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Influence of Spatial Arrangement on Agronomic Performance of Maize (Zea Mays L.) - Groundnut (Arachis Hypogea) Intercropping

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Abstract:
A field study was conducted to evaluate the most appropriate spatial arrangement of intercropping the legume into the cereal using two crops namely maize and groundnut. The groundnut was intercropped in to the maize in two different arrangement at the university of Ghana farm during the major season of 2010.The spatial arrangement were : one row of groundnut after one row of maize (1:1) and two row of groundnut after one row of maize (1:2).Non-intercropped plots served as control. A randomised complete block design was used and replicated four times. Plant growth was evaluated every two weeks by measuring the dry weight of biomass. Other data collected were: Plant height, growth rate, day to tassel, days to flower, chlorophyll content, land equivalent ratios, Leaf area index, yield and yield components. The present study revealed that in terms of the spatial arrangement, the grain yield of groundnut from double row (1:2) performed better than the single row of groundnut (1:1) because of crop complementarities however with regard dry matter accumulation, the 1:2 spatial arrangement for the groundnut produced less than the 1:1, however sole maize performed better than both spacing. In the case of the maize, sole maize produced highest grain yield, dry matter accumulation, leaf area index, height at maturity and harvest index. Land equivalent ratios (LER),the LER values for the intercrops were more than 1.0.This value implies that the intercrops had yield advantage over the sole crops. The intercropping of the groundnut 1:2 spatial arrangement gave the highest LER of 3.39 and for the 1:1 spatial arrangement gave 1.48. The results therefore suggest that in groundnut-maize intercropping system both 1:2 spactial arrangement is best however this will depend largely on crop interested in by the farmer.

Keywords: *inter-cropping, maize, groundnut, spatial arrangement*

1. Introduction

Intercropping is the practice of growing more than one crop simultaneously in alternating rows on the same field (Beets 1990). Intercropping is a popular cropping system among small-scale farmers in the tropics (Snaydon and Harris, 1979 ;) and has for long been practiced in many countries of Africa, India and China (Fawusi, 1985) in order to maximize yield per unit of land. According to Norman (1977), farmers generally give four principal reasons for intercropping which are; (1) Tradition, (2) The need for security, (3) The need to maximize the return from a factor which is limiting such as labor and (4) Beneficial effects of legumes on other crops. Andrew (1974) also reported that intercropping reduces damage caused by pests and diseases and hence ensure greater yield stability. There is the possibility that competition between crops could offer some solutions to weed control (Schoonhoven and Voysest, 1993). It has also been reported that intercropping has proved to be superior to its single component crops in weed suppression (Bantilan and Harwood, 1973; Shetty and Rao, 1979) and thus, it provides an opportunity to utilize the crops themselves as tools for weed management. Delicate or light sensitive plants may be given shade or protection, or otherwise wasted space can be utilized. Maintaining soil fertility is often one of the main challenges in agricultural production and intercropping is one of the options available to maintain soil fertility and crop yields. An example is the tropical multi-tier system where coconut occupies the upper tier, banana the middle tier, and pineapple, ginger, or leguminous fodder, medicinal or aromatic plants occupy the lowest tier. When crops are carefully selected, other agronomic benefits are also achieved. Lodging-prone plants (those that are prone to tip over in wind or heavy rain) may be given structural support by their companion crop (Trenbath, 1976). Where intercropping systems have been studied in West Africa, the findings as a whole indicates that there are yield advantages over the component crops grown as sole crops (Fussel and Serafini, 1985). The main reasons for higher yields in intercropping is that the component crops are able to use natural resources differently and make better overall use of natural resources than grown separately (Willey, 1979). Ofori and Stern (1987) reported that intercropping produce higher and suitable yield in a wide range of component combination. Traditional intercropping systems cover over 75% of the cultivated area in the Semi-Arid Tropics (Steiner 1984).

Intercropping legumes with non-legume is an important feature of many cropping systems in the tropics (Willey, 1979). The mixture of nitrogen fixing crop and non fixing crop give greater productivity than monocropping (Seran and Brintha, 2009). Banik and Sharma (2009) reported that cereal-legume intercropping systems were superior to monocropping. Intercropping of legumes and cereals is an old practice in tropical agriculture that date back to ancient civilization. Snaydon and Harris (1979) found legume-cereal is the most popular intercropping system in the tropics. Intercropping legumes with cereals is the most predominant cropping system in the savanna zone of West Africa (Fisher, 1979). Hardarson and Atkins (2003) found legume-cereal intercropping increase the fixation of nitrogen by legumes. In a legume intercrop, according to Aggarwal *et al.,* (1992), nitrogen leaking from the leaves and decomposition of the legume leaves can result in nitrogen transfer from the legumes to associate crop. Similarly, intercropping affects soil fertility maintenance through nitrogen fixation and differential uptake of nutrients (Reddy *et al.,* 1985). Legume intercrops are potential sources of plant nutrients that complement/supplement inorganic fertilizers. Legume intercrops are included in cropping systems because they reduce soil erosion and suppress weeds (Exner and Cruse, 1993), and fix biological N (Giller, 2001). In addition, certain legume crops can provide food to humans and or livestock. Carruthers *et al.,* (1998) reported that intercropping corn with legumes is an alternative to corn monocropping and is a possible way to reduce the use of inputs, such as herbicides, while maintaining current weed control levels. Systems that intercrop maize with a legume are able to reduce the amount of nutrients taken from the soil as compared to a maize monocrop. During the absence of nitrogen fertilizer, intercropped legumes will fix nitrogen from the atmosphere and not compete with maize for nitrogen resources (Adu-Gyamfi *et al*. 2007). Maize-french bean gave high maize equivalent yield over sole maize yield (Hugar and Palled, 2008) and kernel yield of maize was unaffected in maize-french bean intercropping (Pandita, 2001) and this finding agree with Hugar and Palled (2008). Many studies of maize/groundnut intercropping have shown that the quantity of N fixed by the legume depends on the density and the system of intercropping (Rerkasem and Rerkasem, 1988). Akinnifesi *etal*., (2006) revealed that without nitrogen fertilizer application, gliricidia-maize intercropping system gave high maize yield. West and Griffith (1992) observed maize yield was increased by 26% in maize-soybean strip intercropping. This was supported by Ghaffarzadeh *et al*. (1994). Tsubo *et al*. (2005) found in maize-bean intercropping that maize yield was not affected by the intercropping. Willey and Osiru (1972) and Dagnew (1981) indicated bean and maize yield reduction when plant population density is lowered in intercropping. Vesterager *et al.* (2008) found maize and cowpea intercropping is beneficial on nitrogen poor soils. Maize-cowpea intercropping increases the amount of nitrogen, phosphorous and potassium contents compared to mono crop of maize (Dahmardeh *et al.,* 2010). Suryanta and Harwood (1976) reported that nutrient uptake and utilization are more efficient in corn-rice and corn-soybean intercrops than in those crops as monocrop.

During an investigative research of the intercrop of an 82-day millet and 105-day groundnut, where the intercrop row arrangement was 1 millet: 3 groundnuts and the within-row spacing of each crop was the same in sole crop and intercrop. Calculated on the basis of a Land Equivalent Ratio (LER) intercropping gave 26% more reproductive yield (LER = 1.26) than growing the two crops separately; both these yield increases were statistically significant. The higher intercrop yield appeared to be achieved by an increased efficiency in converting light energy into dry matter and not by any increase in the amount of light energy intercepted. It is suggested that this increased efficiency may have been because the combined intercrop canopy resulted in light being more efficiently spread over a greater surface of leaf (Reddy and Willey 1980).Dry matter yield accumulation of individual maize plant decreases with increases in bean plant population and competitive effect is biggest at the highest level in an arrangement of one row of maize for three rows of beans (Morgado and Willey, 2003). Willey (1979) observed better use of light, nutrients as well as fixed nitrogen in legume-cereal intercropping system. According to Fussel and Serafini (1986), in an intercropping system, the associated crops with contrasting growth habit permit them to exploit time, rainfall and other resources better. The choice of compatible crops for an intercropping system depends on plant growth habit, land, light, water and fertilizer utilization (Brintha and Seran, 2009).

Yamada (1974) reported that on the basis of reproductive yields, all the intercropping systems: millet/groundnut systems, the sorghum/millet system showed some increase in relative advantages with increase in stress because of higher harvest indices in intercropping than in sole cropping. This was in agreement with beneficial effects of nitrogen as reported by Lindemann and Glover (2003), Bliss and Hardarson (1993), and Gomez and Gomez (1983). They also reported significantly higher ($P<0.05$) number of pods/plant, pod yield and seed yield/ha in groundnut when monocropped, were consistent with the findings of Ossom and Nxumalo (2003). Mkandawire and Sibuga (2002) observed that increasing the plant population density reflected negatively on pod yields.

Silwana and Lucas (2000) reported different crop species in mixtures increased capture of growth limiting resources and Andrews (1972) stated that different planting time of component crops improve the resource utilization and reduce the competition. The partitioning of limiting resources among crop plants occurs whenever plants are grown in association (Blade *et al.,* 1997).

Under normal conditions cereal-legume intercropping uses water equally (Ofori and Stern, 1987). Morris and Garrity (1993) found that water-utilization efficiency by intercrops greatly exceeds water-utilization efficiency by sole crops, often by more than 18% and by as much as 99%. Willey (1979) stated cereal-legume use water more efficiently than monocropping. Barhom (2001) reported that water use efficiency was the highest under soybean-maize intercropping compared with monocropping maize and monocropping soybean. Having a variety of root systems in the soil reduces water loss, increases water uptake and increases transpiration. The increased transpiration may make the microclimate cooler, which, along with increased leaf cover, helps to cool the soil and reduce evaporation (Innis 1997). This is important during times of water stress; as intercropped plants use a larger percentage of available water from the field than monocropped plants. Intercropping between high and low canopy crops is a common practice in tropical agriculture and to improve light interception and hence yields of the shorter crops requires that they be planted between sufficiently wider rows of the taller ones. Soybean and maize intercropping has been attributed to better use of solar radiation (Keating and

Carberry, 1993), nutrients (Willey, 1990) and water (Morris and Garrity, 1993) over the mono crop. When two morphologically dissimilar crops with different periods of maturity are intercropped light is the vital factor that determines the yield (Willey, 1979). Competition of light affected the plant height in capsicum-bushitao intercropping (Jeyakumaran and Seran, 2007).

It has generally been observed that crop plants spacing and arrangement have considerable influence on the yield of an intercrop. Giayetto *et al.,* (1998) reported that vegetative growth was sensitive to spacing effect. At an individual plant level, dry matter and leaf area decreased significantly because of the greater intraspecific competition produced by the shortening of distances between rows (from 0.70 to 0.30 m) and between plants (from 0.12 to 0.06 m) and the corresponding density increased from 12 to 56 plants/m2. However, at a population level, most compact spacing's produced more dry matter per surface and leaf area index. This also is related to the lesser time required for plants at these spacings to achieve a radiation interception higher than 90%. Dry matter distribution did not vary with sowing spacing. The number of branches per plant was reduced with the increase of density. Stand density affects plant architecture, alters growth and developmental patterns and influences carbohydrate production and partition (Casal, *et al.,* 1985). Maize is more sensitive to variations in plant density than other members of the grass family (Almeida & Sangoi, 1996). Higher plant densities of maize affect leaf area index (LAI), grain yield, ear size and yield negatively (Wiyo *et al.,* 1999). Furthermore, on the other hand, the use of high populations heightens interplant competition for light, water and nutrients. This may be detrimental to final yield because it stimulates apical dominance, induces barrenness, and ultimately decreases the number of ears produced per plant and kernels set per ear (Sangoi & Salvador, 1998). Hashemi *et al.,* (2005) reported the highest biological yield from 90000 plants ha-1as against 60000 and 30000 plants/ha. Ammanullah *et al.,* (2009) also reported higher biological yield at higher plant populations.

Karunatilake *et al*. (2000) who reported higher stem and root biomass in tilled plots as compared to zero tillage explained that increase in biological yield at higher plant population might be due to increase in number of plants as well as in plant height of individual plants at denser populations.

Ofori and Stern (1987b); Henriet *et al.* (1997); Russell and Caldwell (1989) working on cereal/legume intercropping noted that higher density of maize in intercropping shaded the cowpea, caused by higher maize height, and reduced cowpea growth. These were severe in the 2rowsM:4rowsC pattern and maize density at 40 000 plants ha-1.

Takatlidis and Koutroubas, (2004) found that maize plants at lower planting density tended to flower and mature earlier than those planted at higher density. Hashemi - Dzefouli and Herbert (1992) working on maize also reported similar results. Delay in flowering periods due to plant stress were also reported by Muchow (1989) working on maize, where four days' differences were observed in plants that were under stress. Modiba (2002), working on maize, also indicated that stress on a maize plant delayed flowering at Syferkuil. Rengel and Graham (1995) observed that stressed maize plants flower earlier. Mpangane (2001) observed that days to flowering and maturity of all cowpea cultivars did not differ between the sole and intercrops with maize. Ahmed and Rao (1981) observed that Intercropping delayed maize tasseling and silking by up to 2 days, but did not influence rate of soybean development.

In Ghana the spatial arrangement of legume-cereals intercrop has not been extensively investigated and as such legumes are intercrop with cereal as single row or double rows resulting in low yield and hence low income. It has generally been observed that crop plants spacing and arrangement have considerable influence on the yield of an intercrop. Kowal and Kassam, (1978) recommended investigations in to cereal-intercropping but emphasis placed on keeping the cereal population low and increasing that of groundnut. Thwala *et al*., (2004) observed groundnut intercropped with maize yielded higher than lima bean (Phaseolus lunatus) intercropped with maize, and supported the view that groundnut is more efficient than other legumes in nitrogen fixation ability (Yamada, 1974; Lindemann and Glover, 2003). Differences in intercropping systems are commonly based on differences in population of component crops (Wolfswinkel, 2006) and spatial arrangement of component crops (CSIR, 2005). Although groundnut and maize intercropping is a common practice in Ghana especially the Northern region, quantitative information is lacking on the productivity of the system, its influence on the component crops yield and yield components, and the performance of the component crops under various intercropping patterns. In addition, the effect of management such as intra-row spacing, on yield has not been determined (Yayock *et al.,* 1988). The need to explore alternative intercropping systems which are cheaper and have more space economy cannot be overemphasized.

The general objective of this study was to determine a suitable spatial arrangement of a maize/groundnut for optimal grain yield. The specific objectives were to:

1. determine the yield and yield components of the component crops
2. assess the land equivalent ratios of the groundnut and maize intercrop

2. Materials and Methods

2.1. Study Area

Field experiments was conducted on the University of Ghana farm, Legon. The experimental site is within the coastal Savannah zone, with annual mean rainfall of 750 mm and temperature of 26 ° C. The soil belongs to the Adenta series, ferric Acrisol. (FAO UNESCO, 1990). During the period of study (April-August), maximum mean rainfall was recorded in June (259.7 mm) whilst the minimum was recorded in August (42.1mm). Maximum temperature was 34.4 ^{o}C in April whilst the mean minimum temperature of 23.3 ^{o}C was for both July and August.

2.2. Experimental Design and Treatment

The Experiment was laid in a randomized complete block design (RCBD) with four replications. The planting material of the intercrop components were maize (Obaatampa) and groundnut (*Chinese*) (Morris *et al.,* 1999). The treatments consisted of sole maize; sole groundnut; Maize one row groundnut (1:1); Maize two rows groundnut.

2.3. Agronomic Practices and Data Collection

Inorganic compound fertilizer (15-15-15, NPK) was applied at 100kg/ha two weeks after planting and sulphate of ammonia fertilizer was applied at 50kg/ha six weeks after planting as side-dressing. The following data were collected on both maize and groundnut. Bi-weekly Plant height, growth rate, Chlorophyll content, Total leaf area and Leaf area index, Days to 50% tasseling (maize), Days to silking (maize), Days to 50% flowering (groundnut), Plant height at maturity, Pod number (groundnut), Maize grain yield (economic yield), Total Stover biomass yield (Biological yield-maize), Total haulm biomass yield (Biological yield-groundnut) and harvest Index.

3. Results

3.1 Growth of Component Crops in Maize-Groundnut Intercrop

3.1.1. Plant Height (cm) of Maize and Groundnut

Table 1 shows the plant height of groundnut at the different crop arrangement or plant population at 2, 4, 6 and 8 weeks after planting (WAP). At 2 weeks after planting, significant ($P<0.05$) differences were not observed among the treatments for groundnut plants (Table 1) however sole groundnut recorded the highest mean plant height of 5.17cm and the two rows groundnut recorded the shortest crop with a height of 3.76cm after that however, consistently the two rows groundnut produced the tallest crops through to the eighth week. The two rows groundnut recorded the highest mean plant height of 44.40cm whilst the Sole groundnut recorded the shortest crop with a height of 38.70cm at 8 weeks after planting. The two rows groundnut was significantly higher than the sole groundnut whilst one row groundnut showed no significant ($P<0.05$) differences with sole groundnut and two rows groundnut. At 4 weeks after planting, two rows groundnut recorded the highest plant height. The one row groundnut was significantly different ($P<0.05$) from all the others with the remaining treatment showing no difference between them. For the sixth week, sole groundnut and one row groundnut recorded high values of 34.26 and 30.99 respectively but are not significantly different ($P<0.05$) from each other. Treatments with one row groundnut two rows groundnut are not significantly different from each other however sole groundnut and two rows groundnut were significantly different from each other. Sole groundnut, with plant height 38.70 is the lowest recorded for the eighth week after planting and is not significantly different from one row groundnut. The two rows groundnut was significantly different ($P<0.05$) from sole groundnut. The two rows groundnut recorded the highest plant height with 44.04 for the eight week.

	Weeks after planting (WAP)			
Crop arrangement	**2**	**4**	**6**	**8**
1Maize:1 groundnut	3.85	16.48	30.99	42.13
1Maize:2 rows groundnut	3.76	23.26	26.35	44.04
Sole groundnut	5.17	21.46	34.26	38.70
LSD (P=0.05)	1.85	2.35	5.19	4.89

Table 1: Mean plant height (cm) of groundnut in maize-groundnut intercrop

The maize plants showed an increasing plant height during the period of growth from 2 weeks to 8 weeks after planting (Table 2). There were significant differences ($P<0.05$) among the treatments. At 2 weeks after planting, the treatments sole maize and maize with one row groundnut recorded the highest values of 18.23cm and 15.68cm respectively, which were significantly different ($P<0.05$) from each other and the sole maize with a value of 18.23cm. (Table 2).

At four weeks after planting, treatments maize with one row groundnut and maize with two rows groundnut show no significant difference among them, but are significantly different ($P<0.05$) from the others. Sole maize recorded the highest mean height with 56.20cm followed by maize one row groundnut with 37.75cm (Table 2). For week six, sole maize had the highest plant height (148.90cm). It is significantly different from maize with one row of groundnut and maize with two rows groundnut. Maize with one row groundnut and maize with two rows groundnut are insignificantly different ($P<0.05$). At week 8, sole maize, the sole maize again recorded the highest plant height of 183.10cm. It is significantly different ($P<0.05$) from all the other treatments. Treatments of maize with one row groundnut and maize with two rows groundnut are not different statistically. (Table 2).

	Weeks after planting (WAP)			
Crop arrangement	**2**	**4**	**6**	**8**
1Maize:1 groundnut	13.95	37.75	90.90	153.45
1Maize:2rows groundnut	15.68	35.55	84.40	155.25
Sole maize	18.23	56.20	148.90	183.10
LSD (P=0.05)	2.28	3.94	22.12	6.75

Table 2: Mean plant height (cm) of maize in maize-groundnut intercrop.

3.1.2. Growth Rate of Groundnut and Maize

There are significant differences (P<0.05) among the treatments for growth rate for both groundnut and maize. The two rows groundnut and the sole maize recorded the highest value of 22.26 and lowest value of 20.46 respectively but were significantly indifferent (P<0.05) from each other between two to four weeks of growth (Table 3). They are however significantly different from one row groundnut. For the four to six weeks of growth, there are significant differences between the sole groundnut and the two rows groundnut however treatments with one row groundnut and two rows groundnut show no significance (P<0.05) between them. The highest value is 33.26 for the sole groundnut and the treatment with the lowest value of 25.35 is one rows groundnut. The six to the eight week of growth also produced significant differences (P<0.05) between the two row groundnut and the sole maize. The two rows groundnut recorded the highest of 43.05 with Sole groundnut recording the lowest growth rate of 37.70. The treatments with one row groundnut and two rows groundnut are not significant different from each other (Table 3).

Crop arrangement	Growth rate (cm per week)		
	2 – 4 weeks	4 – 6 weeks	6 – 8 weeks
1Maize:1row groundnut	15.48	29.99	41.13
1Maize:2rows groundnut	22.26	25.35	43.05
Sole groundnut	20.46	33.26	37.70
LSD (P=0.05)	2.35	5.19	4.89

Table 3: Growth rate of groundnut in maize-groundnut intercrop

The maize plants produced significant figures for all growth rate stages (Table 4). The two to four weeks of growth had treatment of sole maize with the highest figure of 55.20 and maize with two rows groundnut with the lowest of 34.55. Sole maize is significantly different (P<0.05) from all other treatments (Table 4). The growth rate for four to six weeks also produced significant differences between the Sole maize and the other treatments. The four to six weeks of growth had treatment of sole maize with the highest figure of 147.90 and maize with two rows groundnut with the lowest of 83.40. Maize with one row groundnut and maize with two rows are not significantly different. For six to eight weeks of grow treatment maize with one row and maize with two rows groundnut are statistically the same. However sole maize recorded the highest value (182.10) whilst maize with one row groundnut recorded the lowest value of 152.45 (Table 4). The values of the growth rate for six to eight also show significant differences between the sole maize and the other treatments.

Crop arrangement	Growth rate (cm per week)		
	2 – 4 weeks	4 – 6 weeks	6 – 8 weeks
1Maize:1row groundnut	36.75	89.90	152.45
1Maize:2rows groundnut	34.55	83.40	154.25
Sole maize	55.20	147.90	182.10
LSD (P=0.05)	3.94	22.12	6.75

Table 4: Growth rate maize in maize-groundnut intercrop

3.1.3. Leaf Area Index of Groundnut and Maize

Table 5 shows leaf area index (LAI) of both groundnuts at the various growth stages. For groundnut, though the LAI increased consistently at all stages of growth under all treatments, no significant differences (P<0.05) existed among the LAI at each growth stage with the exception of week 2 (Table 5). Among the treatments, Sole groundnut performed significantly higher (P<0.05) than two rows and one row groundnut. The sole groundnut recorded the highest LAI with 0.51. There are no significant differences between one row groundnut and two rows groundnut (Table 5).

Crop arrangement	**Weeks after planting (WAP)**			
	2	**4**	**6**	**8**
1Maize:1row groundnut	0.29	0.93	2.78	4.50
1Maize:2rows groundnut	0.27	0.69	1.95	4.70
Sole groundnut	0.51	1.11	3.70	4.80
LSD (P=0.05)	0.17	NS	NS	NS

Table 5: Leaf area index of groundnut in maize-groundnut intercrop

The maize LAI increased consistently throughout the growth stages for all treatments. There are significant differences (P<0.05) among the treatments at all the stages of growth (Table 6). For 2 weeks after planting, maize with two row groundnut was significantly different from maize with one row groundnut but not different from sole maize. Maize with one row groundnut and sole maize are not significantly different. At four weeks, sole maize produced the highest LAI of 1.40 which was significantly different (P<0.05) from maize with one row groundnut. There are no significantly differences between sole maize and maize with two rows groundnut. There are also no significant differences (P<0.05) between maize with one row groundnut and maize with two rows groundnut. Six weeks after planting reveal that Treatment of Sole maize and maize with one row groundnut are significantly different (P<0.05). Sole maize recorded the highest LAI of 3.07 with one row groundnut recording the lowest with LAI 0.82. Consequently, the latter treatments are significantly different. For week 8, Sole maize recorded the highest LAI with 3.84 and maize with one row groundnut recorded the lowest LAI with 1.20. There is significant difference (P<0.05) between sole maize and maize with one row groundnut and maize with two row groundnut (Table 6). There is no difference between one row and two row groundnut.

Crop arrangement	Weeks after planting (WAP)			
	2	4	6	8
1Maize:1row groundnut	0.17	0.54	0.82	1.20
1Maize:2rows groundnut	0.33	0.92	2.38	2.11
Sole maize	0.20	1.40	3.07	3.84
LSD (P=0.05)	0.13	0.55	1.33	1.64

Table 6: Leaf area index of maize in maize-groundnut intercrop

3.1.4. Mean Chlorophyll Content of Groundnut and Maize Leaves

Results showed that there was no significant (P<0.05) differences among all the treatments for both groundnut and maize at the growth stages of two and four weeks after planting (Table 7). However, the figures revealed that those for four weeks are little higher than that of two weeks. There were differences among the values for each treatment for each week for both crops.

Crop arrangement	Groundnut		Maize	
	2WAP	4WAP	2WAP	4WAP
1Maize:1row groundnut	38.15	38.75	31.02	38.15
1Maize:2rows groundnut	37.01	39.19	29.40	37.01
groundnut / sole maize	36.04	36.97	30.98	36.04
LSD (P=0.05)	NS	NS	NS	NS

Table 7: Influenced of intercropping on leaf chlorophyll content in maize-groundnut intercrop

3.1.5. Dry Matter Yield of Groundnut and Maize

Table 8 depicts dry matter production of groundnut at the different plant population. Results in table 8 showed that there were no significant differences (P<0.05) between treatments at all the stages of growth. At 2 weeks and 4 weeks there were no significant differences among all the treatments. In the sixth week however there were significant differences (P<0.05) between sole groundnut and two rows groundnut. Treatment one row groundnut and two row groundnut showed no differences. Sole groundnut recorded the highest dry matter yield with 29.4 whilst the two rows groundnut recorded the lower dry matter with 17.1 in the sixth week (Table 8). For the eighth week after planting, treatments with one row groundnut and two rows groundnut are significantly not different. However, the sole groundnut was significantly different (P<0.05) from the one row and the two rows groundnut (Table 8). Sole groundnut recorded the highest dry matter yield of 32.20 and the two rows groundnut recorded the lowest dry matter yield with 23.94.

Crop arrangement	Weeks after planting (WAP)			
	2	4	6	8
1Maize:1row groundnut	3.36	9.35	24.1	25.93
1Maize:2rows groundnut	2.98	9.92	17.1	23.94
Sole groundnut	3.38	11.67	29.4	32.20
LSD (P=0.05)	NS	NS	9.25	2.01

Table 8: Shoot dry weight (kg/ha) of groundnut in maize-groundnut intercrop.

For the maize plants, the results showed that, there were no significant (P<0.05) differences in plant dry matter accumulation of maize at 2, 4 and 8 weeks after planting (WAP), however at 6 weeks after planting there was significant (P<0.05) differences among the treatments (Table 9). Differences were observed between sole maize and maize with two rows groundnut. Sole maize had the highest value of 52.10 whilst maize with two row groundnut had the lowest figure of 27.90.

Crop arrangement	Weeks after planting (WAP)			
	2	4	6	8
1Maize:1row groundnut	2.44	20.90	32.70	47.60
1Maize:2rows groundnut	3.93	11.00	27.90	38.60
Sole maize	3.70	23.50	52.10	70.90
LSD (P=0.05)	NS	NS	22.72	NS

Table 9: Shoot dry weight (kg/ha) of maize in maize-groundnut intercrop

3.1.6. Number of Days to Flowering in Groundnut and Tasselingin Maize

The number of days to flowering in groundnut is shown in table 10. In table 10, days to 50% flowering among the groundnut plants had no significant differences (P<0.05) among the treatments. However, two rows groundnut intercropped at the same time with maize and sole groundnut recorded the earliest flowering days of 24.0. The late or longer days to flowering was recorded by one row groundnut with a figure of 26 (Table 10). The groundnut is earlier in flowering than the maize plants for all the treatments. Days to tasseling among the maize plants had no significant difference among treatments (Table 11).

Crop arrangement	Days to 50% flowering	Height at maturity (cm)	Grain yield (kg/ha)	Harvest index
1Maize:1row groundnut	26.00	44.33	1374.00	31.05
1Maize:2rows groundnut	24.00	46.25	3834.00	83.00
Sole groundnut	24.00	40.90	1438.00	35.20
LSD (P=0.05)	NS	4.89	120.40	3.74

Table 10: Number of days to 50% flowering, height at maturity, grain yield and harvest index of groundnut in maize-groundnut intercrop

3.1.7. Plant Height at Maturity for both Groundnut and Maize

Table 10 and 11 shows plant height for both groundnut and maize at maturity. The results of groundnut (Table 10) show that intercropping groundnut with maize had increased height for groundnut for all the treatments with reference to the sole groundnut. There were no significant differences (P<0.05) between treatments one row groundnut. However, differences existed between sole groundnut and two rows groundnut (Table 10). The two rows groundnut recorded the tallest crop height at maturity with 46.25cm and lowest height was recorded by the sole maize is 40.89cm.

The height for maize plants at maturity intercropped with groundnut was observed to have lower heights with reference to the sole maize crops (Table 11). The sole maize was significantly different (P<0.05) from all the other treatments with a recorded height of 185.30. The treatment maize with one row groundnut and maize with two rows groundnut were not different from each other as shown in table 11.

Crop arrangement	Days to 50% tasseling	Height at maturity (cm)	Grain yield (kg/ha)	Harvest index
1Maize:1row groundnut	52.00	155.65	1553.00	9.98
1Maize:2rows groundnut	52.00	157.45	2108.00	13.38
Sole maize	54.00	185.30	2966.00	15.99
LSD (P=0.05)	NS	6.75	255.80	1.23

Table 11: Number of days to 50% tasseling, height at maturity, grain yield and harvest index of maize in maize-groundnut intercrop.

3.2. Yield and Components of Yield of Component Crops in Maize-Groundnut Intercrop

3.2.1. Grain Yield of Groundnut and Maize

The grain yield per hectare for groundnut and maize showed significant differences among all treatments. The groundnut crop recorded a low grain yield of 1374.0 kg/ha for one rows groundnut and the highest of 3834.0 kg/ha for two rows groundnut (Table 10). However, there were significant differences (P<0.05) between two rows groundnut and all the other treatments. Two rows groundnut and one row groundnut showed no significant difference between them.

For the maize, the grain yield had sole maize recording the highest of 2966.0 kg/ha and maize with one row groundnut recording the 1553.0 kg/ha. There are significant differences (P<0.05) among all treatments for the grain yield of maize (Table 11).

3.2.2. Harvest Index (hi) of Groundnut and Maize

The harvest index depicts similar trend as the yield per hectare (Table 10 and 11). The harvest index for groundnut had 31.05 as the smallest for one row groundnut and 83.00 as the highest for two rows groundnut (Table 10). The latter treatment was significantly different (P<0.05) from all other treatments. The two rows groundnut and sole groundnut, as well as one row groundnut were significantly different (P<0.05) from one another (Table 10).

The harvest index for maize had 15.99 as the highest and was for sole maize and the lowest is 9.98 which is for maize with one row groundnut (Table 11). The treatments maize with one row groundnut, maize with two rows groundnut sole maize are significantly different (<0.05) from each other. The highest harvest index for groundnut is four times larger than that of the maize crop (Table 10 and 11).

3.2.3. Land Equivalent Ratios of Maize-Groundnut Intercrop

The land equivalent ratio values of the intercrops were more than 1.0 (Table 12). Maizewith two rows groundnut recorded the highest value of 3.39 before maize with one row groundnut as shown in table 12.

Treatment	Land equivalent ratios
Maize, one row groundnut	1.48
Maize, two rows groundnut	3.39

Table 12: Land equivalent ratios of maize-Groundnut intercrop

4. Discussion

4.1. Growth of Component Crops in Spatial Maize-Groundnut Intercrop

Plant height of groundnut and maize increased regularly at all developmental stages under all the treatments. The results showed that the groundnut intercropped plants produced much more heights than the sole groundnut and this might be due to competition for sunlight between the maize and groundnut. The maize plants were tall in stature than the groundnut casting some shadow on the groundnut. Since plants need sunlight for photosynthesis, the intercropped groundnut then tends to grow in such a manner to enable it grow out of the shadow to obtain light and this causes it to grow a little much taller than their sole counterparts. The two rows of groundnut produced the tallest groundnut. The intercrops produced between 8-70% taller crops than their sole counterparts. Shading imposed on the groundnut by the maize leads to lengthening of the groundnut internodes in order to capture sunlight. This result is in agreement with work done by Stirling *etal*., (1990) where it was observed that shade effects on growth and yield of legume crops increase plant height. The taller groundnut plants observed in the groundnut-maize association were probably a consequence of light and space competition with the maize. Competition and a shady habitat had been shown to trigger the development of longer plant parts.

The maize intercropped plants have plants whose heights are a little shorter than their sole counterparts. The sole maize recorded 5-19% in height than the intercrops. The maize plants normally grow taller than the groundnut plants and thus the decrease in height with reference to the sole crop might be due to competition for soil nutrients. The plant obtains enough sunlight for photosynthesis but seems to have fewer nutrients from the soil for active growth due to competition for nutrients with the groundnut plants. This result is in agreement with work done by Wahua (1983) who reported that crops in association compete for nutrients resources, which may affect the associated crop negatively. Ahmed and Rao (1981) indicated reduction in plant growth during intercropping as against sole cropping in cereal-legume intercropping.

The growth rate of a crop determines the rate at which the crop increases in height per period of time. The groundnut crop usually does not grow tall and thereby its increases in height are minimal and may explain why its growth rates were not as high as that of maize plant. There were however significant differences ($P<0.05$) among the treatments as compared to the sole groundnut, meaning that intercropping had effect on the growth rate of the groundnut. The growth rate for maize was much higher than that of groundnut ranging from 20-90cm weekly where as that of the groundnut was 9-29cm. The maize plant is a much taller plant than the groundnut and grows much faster than groundnut which causes it to have a higher growth rate than the groundnut. There were significant differences among the treatments at all the three stages for the maize. However, from the four week to the eight week, the sole maize had a higher growth rate than the other treatments, meaning that when maize plants are intercropped with groundnut the crop's growth reduces which may be due to competition for nutrients. This result is in agreement with work done by Wahua (1983) who reported that crops in association compete for nutrients resources, which may affect the associated crop negatively.

According to Saxena *et al.* (1983), the leaf area index of groundnut varies with environmental conditions, cultural practices and stages of crop growth. From this study, sole groundnut grown in the field had higher Leaf area index (LAI) consistently than the ones with single rows and double rows groundnut. Leaf area index (LAI) decreased with sowing density. These results are similar to those obtained previously by Forcella *et al., (*2002) who reported that plants in wider rows compensated for yield by producing more branches and leaves. The groundnut, though intercropped and sowed solely did not show any significance among them except for the first two weeks where the above inference was made.

For the maize, the sole maize crop recorded higher Leaf area index (LAI) than all of the other treatments although the maize fields that had two rows of groundnuts have higher leaf area index than those with only one row. This is in agreement with the report that maize is more sensitive to variations in plant density than other members of the grass family (Almeida & Sangoi, 1996). Higher plant densities of maize affect leaf area index (LAI) negatively (Wiyo *et al.,* 1999) which might be due to the fact that when maize is intercropped with groundnut, because of the increased density of the intercrop, there is an increases the competition for soil nutrients. It also reveals that the intercrop ability to intercept sunlight for photosynthesis is reduced with reference to the sole crop.

The dry matter for the groundnut plants showed significance among the treatments during the period of growth. The plants thus accumulated dry matter differently at the different stages of growth as indicated by the treatments. In general, the sole groundnut field showed higher dry matter accumulation at all sampling stages consistently than the other treatments. Furthermore, it was observed from the results that increased density significantly reduced ($P<0.05$) dry matter accumulation for the groundnut. This is in agreement with information from previous studies which indicates that shade effects on growth and yield of legume crops decrease dry matter accumulation (Stirling *et al.,* 1990). This as well means that the sole groundnut accumulated much dry matter, because of the absence of competition from the maize for nutrient and also benefited from the wider spacing as compared with those in competition whose spacing was narrower and so only grew taller and thinner. This reasoning conforms to Inal *et al*., (2007) who revealed that shoot yields of peanut and maize plants were decreased by intercropping the plants, as compared to monoculture plants.

Results for maize obtained in this study showed that dry matter accumulations were not significantly different among the treatments except on the sixth week. Bell *et al.,* (1987) reported biological yield (above-ground biomass plus pods) was unresponsive to spatial ratio over the range 1:1-1:7:19. The sole maize gave the highest yield in the sixth week. This conforms to the findings that shootyields of maize plants were decreased by intercropping the plants as compared to monoculture plants (Inal *etal*., 2007). This finding was however contradicted by Rerkasem and Rerkasem, (1998) who found that dry matter production increased when maize is intercropped relative to sole maize. The dry matter accumulation of maize is larger than that of groundnut, and this might be due to the fact that the maize plant is bigger in stature than that of groundnut.

The days to flowering of groundnut depends on whether it is planted solely or intercropped. This study revealed that, groundnut plant flowers early when planted solely and a little late when intercropped with maize. Rhoda (1989) reported that increasing planting densities could delay flower formation in legumes. The results showed that the shading effects caused by taller maize plants delay flowering and maturity of cowpeas. The result however contradicts findings with cowpea where Mpangane (2001) observed that days to flowering and maturity of all cowpea cultivars did not differ between the sole and intercrops with maize.

The days to tasseling of the maize plants was not significantly affected by intercropping.

The intercropped groundnut plants especially those that were delayed for a week or two weeks showed increased height at maturity than the sole crop with a difference of up to 28cm in height. The two rows of groundnut produced the tallest plants with a mean height of 68.08cm. This may be due to the fact that the plants committed resources to grow taller to intercept sunlight for photosynthesis hence as a survival mechanism. Maize provided shade to the legumes, and sunlight was limiting to the legume crops; therefore, leaf formation in legumes was impaired. Intercropped groundnut crops grew taller than their sole counterparts. Thwala and Ossom (2004) observed that intercropped legume crops grew taller than their sole counterparts. The taller groundnut plants observed in the groundnut-maize association were probably a consequence of light and space competition with the maize. Competition and a shady habitat had been shown to trigger the development of longer plant parts.

The maize crop in the intercropped plots has lower heights with reference to the sole maize crop with a mean difference of 30cm in height. The intercropping of maize with the groundnut might have resulted in competition for nutrients among the two crops, thereby denying the maize crop many nutrients for growth in terms of height. The height at maturity of maize intercropped with groundnut is affected by the competition for nutrients by both crops thereby resulting in reduced heights with reference to the sole maize crop. Wahua (1983) reported that crops in association compete for nutrients resources, which may affect the associated crop negatively.

4.2. Yield and Components of Yield of Component Crops in Spatial and Temporal Maize-Groundnut Intercrop

The harvest index refers to the portion of the crop that is used for economic purpose with reference to the whole crop. It measures the percentage of the plant part that is taken for the economic purpose when harvested as compared to the whole. The two rows of groundnut produced the highest harvest index of 83.00, which shows that this treatment produced the highest number or weight of grains of groundnut among the other treatments and even the sole groundnut. The results indicated that intercropping of groundnut at close spacing can produce a highly significant effect on yield and increase harvest index. This is in agreement with Mozingo and Wright (1995) who found a high density sowings had a greater yield than the most spaced configurations. Furthermore, Kowal and Kassam (1970) reported that, mixtures involving groundnut and cereal produce a greater total yield per hectare/season than one sole crop. Therefore, two rows of groundnut in between maize plant are appropriate to obtain much grains of groundnut

The sole maize had the highest harvest index of 21.6. This as well reveals that such plots or treatments produced the highest number or weight of grains as compared to the intercropping. Mkandawire and Sibuga (2002) observed that increasing plant population density reflected negatively on yield. This could be due to the fact that the sole maize had nutrient availability and absorption advantage over the intercrop maize because it was not competing with groundnut in the same space for growth factors.

The grain yield is the weight of grains harvested from the crops on the field per plot or treatments as used in the experiment. There was a relationship between the grain yield and the harvest index of the crop which was the higher the harvests index of a crop the greater the yield. The grain yield of the legume increased with intercropping whilst the grain yield of the maize decreased with intercropping of the legume. The field of the two rows of groundnut significantly ($P<0.05$) produced higher harvest index for groundnut and eventually produced the highest grain yield of groundnut. This conforms the findings of Li *etal.,* (2001) reported yield advantage of intercropping as against monocropping for legumes. Also Willey and Osiru (1972) indicated beans yield reduction when plant population density was lowered in intercropping. The higher intercrop yield appeared to be achieved by an increased efficiency in converting light energy into dry matter and not by any increase in the amount of light energy intercepted. It is suggested that this increased efficiency may have been because the combined intercrop canopy resulted in light being more efficiently spread over a greater surface of leaf (Reddy and Willey, 1980).

However, the same cannot be said for the maize. The sole maize significantly gave the highest grain yield than the single row and double row groundnut. This is in agreement with Mkandawire and Sibuga (2002) who observed that increasing plant population density reflected negatively on yield. This could be due to the fact that the sole maize had nutrient availability and absorption advantage over the intercrop maize because it was not competing with groundnut in the same space for growth factors.

The yield advantage of intercropping was calculated according to Ofori and Stern (1987), and Willey and Rao (1980). The land equivalent ratio (LER) gives an accurate assessment of the greater biological efficiency of the intercropping situation. The greater than one (1) LER means that in this study intercropping maize and groundnut was beneficial. The two rows of groundnut between the maize recorded higher LER values than the single rows treatment. LER values indicated that groundnut recorded yield advantage in all intercropping systems due to crop complementarities which corroborates the findings of several researchers (Willey, 1979) and (Reddy and Willey, 1980). This study also confirms earlier reports by Altieri (1987) that total yield per hectare in mixtures are often higher than sole crop yield even when yields of individual components are reduced. Natarajan *et al.* (1985) observed that on the basis of a Land Equivalent Ratio (LER) intercropping gave 26% more reproductive yield (LER = 1.26) than growing the two crops separately; both these yield increases were statistically significant. It is suggested that this increased efficiency may have been because the combined intercrop canopy resulted in light being more efficiently spread over a greater surface of leaf (Reddy and Willey, 1980). Where groundnut is considered the major crop then the two row of groundnut should be adopted for maximum harvest. If the farmer considers maize to be the major interest for the faming, then the row of maize followed by one row of groundnut would be ideal. Where the farmer wants to maximize the use of the land for both crops equally, then the two rows of groundnut in maize is the best system.

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