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Groundnut (*Arachis hypogaea* L.) varietal response to spacing in the Guinea savanna agro-ecological zone of Ghana: Growth and yield

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An experiment was conducted at the Savanna Agricultural Research Institute (SARI) in 2006 and 2007 to assess the effect of spacing arrangement on the growth and yield of six new groundnut varieties (Adepa, Azivivi, Jenkaar, Kpanieli, Manipintar and Nkosuor) in three (3) spacing arrangements (30 cm × 15 cm, 40 cm × 10 cm and 50 cm × 10 cm). The factorial experiment was laid in randomized complete block with three replicates. The results showed that groundnut variety and spacing arrangement significantly influenced its growth and yield performance. The Adepa and Manipintar varieties significantly increased pod yield by 9.1 and 77.7 %, while Nkosuor and Azivivi increased mean (100) seed weight by 0.4 and 0.6 %, respectively in 2006 and 2007. The SP1 spacing (30 cm × 15 cm) arrangement improved pod yield by 6.2 and 16.0 % in 2006 and 2007 respectively over their respective means. Based on the pod yield results, the recommended groundnut varieties were Adepa and Manipintar using the 30 cm × 15 cm spacing arrangement.

Key words: *Arachis hypogaea*, sub-optimum, semi-arid, Guinea savanna, smallholder.

INTRODUCTION

The total annual production of groundnut (*Arachis hypogaea* L.) in the Guinea savanna zone of Ghana has been fairly static over the past years despite yearly increases in the total acreage under the crop (Tsigbey et al., 2003). These poor yields result from a cocktail of factors including infertile soils, weed problems, inappropriate varieties and sub-optimum plant population densities among others. Establishment of sole groundnut crop in wide rows is reported to lead to lower yields as a result of the sub-optimum plant population densities thus encouraging under-utilization of land in the face of pressing need for cash income by the farm family (Kafiriti, 1994).

Cultivation of groundnut in narrow rows can lead to maintenance of a complete crop cover over the soil which inhibits weed seed germination and reduces the need to carry out weeding (Lee et al., 1994). Early canopy closure by closely spaced groundnut crop has been shown to smother weeds hence reducing weed/crop competition, especially for soil nutrients and water (Coolman and Hoyt, 1993; Thellen, 2006). Such benefits are more evident under low input conditions as seen on most smallholder farms.

Apart from weed control, narrow rows have been shown to significantly reduce the occurrence and spread of tomato spotted wilt virus (TSWV) in groundnut crop

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(McGriff et al., 1999; Branch et al., 2004). This is because decreasing row spacing increases the number of plants per acre and this dilutes the thrips (*Scirtothrips* spp., *Frankliniella* spp.) vector such that there is a lower probability of individual plant infection (Brown et al., 2005; Jadhav, 2006). Also, narrow rows have been used elsewhere as cultural control methods to effectively reduce the incidence and spread of groundnut rosette virus (GRV) since it slows down reproduction by the vector; *Aphis craccivora* (Mahmoud et al., 1992). However, the advantages of planting groundnut closely have been documented in studies largely conducted in other countries, especially in the Americas. Several workers have reported higher yields in close spaced compared to wide spaced groundnut systems (Mickelson and Renner, 1997; Ahmad et al., 2007), usually attributed to higher plant population densities that effectively utilize water, nutrients and perhaps more importantly light (Wells et al., 1993). It is known that yield increases in these systems are closely linked to increased light interception that occurs in close spaced compared to wide spaced systems (Dalley et al., 2004). Recent study has shown a continuous yield increase with decreasing row spacing which became multiples with the addition of chemical fertilizers (Schilling and Gibbons, 2002). Also, close spaced groundnut has been shown to give greater ground cover, leave area indices, better canopy light interception, crop growth rates and ultimately higher pod yields when compared to conventional wide row crop (Jaaffar and Gardner, 1988).

The objective of this study was therefore to assess and compare the effects of close spatial arrangement on the growth and yield of six new groundnut varieties at Nyankpala within the Guinea savanna agro-ecological zone of Ghana.

MATERIALS AND METHODS

Experimental site

The experiment was conducted in 2006 and 2007 on the research station of the savanna agricultural research institute (SARI) at Nyankpala. Nyankpala is a farming community 16 km west of Tamale. It is located on latitude 9°25'N and longitude 1°00' west at 183 m above sea level. The land has a gentle slope of about 2 % and is strongly disturbed by sheet erosion. It is a well drained Voltaian sandstone soil unit locally referred to as Tingoli series. The experimental field was left fallow for three years after being cropped to maize previously. The initial analysis of soil samples taken at the site revealed a pH of 6.5 in calcium chloride ($CaCl_2$), 0.044 % total nitrogen, 10.5 mg kg^{-1} available P and 0.37 % organic carbon.

The climate is warm, semi-arid with mono-modal annual rainfall of up to 1200 mm which falls mostly between May and September. This is then followed by seven months of dry season, which is characterized by the dry harmattan winds with high risk of uncontrolled bushfires resulting in the loss of vegetative cover of the soil. The average monthly atmospheric temperatures range from 26 to 39°C with an annual mean of 32°C. The total amount of rainfall during the period of the experiment in 2007 was 873.5 mm which was higher but less evenly distributed than the rainfall of 740.4 mm received during the same period in 2006.

Experimental design and treatments

The experiment was laid out in randomized complete block (RCB) design with three replicates. Each plot measured 6 m × 6 m. A net plot which measured 4 m × 4 m was taken for crop growth data and yield analysis. The factors tested were groundnut variety and plant spacing. These comprised six varieties (Adepa, Azivivi, Jenkaar, Nkosuor, Kpanieli and Manipintar) and three different spacing (SP1 (30 × 15 cm); SP2 (40 × 10 cm) and SP3 (50 × 10 cm)). Initial weed control was carried out using hand hoe three weeks after planting (WAP). Hand pulling was subsequently used to achieve effective weed control at six WAP. Data collected included growth parameters, yield and yield components.

Growth parameters and yield measurements

Plant height and canopy width

Five plants of each plot were randomly selected and identified with a tag. Heights and widths of these plants were monitored at two weeks interval through the growing period of each experiment. Height measurement was done from the ground level to the last terminal leaf while canopy spread was measured from the last leaf on one side to the last leaf on the other side using a measuring tape. This was done at 4, 6 and 8 WAP. The average of five plants was then calculated for each sampling occasion.

Yield and yield components

Pod harvest from five consecutive groundnut plants were counted and the average of this taken as the number of pods $plant^{-1}$. The harvests from five consecutive plants from each treatment were then shelled and the seeds counted. The number of seeds for each treatment was divided by the number of respective pods to obtain the number of seeds pod^{-1}. The total weight of groundnut from the respective net plots were recorded after harvesting and drying to a moisture content of 13 % which was determined using a moisture meter. The weight of groundnut harvest from each net plot was then extrapolated to total pod yield per hectare. After shelling, the seed were weighed and the differences between the pod and seed weights of treatments used to compute shelling outturn.

Correlation analysis

Correlations among some growth parameters and yield components were determined using Microsoft excel and the results interpreted by the Pearson Product Moment Correlation (PPMC) coefficient method (Pelosi and Sandifer, 2003).

Statistical methods

The data collected were subjected to statistical analysis using Genstat discovery edition11 (2011). The analysis of variance procedure was followed to determine whether differenced existed among treatments. Treatments were compared using the least significant difference (LSD) at 5 % probability level.

RESULTS

Rainfall and temperature

Mean monthly rainfall in March, May, August and

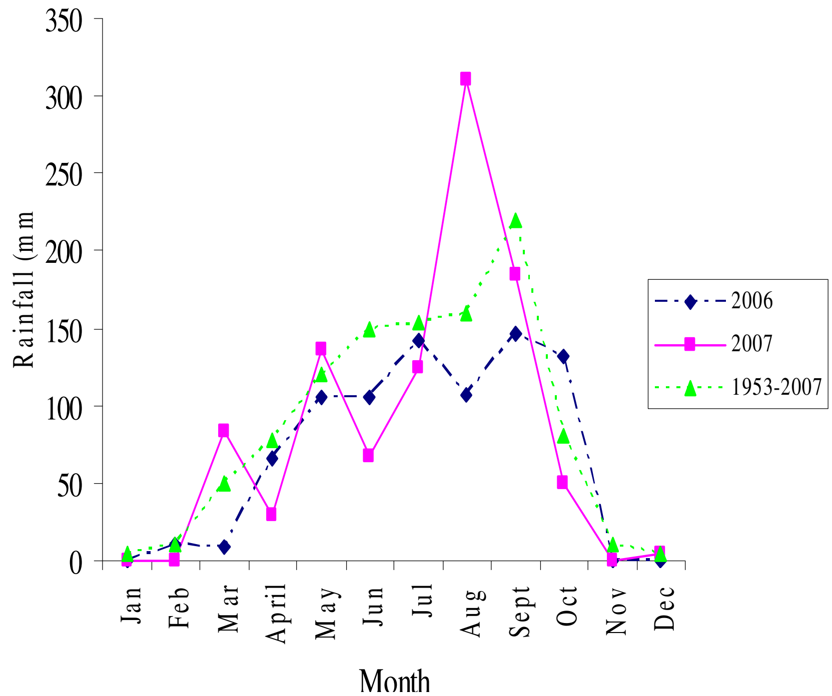

Figure 1. Mean monthly rainfall at Nyankpala in 2006 and 2007 compared to national mean monthly rainfall from 1953 to 2007.

Table 1. Mean monthly temperatures at Nyankpala in 2006 and 2007.

Month	2006 (°C)			2007 (°C)		
	T min	T mean	T max	T min	T mean	T max
January	21.7	29.7	37.6	18.8	26.6	34.3
February	22.8	30.6	38.4	23.1	30.6	38.1
March	25.9	33.6	37.7	24.4	32.2	39.9
April	24.7	30.7	36.7	25	31	37
May	23.7	28.3	32.9	24.4	28.8	33.1
June	23.4	27.6	31.7	24.1	28.1	32
July	23.5	27.2	30.9	23.7	27.4	31
August	22	26	29.9	23.1	26	28.9
September	22.5	26.3	30	22.7	26.5	30.3
October	23	27.3	31.5	23.1	28.2	33.3
November	18.8	25.9	32.9	24.4	29.6	34.7
December	17.9	26.6	35.3	20.3	27	33.7
Mean	22.6	28.2	33.8	23.1	28.5	33.9

T min = minimum temperature, T mean = mean temperature, T max = maximum temperature.

September in 2007 were all higher than both their respective 2006 mean values and the national mean values from 1960 to 2007. The total annual (814.4 mm) and mean monthly rainfall (91.6 mm) in 2007 were also higher than that received in 2006 (Figure 1). No wide fluctuations in the minimum mean and maximum temperatures (Table 1) were recorded in both years despite the differences in rainfall. However, the minimum and mean temperatures were inversely related to rainfall. The reduced rainfall (8.7 mm) received in March led to the highest minimum temperature (Table 1). This resulted in the highest mean temperature in 2006. Again, the high rainfall received in August 2007 led to the lowest mean and maximum monthly temperatures in that year (Table 3).

Table 2. Plant heights at 4, 6 and 8 weeks after planting as affected by groundnut variety and spacing arrangement.

Variety	4 WAP (cm)		6 WAP (cm)		8 WAP (cm)	
	2006	2007	2006	2007	2006	2007
Adepa	13.7	15.0	20.9	17.3	30.5	30.6
Azivivi	12.6	13.3	21.0	19.9	29.8	32.7
Jenkaar	13.2	13.8	20.6	18.6	31.2	31.2
Kpanieli	*	15.5	*	25.1	*	40.0
Nkosuor	14.2	14.4	20.7	18.7	28.4	31.8
Manipintar	*	20.8	*	35.0	*	46.4
Lsd $_{0.05}$	ns	2.7	ns	4.7	ns	3.9
Spacing (cm)						
30 x 15	12.6	14.9	20.2	23.7	30.9	36.7
40 x 10	13.9	16.8	21.3	21.9	30.9	35.5
50 x 10	13.8	14.7	21.0	21.7	28.2	34.2
Lsd $_{0.05}$	ns	1.9	ns	ns	ns	ns
CV (%)	5.7	0.7	5.1	1.7	4.5	3.3

*Data not taken in that year, cm = centimeters; WAP = weeks after planting, ns = no significant differences.

Table 3. Plant canopy spread at 4, 6 and 8 weeks after planting as affected by groundnut variety and spacing arrangement.

Variety	4 WAP (cm)		6 WAP (cm)		8 WAP (cm)	
	2006	2007	2006	2007	2006	2007
Adepa	18.9	23.8	32.8	44.3	47.6	59.3
Azivivi	17.2	22.1	29.2	40.4	45.6	62.0
Jenkaar	16.2	25.0	31.4	46.0	47.3	59.9
Kpanieli	*	23.1	*	93.3	*	57.7
Nkosuor	17.5	23.0	29.5	43.2	42.9	63.6
Manipintar	*	22.2	*	39.6	*	61.2
$Lsd_{0.05}$	ns	ns	ns	5.3	ns	ns
Spacing (cm)						
30 x 15	16.2	22.5	27.2	39.9	41.6	59.2
40 x 10	15.7	23.0	28.7	42.2	43.7	61.2
50 x 10	20.5	24.2	36.3	44.2	52.1	61.5
$Lsd_{0.05}$	2.8	ns	4.5	3.8	5.6	ns
CV (%)	5.1	10.9	5.5	2.7	3.1	0.9

CM = centimeters; WAP = weeks after planting, ns = no significant differences.

Plant height and canopy spread

Plant height of all treatments increased from 4 through 6 to 8 WAP in both cropping seasons (Tables 2). In 2007, Manipintar recorded significantly taller ($P<0.05$) plants than all other varieties 4, 6 and 8 WAP. Additionally, plants of the Kpanieli variety were significantly taller ($P<0.05$) than those of the remaining varieties (6 and 8 WAP) whose heights were similar on both sampling occasions. The effect of the SP2 spacing resulted in significantly taller ($P<0.05$) plants than those of the SP1 and SP3 spacing at 4 WAP in 2006. Groundnut varieties did not significantly influence canopy width in 2006 and at 4 and 8 WAP in 2007 (Table 3). At 6 WAP in 2007, effect of the Jenkaar variety on canopy width was significantly ($P<0.05$) higher than the effects of the Azivivi, Kpanieli and Manipintar varieties. The effect of the SP3 spacing on canopy spread was significantly higher ($P<0.05$) than the effects of the SP1 and SP2 spacing arrangements which recorded similar effects on the three sampling occasions in 2006 (Table 2). In 2007, spacing effect on canopy spread was significant only during sampling at

Table 4. Number of pods per plant, seeds per pod and mean (100) seed weight as affected by groundnut variety and spacing arrangement.

Variety	Pods plant^{-1}		Seeds pod^{-1}		MSW (g)	
	2006	2007	2006	2007	2006	2007
Adepa	11.2	13.8	1.6	1.7	44.3	34.6
Azivivi	17.9	17.3	1.7	1.7	43.9	36.3
Jenkaar	18.1	16.0	1.6	1.7	44.1	35.1
Kpanieli	*	17.3	*	1.7	*	39.7
Nkosuor	11.8	14.8	1.7	1.8	44.4	35.1
Manipintar	*	14.3	*	1.8	*	35.7
$Lsd_{0.05}$	3.6	2.8	ns	ns	ns	4.0
Spacing (cm)						
30 x 15 cm	13.3	16.7	1.6	1.7	44.8	35.6
40 x 10 cm	14.8	15.7	1.7	1.7	45.3	36.6
50 x 10 cm	16.2	14.4	1.7	1.8	42.5	36.0
$Lsd_{0.05}$	3.1	2.0	ns	0.1	ns	ns
CV (%)	14.6	1.3	5.6	0.3	1.8	1.0

*Data not taken in that year, pods plant^{-1} (number of pods per plant); seeds pod-1 (number of seeds per pod); g (grams), MSW (mean seed weight), ns = no significant differences.

6 WAP when the effect of the SP3 spacing was significantly higher (P<0.05) than that of the SP1 spacing.

Yield and yield components

There were no significant influences of varieties on dry pod yield in both years although yield recorded by all varieties in 2006 were generally higher than in 2007 (Table 5). In 2007, differences in varietal effects resulted in Manipintar recording the largest pod yield which was significantly more (P<0.05) than the effects of each of the remaining varieties. The effects of the SP1 and SP spacing arrangement on pod yield were similar in 2007, but either effect on pod yield was significantly more than (P<0.05) the effect of the SP3 spacing (Table 4).

In 2006, Azivivi and Jenkaar produced similar number of pods but the effect of each variety on the number of pods per plant was significantly (P<0.05) higher than the effects of Adepa and Nkosuor varieties (Table 4). Also, the number of pods recorded by Azivivi and Kpanieli in 2007 were significantly more (P<0.05) than that recorded by Adepa and Manipintar. The influence of spacing on number of pods per plant resulted in the SP1 spacing arrangement producing significantly (P<0.05) higher than the SP3 spacing in 2007. Groundnut varietal effects did not significantly influence the number of seeds per pod in both years. The effect of the SP3 spacing on number of seeds pod^{-1} was significantly higher (P<0.05) than the effects of the SP1 and SP2 spacing (Table 4) in 2007.

Mean seed weight values in 2006 cropping season were generally higher than that recorded in 2007 (Table 4) although the differences observed between varieties (2006) and spacing arrangements (2006) were not significant. In 2007, the effect of the Kpanieli variety on mean seed weight was significantly higher (P<0.05) than the effect of the Adepa variety only. The results also show that all the treatments gave higher values for shelling outturn (%) in 2006 than in 2007 (Table 5) although no significant differences were observed amongst varieties in 2006 and between spacing in both years.

Correlations

The results of correlations among some growth parameters and yield components (Table 6) indicates that plant height was positively and highly correlated with pod yield in 2006 (r = 0.55, P<0.05) and 2007 (r = 0.61, P<0.01). Also, plant canopy spread was positively and highly correlated with mean seed weight in 2006 (r = 0.60, P<0.01) and 2007 (r = 0.47, P<0.05). Mean seed weight was also positively and highly correlated with shelling outturn (r = 0.50, P<0.05) in 2007.

DISCUSSION

Plant height and canopy width

Manipintar, being the only indeterminate variety among the six groundnut varieties recorded taller plants at all the sampling occasions in 2007. Plant height was however affected by plant spacing at the early stages (4 WAP) when seedlings at close spacing produced taller plants. This was probably as a result of early competition between closely spaced seedlings for light which

Table 5. Dry pod yield and shelling outturn as affected by groundnut variety and spacing.

Variety	Dry pod yield (tha^{-1})		Shelling outturn (%)	
	2006	2007	2006	2007
Adepa	1.770	0.764	62.9	45.2
Azivivi	1.499	0.781	58.8	46.1
Jenkaar	1.640	0.788	58.5	44.9
Kpanieli	*	0.758	*	48.4
Nkosuor	1.581	0.940	57.5	37.9
Manipintar	*	1.230	*	46.6
$Lsd_{0.05}$	0.3	0.2	ns	7.5
Spacing (cm)				
30 x 15	1.724	1.018	59.8	45.2
40 x 10	1.623	0.891	60.6	46.6
50 x 10	1.519	0.722	57.8	42.8
$Lsd_{0.05}$	ns	0.1	ns	ns
CV (%)	2.0	14.1	6.6	8.9

*Data not taken in that year, tha-1 (tons per hectare), ns = no significant differences.

Table 6. Correlations among some growth and yield components of groundnut varieties in 2006 and 2007.

Component	2	3	4	5	6
2006					
Plant height (cm)	0.01	-0.10	0.32	0.55*	0.45
Canopy width (cm)		0.37	0.60**	-0.07	0.28
Pods $plant^{-1}$			-0.39	-0.39	-0.24
100 seed weight (g)				0.31	0.25
Pod yield (tha^{-1})					0.35
Shelling outturn (%)					- - -
2007					
Plant height (cm)	0.39	0.09	0.27	0.61**	0.26
Canopy width (cm)		0.15	0.47*	0.10	0.44
Pods $plant^{-1}$			0.44	-0.01	0.23
100 seed weight (g)				-0.12	0.50*
Pod yield (tha^{-1})					0.12
Shelling outturn (%)					- - -

**Significant at 1 %; *Significant at 5 %; tha^{-1} = tons per hectare; cm = centimeters.

encouraged vertical growth. At the later stages, the lack of differences between close and wide spaced seedlings may have resulted from depletion of soil nutrients as well as other negative effects such as intra-specific plant competition associated with close planting (Farnham, 2001; Porter et al., 1997). Close spacing significantly reduced canopy width in both years as plants were compelled to grow vertically to compete for space and light (Farnham, 2001). In both years, wide spacing arrangement supported wider canopy sizes probably as a result of more available space for horizontal growth compared to the space available to closely spaced crop. However, close spacing resulted in complete and early canopy closure, consistent with the findings of Tillman et al. (2006) and Brown et al. (2005).

Yield and yield components

The number of pods $plant^{-1}$ recorded by this study differed between varieties and spacing arrangements. These were lower than that reported by other studies (Abdullah et al., 2007; Virender and Kandhola, 2007), probably due to the fact that no fertilizer input was made. The variations in the number of pods observed were probably largely attributable to the genotypes of the groundnut varieties (Ahmad and Mohammad, 1997; Virk et al., 2005). The Azivivi variety which recorded significant number of pods in both years compared to the Adepa and Jenkaar could be said to exhibit genetic stability across two varying seasons with dis-similar climatic conditions (Ogundele, 1988). Also, the relatively lower pod productions by both variety and spacing treatments was probably due to the adverse effects of the reduced rainfall received at the early stages of the 2007 cropping season. Since situations of water stress are normally accompanied by heat stress, the low pod production in 2007 can be attributed to the combined effects of moisture and heat stresses experienced during the drought period (Sivakumar et al., 1993; Vara Prasad et al., 1998). Also, the higher number of pods plant^{-1} recorded by wide spacing arrangements were probably because of lesser intra-specific competition for growth resources among the wide spacing compared to close spacing crop (Mozingo and Steele, 1989).

Generally, variations in the number of seeds pod^{-1} were observed both among the varieties and spacing treatments. This indicates the genetic control of the trait as well as it being subject to environmental influence (Ahmad and Mohammad, 1997; Ogundele, 1988). Also, insufficient nutrient supply and adverse environmental conditions such as drought and heat stress during crop growth and pod filling periods could have affected the number of seeds pod^{-1} since no soil amendment was used (Sivakumar et al., 1993). This probably explains why spacing arrangement that resulted in relatively low plant densities, characterized by the availability of potentially more growth resources per plant and reduced intra-specific competition for space and light, recorded significantly higher number of seeds pod^{-1} in 2006 and 2007 compared to the close spacing arrangements.

Pod yield of groundnut varieties in 2006 were generally higher than in 2007, following the pattern of number of pods, seeds and mean seed weight. The variations in pod yield of varieties both within and between seasons were probably attributable to genetic differences between varieties and how they responded to environmental changes. Similar findings have been reported by earlier studies (Shambharkar et al., 2006; Abdullah et al., 2007; Mayeux and Maphanyane, 1989; Virender and Kandhola, 2007). Drought induced moisture stress at the early stage (June) of growth in 2007 might have resulted in the allocation of more dry matter to the roots for moisture and nutrient uptake (Ali and Malik, 1992; Banerjee et al., 2005). Subsequent excessive rains in the season probably promoted vegetative growth at the expense of reproduction development (Schilling and Gibbons, 2002), resulting in reduced pod yields by all treatments in 2007 compared to 2006. Pod yield however, was not directly related to yield components in both years. Generally, decrease in spacing reduced the number of pods plant^{-1}, number of seeds pod^{-1} and mean seed weight but the additional plants m^{-2} more than compensated for the reduction, resulting in higher pod yield. Such compensation effects have been reported by Ahmad et al. (2007), Norden and Lipscomb (1974) and Duke and Alexander (1964). Thus spacing arrangement that resulted in high plant population density was more efficient in the use of solar energy and other resources for pod production (Virk et al., 2005).

Mean seed weights recorded by this study in both years were lower than that reported by other research works (Sivakumar et al., 1993; Virenda and Kandhola, 2007). Variations in mean seed weight within the growing season were strongly influenced by groundnut varietal differences (Karkannavar et al., 1991). However, the variations recorded between seasons indicate the possibility of environmental influence on mean seed weight (Ahmad and Mohammad, 1997; Ogundele, 1988). The relatively lower mean seed weights recorded in 2007 for all varieties and spacing treatments compared to 2006 were probably attributable to the adverse effects of the relatively low rainfall received at the start of the cropping season in 2007. These conditions affected early seedling establishment and growth, whilst the subsequent heavy rains encouraged vegetative growth at the expense of pod formation and filling (Schilling and Gibbons, 2002). Following the patterns of seed number and mean seed weights, significant variations in shelling outturn were recorded among treatments and were found to be consistent with the findings of Ghosh et al. (2007), Abdullah et al. (2007) and Virender and Kandhola (2007). The large variations observed among varieties in 2007 were probably due to varietal response to the erratic nature of rainfall in that year.

Correlations

The high and positive correlations between growth parameters and reproductive indices in both years can be attributed to higher rates of photosynthesis by larger plants that probably made more dry matter available for pod formation and filling. Such positive correlations in groundnut have been reported by Boote et al. (1992) and Lapang et al. (1980). Also, the strong and positive correlation coefficient between mean seed weight and shelling outturn confirms the relationship described by Bell et al. (1993), suggesting that shelling outturn of groundnut improves with increase in seed size.

Conclusions

Based on the findings of this research work, it can be concluded that the yields obtained from the SP1 spacing arrangement were higher. Also, this arrangement achieved rapid canopy closure with a potential to smother weeds and prevent subsequent germination of weed seeds. Added to these benefits is the large stover that the

SP1 spacing can potentially produce, making more nutrients available through biological nitrogen fixation to the succeeding non-legume crop if grown in rotation. On the bases of pod yield, Adepa and Manipintar, established using the SP1 spacing are of great potential for further research work and adoption in an attempt to increase groundnut production in the Guinea savanna agro-ecologies. This can be achieved without necessarily increasing the acreage under groundnut cultivation.

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