000