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Yield response of three groundnut (*Arachis hypogaea L.*) varieties intercropped with maize (*Zea mays*) in the guinea savanna zone of Ghana

Konlan S.[1]*, Sarkodie-Addo, J.[2], Kombiok . M. J.[3], Asare, E.[2] and Bawah, I.[3]

[1]Cocoa Research Institute of Ghana (CRIG), New Tafo-Akim, Ghana.
[2]Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana.
[3]Savanna Agricultural Research Institute (SARI), Nyankpala, Ghana.

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A field experiment was conducted under rain-fed conditions on the research farm of Savanna Agricultural Research Institute, Nyankpala, during the 2007 and 2008 seasons. The objective was to study the response of three new groundnut varieties (Jenkaar, Kpanieli and Nkosuor) to row intercropping with maize. The experiment was laid in randomized complete block design with four replicates. Treatments comprised sole groundnut, sole maize, single row groundnut alternated with single row maize (G1M1), single row groundnut alternated with double row maize (G1M2), double row groundnut alternated with single row maize (G2M1) and double row groundnut alternated with double row maize (G2M2). The population densities of groundnut and maize in the intercrops affected their yield performance. Row intercropping arrangement that encouraged large leaf area in groundnut supported the formation of more pods per plant and subsequently larger dry pod yield. The highest groundnut and maize yields in the intercrop in both years were obtained respectively from G2M1 and G1M2. The G1M1 and G1M2 row intercropping arrangement was therefore the most advantageous in both years, achieving a land equivalent ratio values greater than 1. Combinations of the Kpanieli variety and maize which achieved land equivalent ratio greater than 1 was also more advantageous than intercropping maize with the Jenkaar and Nkosuor varieties in both years.

Key words: Guinea savanna, rain-fed, row intercropping, yield performance, land equivalent ratio.

INTRODUCTION

The groundnut (*Arachis hypogaea* L.) is an important oilseed crop of the semi-arid tropics (Tarimo, 1997; ICRISAT, 2008) that ranks thirteenth (13^{th}) in importance among world crops (Hatam and Abbasi, 1994). Groundnut is a staple food in a number of developing countries much valued for its protein content and as source of income for small holder farmers (Peanut CRSP, 1990). It is also a good source of edible oil for humans, as well as a nutritive feed supplement for livestock (Abulu, 1978; Goldsworthy and Fisher, 1987). In Ghana, groundnut is grown by farm families on small scale, both in pure stands and in crop mixtures, especially with cereals (Tsigbey et al., 2003). Yields obtained from the crop are traditionally low due to a combination of factors including unreliable rains, little technology available to small scale farmers, pest and disease occurrences, poor seed technology and agronomic practices, as well as increased cultivation on marginal lands (Konlan et al.,

*Corresponding author. E- mail: Sampson.konlan@gmail.com. Tel. +233 (0) 243 314 068.

2013a). Despite the numerous problems facing groundnut cultivation, it ranks as the number one grain legume grown in the Guinea savanna zone of Ghana (Tsigbey et al., 2003; Naab et al., 2005).

Incidentally, maize (*Zea mays*) is the most important and widely cultivated cereal in Ghana. However, competition between the two crops for limited land holdings by farm families who need to produce both the maize to feed the family and groundnut for income to cater for the health, education and other needs of the family is intense. To enable the farm family meet its household food needs and cash requirements, many subsistence farmers therefore practice intercropping in which groundnut frequently forms an important part of the system (Tsigbey et al., 2003; Naab et al., 2005). Groundnut-maize intercropping, as a common practice among farmers in dry land areas is well documented in Ghana (Atuahene-Amankwah et al., 1990; Tsigbey et al., 2003; Naab et al., 2005) and elsewhere (Molatudi and Mariga, 2012; Siddig et al., 2013; Mehdi, 2013; Reddy et al., 1987). In most of these reports, groundnut-maize intercropping achieved land equivalent ratios (LER) greater than 1 and gave higher economic returns. The yields obtained from the intercrops were found to relate directly to their population densities (Langat et al., 2006), giving an indication that the overall plant population can be skewed to favour one crop over the other in the intercrop depending on the farmer's priority or individual crop profitability. After successfully establishing the advantages of groundnut-maize intercropping systems through decades of scientific research, new promising maize and groundnut varieties should as a matter of principle, be evaluated and only released to farmers based on their ability to meet the demands of current intercropping systems. This will help meet the two-pronged need of the farm family to produce food and obtain cash income from the same piece of land. The yield response and nitrogen fixing capacities of these groundnut varieties were earlier evaluated under high density planting in sole systems (Konlan et al., 2013a; 2013b). This study was therefore set up to evaluate their growth and yield response to row intercropping arrangement with maize in the Guinea savanna zone under rain-fed conditions.

MATERIALS AND METHODS

Experimental design and treatments

The experiment was laid out in randomized complete block design with four replicates and six treatments. The three new groundnut varieties (Jenkaar, Kpanieli and Nkosuor) were intercropped with maize (*Obatanpa* variety) under different row intercropping arrangements. The treatments evaluated were:

1. Sole maize planted at 60 x 40 cm giving plant population density of 41, 667 plants per hectare.
2. Sole groundnut planted at 30 x 15 cm (Konlan et al., 2013a) giving plant population density of 222,222 plants per hectare.
3. G1M1: 1 row of groundnut (90 x 15 cm) alternated with 1 row of maize (90 x 40 cm) giving a final plant population of 74,074 groundnut plants / ha and 27, 778 maize plants / ha.
4. G2M1: 2 rows of groundnut (67.5 x 15 cm) alternated with 1 row of maize (135 x 40 cm) giving final plant population of 98, 765 groundnut plants / ha and 18, 518 maize plants / ha.
5. G1M2: 1 row of groundnut (165 x 15 cm) alternated with 2 rows of maize (82.5 x 40 cm) giving a final plant population of 40, 404 groundnut plants / ha and 30, 487 maize plants / ha.
6. G2M2: 2 rows of groundnut (105 x 10 cm) alternating with 2 rows of maize with maize (105 x 40 cm) giving a plant population of 95, 238 groundnut plants / ha and 23, 809 maize plants / ha.

A single plough operation, followed by a single harrowing was carried out using a tractor prior to lining and pegging. Two seeds and one seed per hole respectively of maize and groundnut were planted on flats and the first weeding done with a hand hoe 4 weeks after sowing (WAS). 60 kg N / ha of NPK (23:10:5) was applied to the maize plants 2 WAS. The fertilizer was placed in holes drilled closed to the maize plants and covered with soil. A top dressing of 50 kg Sulphate of Ammonia per hectare was applied to the maize at 6 WAS just after the second weed management operation using the same localized placement method.

Growth parameters and yield measurements

Plant stand and height

Plant stand (m^2) data was taken 2 WAS. All plants within the net plots were counted and subjected to square root transformations to obtain plant stand per every 4 m^2. Five plants of each net plot were randomly selected and identified with a tag. Heights of these selected plants were monitored at two weeks interval from 4 to 8 WAS in both years. The height of each plant was measured using a measuring tape. Measurement was done from the ground level to the tip of the longest leaf blade or tassel (maize) or the tip of the apical meristem for groundnut.

Leaf area index

Five groundnut plants from each border rows were cut at the ground level and all the leaves stripped. The fresh leaves were weighed (W_f) and the weights recorded. Fifty leaf discs of the fresh leaves were made using a 1.0 cm diameter cork borer. These were also weighed (W_b). Since the diameter of the cork borer was known, the area of each leaf disc was estimated as:

$$A = \pi r^2$$

The total area of 50 leaf discs was then determined to be the product of the area of one disc and the number of discs in cm^2. By relating the area of 50 discs to the weight, it was possible to calculate the leaf area as W_f / W_b x area of leaf discs. The LAI of groundnut was then calculated as the ratio of the total leaf area and the area of ground space covered by each plant as described by Watson (1952).

The lengths and breadths at the widest portions of the leaves of five maize plants randomly selected and tagged from each maize plot were also measured. The product of the length and breadth gave the leaf area, which was then multiplied by a factor of 0.75 as described by Kamprath and Moll (1977) to get the total leaf area. The ratio of the total leaf area and the area of ground space covered by each plant gave the LAI (Watson, 1952).

Table 1. Plant stands of groundnut and maize as affected by intercropping and row arrangement two weeks after sowing.

Int. partner	Groundnut stand (m^2)		Maize stand (m^2)	
	2007	2008	2007	2008
Sole crop	4.3	4.4	2.1	2.0
Maize/Jenkaar	2.2	2.3	2.0	2.0
Maize/Kpanieli	2.0	2.2	2.0	2.0
Maize/Nkosuor	2.1	2.0	2.0	2.0
Lsd $_{0.05}$	1.4	0.2	ns	ns
Row pattern				
G1M1	2.9	3.1	4.2	4.1
G2M1	4.3	4.4	4.0	4.0
G1M2	2.4	3.2	3.8	3.7
G2M2	4.0	4.2	3.0	3.1
Lsd $_{0.05}$	ns	ns	0.3	0.3

Plant stand means are square root transformations. G1M1, 1 row groundnut, 1 row maize; G2M1, 2 rows groundnut, 1 row maize; G1M2, 1 row groundnut, 2 rows maize; G2M2, 2 rows groundnut, 2 rows maize, Int partner, intercrop partner.

Yield and yield components

Yield data collected included number of seeds per pod, number of pods per plant, mean (100) seed weight, shelling outturn (%) and dry pod yield (t ha^{-1}). To determine shelling outturn, pods and cobs from the five randomly tagged groundnut and maize plants respectively were each put in open bags and air dried thoroughly to a moisture level of 13 % before shelling. These were then weighed before shelling (Wp and Wc respectively). After shelling, the shelled seeds were weighed and recorded. The shelling percentage was determined as the weight of groundnut seed (Ws) divided by weight of pods (Wp).

Shelling outturn (%) = $\frac{Ws}{Wp}$ x 100 for groundnut

Where, Ws = weight of groundnut seed, and Wp = weight of groundnut pods

In the case of the maize, shelling outturn was determined as the weight of maize seed (Ws) divided by weight of cobs (Wc), thus;

Shelling outturn (%) = $\frac{Ws}{Wc} \times 100$

Where, Ws = weight of maize seed, and Wc = weight of maize cobs

Land equivalent ratio

The Land Equivalent Ratios (LER) of the groundnut and maize intercropping systems were calculated by expressing the intercrop grain yield as a ratio of the sole crop grain yield. This was done following the procedure described by Wiley and Osiru (1972) as;

$$LER = L_a + L_b = \frac{Ya}{Sa} + \frac{Yb}{Sb}$$

Where, L_a and L_b are LERs of crop variety a and b; Y_a and Y_b are the individual crop yields in the intercrops, and S_a and S_b are the sole crop yields.

By this procedure, a partial LER for each crop component was obtained. To determine the total LER, the partial LERs of the component crops were added.

RESULTS

Plant stand, height and leaf area index

Intercropping groundnut with maize significantly (α = 0.05) reduced the population densities of both crops compared to their respective sole systems (Table 1). The overall maize densities were not significantly affected by intercropping compared to groundnut whose population density was significantly reduced. Row arrangement was also not found to significantly (α = 0.05) influence groundnut population density (Table 1) although plant arrangement that favoured more rows of groundnut resulted in relatively higher plant densities for groundnut. Densities of maize was however significantly (α = 0.05) influenced by row arrangement with higher densities resulting from the G1M1 and G2M1 arrangement which were significantly (α = 0.05) different from the densities recorded by the G2M2 arrangement in both years (Table 1). The height of groundnut varieties were not significantly (α = 0.05) influenced by intercropping them with maize as well as by the row arrangement at 4 WAS (Table 1). At 6 WAS, intercropping significantly (α = 0.05) reduced the height of the Jenkaar and Nkosuor varieties. Intercropped Kpanieli which recorded similar height as the sole groundnut crop was also found to be significantly taller (α = 0.05) than plants of intercropped Jenkaar and Nkosuor (Table 2). At 8 WAS, height of intercropped Jenkaar and Nkosuor were similar to the sole crop all of which were significantly (α=0.05) shorter than the intercropped

Table 2. Groundnut and maize height at 4, 6 and 8 weeks after sowing as affected by intercropping and row arrangement.

Int. partner	Groundnut height (cm)						Maize height (cm)					
	2007			2008			2007			2008		
	4 WAS	6 WAS	8 WAS	4 WAS	6 WAS	8 WAS	4 WAS	6 WAS	8 WAS	4 WAS	6 WAS	8 WAS
Sole crop	9.0	19.2	33.2	8.5	28.3	47.5	45.4	88.8	194.5	39.5	139.1	192.1
Maize/Jenkaar	8.5	17.9	33.4	7.1	20.5	35.8	37.6	97.8	182.1	38.8	125.5	169.8
Maize/Kpanieli	9.0	19.7	39.4	7.9	29.2	48.9	43.6	96.7	182.5	38.2	134.2	175.9
Maize/Nkosuor	8.6	18.4	34.1	7.4	20.6	36.5	44.7	98.0	180.4	38.8	121.1	167.8
Lsd $_{0.05}$	ns	1.5	3.1	ns	5.3	9.7	ns	ns	ns	ns	ns	ns
Row pattern												
G1M1	9.6	21.8	39.3	7.1	23.8	39.2	44.4	97.8	191.7	38.1	128.3	165.1
G2M1	8.2	18.5	34.8	6.9	17.8	30.3	42.1	95.8	179.2	35.3	126.9	164.4
G1M2	8.8	20.7	37.8	7.2	21.3	36.5	45.7	94.0	185.4	35.2	136.3	169.5
G2M2	8.0	18.5	35.1	7.8	18.3	35.6	45.8	98.6	188.5	35.8	126.3	165.7
Lsd $_{0.05}$	ns	1.7	0.7	ns	2.7	2.3	ns	ns	ns	ns	ns	ns

WAS, weeks after sowing; G1M1, 1 row groundnut, 1 row maize; G2M1, 2 rows groundnut, 1 row maize;, G1M2, 1 row groundnut, 2 rows maize; G2M2, 2 rows groundnut, 2 rows maize; cm, centimeters; Int partner, intercrop partner.

Kpanieli (Table 2). Row arrangement did not significantly (α = 0.05) influence groundnut height at 4 WAS in both years (Table 2). At 6 and 8 WAS in both years, a single row of groundnut alternated with single row maize (G1M1), and single row groundnut alternated with double row maize (G1M2) recorded similar height measurements both of which were significantly (α = 0.05) different from the double row groundnut alternated with single (G2M1) and double (G2M2) row maize. The height of maize plants in both years was not significantly (α = 0.05) influenced by either intercropping with the groundnut varieties or row arrangement (Table 2).

Leaf area indices of groundnut varieties were significantly (α = 0.05) reduced by intercropping with maize (Table 3). All intercropped groundnut varieties recorded significantly (α = 0.05) smaller LAI compared to the sole groundnut crop at 4, 6 and 8 WAS in both years (Table 3). Also, the LAI of intercropped Kpanieli was significantly (a = 0.05) larger than those of intercropped Jenkaar and Nkosuor during the three data collection occasions in both years. Leaf area indices of the groundnut varieties were significantly (α = 0.05) improved by double groundnut row intercropping (G2M1 and G2M2) which were found to be significantly larger at 4, 6 and 8 WAS in both years than the single groundnut row (G1M1 and G1M2) intercropping (Table 3). Maize leaf area index was not influenced by intercropping or row arrangement in both years (Table 3).

Yield, yield components and correlations

The number of seeds per pod of groundnut varieties was not significantly influenced by either intercropping or row arrangement (Table 4). The number of pods per plant of the intercropped Kpanieli was similar to that of the sole groundnut, both of which were significantly (α = 0.05) higher than that recorded for Jenkaar and Nkosuor (Table 4).

The two double row groundnut arrangement improved the number of pods per plant significantly (α = 0.05) when compared to the single row arrangements. The mean seed weights of the intercropped groundnut varieties were all similar and significantly lower than that of the sole groundnut in both years. The two double row groundnut arrangement also significantly (α = 0.05) improved mean seed weight compared to the single row arrangements in both years (Table 4). Also, shelling outturn of all groundnut varieties were significantly reduced by intercropping with maize in both years. The shelling outturn of the Kpanieli variety was however, found to be significantly (α = 0.05) higher than that of the Nkosuor variety in both years. Like mean seed weight, shelling outturn was favoured by the double groundnut row arrangement which recorded significantly (α = 0.05) higher values compared to the single groundnut row arrangement (Table 4). Intercropping groundnut varieties with maize significantly reduced the pod yield of the varieties in both years. Pod yield of the Kpanieli variety was also found to be significantly (α = 0.05) higher than those of the Jenkaar and Nkosuor varieties. The yield differences between the Jenkaar and Nkosuor varieties were also significant (α = 0.05). Following the pattern of mean seed weight and shelling outturn, double row (G2M1 and G2M2) groundnut arrangement resulted in significantly higher (α = 0.05) pod yields when compared to the single (G1M1 and G1M2) row arrangements which recorded similar pod yield values (Table 4). Maize mean

Table 3. Groundnut and maize leaf area indices at 4, 6 and 8 weeks after sowing as affected by intercropping and row arrangement.

Int. partner	Groundnut LAI						Maize LAI					
	2007			2008			2007			2008		
	4 WAS	6 WAS	8 WAS	4 WAS	6 WAS	8 WAS	4 WAS	6 WAS	8 WAS	4 WAS	6 WAS	8 WAS
Sole crop	1.64	3.86	3.97	1.93	4.18	4.40	1.34	3.17	4.31	1.25	1.60	2.39
Maize/Jenkaar	1.22	2.04	2.85	1.43	2.45	3.10	1.37	2.86	3.32	1.32	1.64	2.44
Maize/Kpanieli	1.31	2.66	3.41	1.64	2.78	3.64	1.28	2.90	3.30	1.48	1.89	2.98
Maize/Nkosuor	1.21	2.03	2.84	1.46	2.45	3.10	1.23	3.10	3.55	1.39	1.75	2.35
Lsd $_{0.05}$	0.02	0.02	0.02	0.04	0.02	0.03	ns	ns	ns	ns	ns	ns
Row pattern												
G1M1	1.24	1.43	2.87	1.50	1.91	3.32	1.55	3.83	3.81	1.67	1.77	2.68
G2M1	1.30	2.70	3.71	1.62	3.22	4.03	1.47	3.80	3.69	1.71	1.81	2.48
G1M2	0.98	1.40	1.88	1.04	1.45	1.95	1.85	3.12	3.73	1.58	1.73	2.36
G2M2	1.33	2.81	3.71	1.55	3.21	3.72	1.53	3.26	3.53	1.66	1.82	2.59
Lsd $_{0.05}$	0.15	0.02	0.02	0.01	0.02	0.04	ns	ns	ns	ns	ns	Ns

LAI, leaf area index; WAS, weeks after sowing; G1M1, 1 row groundnut, 1 row maize; G2M1, 2 rows groundnut, 1 row maize;, G1M2, 1 row groundnut, 2 rows maize; G2M2, 2 rows groundnut, 2 rows maize; Int partner, intercrop partner.

Table 4. Groundnut yield and yield components as affected by intercropping with maize and row arrangement.

Int. Partner	Seeds pod^{-1}		Pods plant^{-1}		Pod yield (tha^{-1})		MSW (g)		Shelling outturn (%)	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
Sole groundnut	1.8	1.8	11.1	10.3	2.145	2.127	45.1	47.4	53.8	49.0
Maize/Jenkaar	1.8	1.8	8.2	9.1	0.834	0.824	43.5	44.7	45.3	44.3
Maize/Kpanieli	1.8	1.8	10.4	10.7	1.163	1.101	41.5	45.7	47.8	47.1
Maize/Nkosuor	1.8	1.8	8.7	9.3	0.732	0.703	41.2	44.2	43.8	43.9
Lsd $_{0.05}$	ns	ns	2.7	1.7	0.35	0.12	1.5	2.9	3.3	1.8
Row pattern										
G1M1	1.7	1.8	9.6	9.1	0.665	0.618	42.1	42.4	42.8	41.3
G2M1	1.7	1.8	9.7	9.8	0.926	0.928	43.7	45.4	47.4	47.2
G1M2	1.7	1.8	6.5	7.3	0.381	0.306	41.9	43.8	37.6	35.6
G2M2	1.7	1.8	9.6	9.1	0.431	0.400	43.6	45.7	48.3	47.3
Lsd $_{0.05}$	ns	ns	1.3	1.8	0.47	0.13	1.7	1.7	3.9	2.1

Seeds pod^{-1}, Number of seeds per pod); Pods plant^{-1}, number of pods per plant; tha^{-1} , tons per hectare; MSW, mean seed weight in grams; G1M1, 1 row groundnut, 1 row maize; G2M1, 2 rows groundnut, 1 row maize;, G1M2, 1 row groundnut, 2 rows maize; G2M2, 2 rows groundnut, 2 rows maize; Int partner, intercrop partner.

seed weight was not significantly (α = 0.05) influenced by either intercropping or row arrangement in both years (Table 5). Grain yield of maize was significantly (α = 0.05) reduced by intercropping with the groundnut varieties (Table 5). The G1M2 and G1M2 row arrangements produced similar yields both of which were significantly (α = 0.05) higher than the yields recorded by the G2M1 and G2M2 row arrangements (Table 5).

The number of pods per plant and ultimately dry pod yield were positive and strongly correlated to groundnut leaf area index in 2007 (Figures 1a and 1b) and 2008 (Figures 2a and 2b). Maize grain yield also showed strong and positive correlations with plant population densities in both years (Figure 3a and 3b) although yield indices were unaffected by either intercropping or row arrangement.

Land equivalent ratio

Land equivalent ratios (LER) ranged between 1.01 and 1.11 in 2007 and 0.96 and 1.11 in 2008 as a result of

Table 5. Maize yield and yield components, and land equivalent ratio as affected by intercropping and row arrangement.

Int. partner	MSW (g)		Shelling outturn (%)		Grain yield (tha^{-1})		LER	
	2007	2008	2007	2008	2007	2008	2007	2008
Sole maize	32.3	32.1	79.0	77.3	3.220	3.920	-	-
Maize/Jenkaar	32.7	33.1	79.2	78.0	2.305	2.117	1.10	0.98
Maize/Kpanieli	33.5	32.6	81.4	77.9	2.476	2.115	1.11	1.11
Maize/Nkosuor	33.3	33.3	79.5	78.1	2.375	2.190	1.01	0.96
Lsd $_{0.05}$	ns	ns	ns	ns	0.31	0.47		
Crop pattern								
G1M1	33.8	34.2	79.7	76.7	2.876	3.056	1.10	1.11
G2M1	32.5	32.2	80.4	78.1	1.476	1.720	0.97	0.84
G1M2	33.0	32.5	80.4	80.6	2.718	2.867	1.14	1.12
G2M2	33.1	33.1	79.7	76.7	1.182	1.453	1.08	0.99
Lsd $_{0.05}$	ns	ns	ns	ns	0.39	0.44		

MSW, mean seed weight; tha^{-1}, tons per hectare; LER, land equivalent ratio; G1M1, 1 row groundnut, 1 row maize; G2M1, 2 rows groundnut, 1 row maize;, G1M2, 1 row groundnut, 2 rows maize; G2M2, 2 rows groundnut, 2 rows maize; Int partner, intercrop partner.

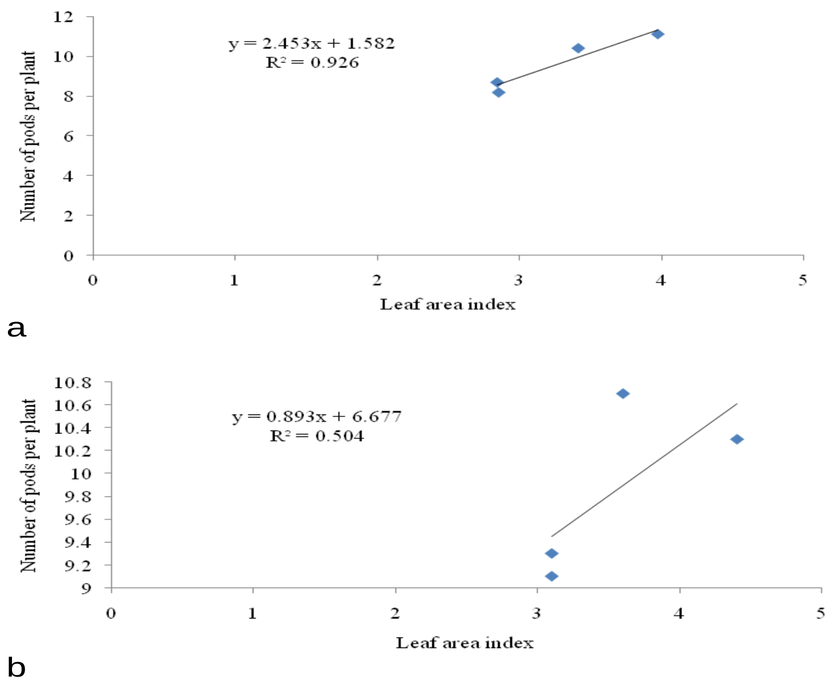

Figure 1. The relationship between groundnut leaf area index and number of pods per plant in 2007 (a) and 2008 (b) was strong and positive in both years.

intercropping groundnut and maize (Table 5). In both years, the highest LER was recorded by the Kpanieli-maize intercrop. Row arrangement with its consequences ranging from 0.97 to 1.14 in 2007 and 0.99 to 1.12 in 2008. Land equivalent ratios greater than 1 was achieved in both years by the G1M1 and G1M2 row intercropping (Table 5), highlighting the contribution of maize yield to LER in the intercrop.

DISCUSSION

Intercropping generally resulted in reductions in both groundnut and maize population densities with a simple

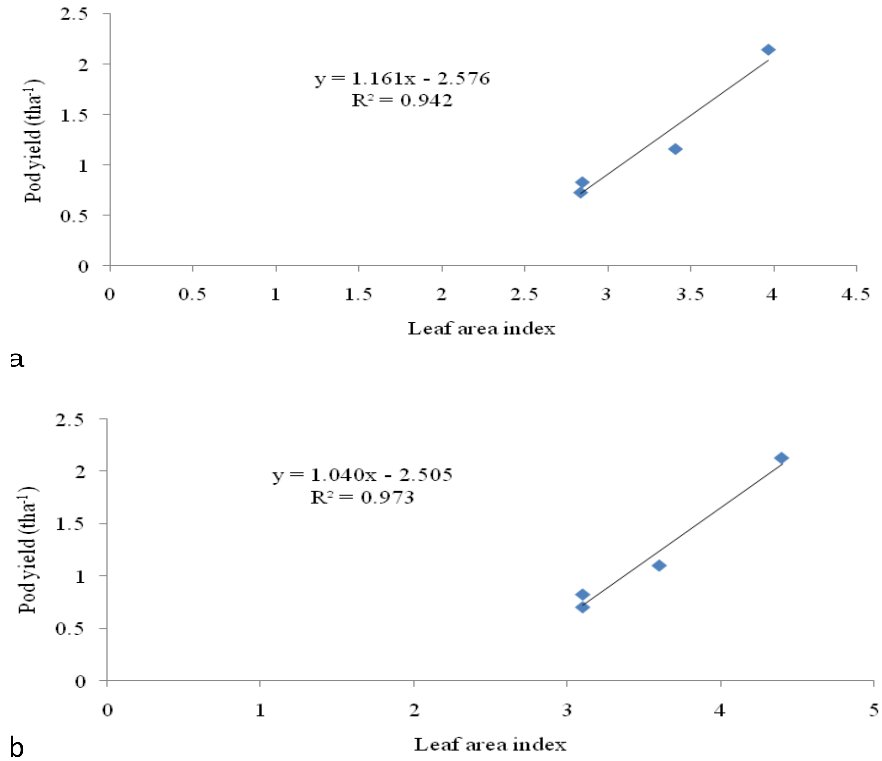

Figure 2. The relationship between groundnut leaf area index and dry pod yield in 2007 (a) and 2008 (b) shows that dry pod yield responded positively and strongly to increases in groundnut leaf area index. (tha^{-1}, tons per hectare).

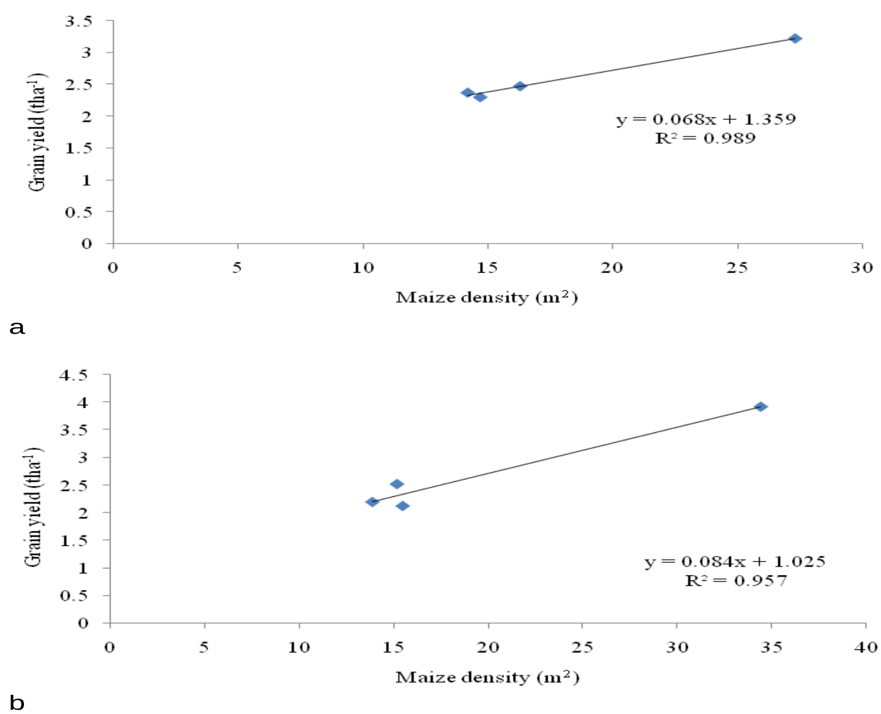

Figure 3. The relationship between maize population density and grain yield (tha^{-1}) in 2007 (a) and 2008 (b) shows that grain yield responded positively and strongly to increases in maize population density in the intercrop in both years.(tha^{-1}, tons per hectare; m^2, square metres).

inverse relationship between the population densities of the two crops. This was so because the population densities of both crops could not be increased at the same time in the planting pattern evaluated (Molatudi and Mariga, 2012**;** Siddig et al., 2013; Mehdi, 2013). The lack of differences in the height of intercropped and sole groundnut crop were probably because of a strong influence on height by the genotypes which was not significantly influenced by the modified environment due to the presence of the taller and potentially shading maize.

Also maize shade was not so dense as to elicit vigorous vertical growth by the groundnut varieties. Consequently, row arrangement in the groundnut-maize intercrop that allowed more sunlight to penetrate encouraged relatively shorter plants. On the other hand, a single row of groundnut embedded between single and double rows of maize with relatively reduced aerial space and light penetration produced relatively taller plants in response to a relatively more dense shade by the maize plants (Konlan et al., 2013a).

The reduction in leaf area indices of intercropped groundnut was probably as a result of reduced photosynthesis due to the shading effect of the maize plants. Less dry matter was therefore available to support new leaf production and development, leading to reduced LAI in the intercropped groundnut compared to its sole counterpart in both years (Dalley et al., 2004). The behaviour of the intercropped Kpanieli which supported larger LAI and taller plants compared to the other two varieties in both years was probably a varietal characteristic (Ahmad and Mohammad, 1997). In spite of the fact that groundnut-maize intercropping led to significant reductions in groundnut LAI, row arrangements that allowed in more sunlight supported groundnut LAI that were similar to the sole groundnut crop in both years.

This suggests that sunlight availability was critical for photosynthate production and played a major role in the formation of leaves and development of larger LAI which then supported more photosynthesis (Dalley et al., 2004).The lack of differences in the number of seeds recorded per pod was probably due to the fact that it is controlled by the plant genotype (Ahmad and Mohammad, 1997) and was not influenced by intercropping with maize.

The number of pods per plant was however easily influenced by modification of the crop environment due to intercropping, suffering significantly from limited light reception and nutrient availability. This probably led to the Jenkaar and Nkosuor varieties suffering reduced number of pods per plant in both years. The generally reduced LAI of intercropped groundnut which might have affected dry matter production and hence the availability of assimilates for pod production and filling probably led to the lower mean seed weights and shelling outturn recorded by the intercropped groundnut varieties compared to their sole crop. However, row arrangement in the intercrop that allowed more ground space and light penetration led to formation of larger LAI and supported higher number of pods per plant, mean seed weight and shelling outturn in both years. This could be attributed to reduced competition for nutrients and potentially higher photosynthetic rates resulting in the availability of dry matter for pod formation and filling (Ahmad et al., 2007). The intense competition experienced by the groundnut varieties in the groundnut-maize intercrop which affected the yield components translated into reduced dry pod yields in both years. On the other hand row arrangement that made more space available to the groundnut, potentially increased groundnut population density in the intercrop while at the same time reducing competition for nutrients and allowing the interception of more Photosynthetically active radiation (PAR), leading to higher dry pod yields.

The lack of differences in height of maize under the different row intercropping arrangements was probably due to the absence of significant competition as a result of intercropping with the groundnut. This could be attributed to the fact that the groundnut varieties probably supplied their own nitrogen requirement through biological nitrogen fixation (Giller, 2001) and did not need to compete with the maize for the available nitrogen (Francis, 1986; Rwamugira and Massawe, 1990). Also, the relatively shorter groundnut plants in the intercrop meant that they were growing below the maize plants, effectively removing competition for light. Maize LAI was therefore unaffected by either intercropping or row arrangement in the intercrop.

Maize yield was however, directly proportional to the maize population density, with row arrangement favouring higher maize population densities producing higher seed yield in both years. In the groundnut, row arrangement giving larger LAI resulted in higher number of pods per plant and larger dry pod yield in both years. This was probably because such large leaf areas in groundnut is known to intercept more incident solar radiation for photosynthesis, which then makes assimilates available for pod formation and pod filling (Ali and Malik, 1992; Wells et al., 1993; Jaaffar and Gardner, 1988). Even though increase in the population of maize plants per unit area has been shown to reduce individual plant yield, the additional plants per square metre probably more than compensated for the reduction in the yield of individual plants, leading to higher grain yield when maize population density was increased. The higher LER obtained from the Kpanieli-maize intercrop was basically due to the higher pod yield of the Kpanieli groundnut variety in the intercrop since maize yield when intercropped with the other groundnut varieties were similar. The relatively higher maize yield obtained from the G1M1 and G1M2 row intercropping arrangement was the major determining factor leading to the achievement of land equivalent ratios greater than 1 by the two treatments in both years.

Conclusion

In cropping systems where groundnut-maize intercropping is considered in the Guinea savanna zone of Ghana, it would be more beneficial to choose the Kpanieli groundnut variety and establish the intercrop in either a single row groundnut (90 x 15 cm) alternated with single row maize (90 x 40 cm) or single row groundnut (165 × 15 cm) alternated with double row (82.5 x 40 cm) maize.

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