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GROUNDNUT (*Arachis hypogaea* L.) VARIETAL RESPONSE TO SPACING IN THE HUMID FOREST ZONE OF GHANA

Konlan S.[1], Sarkodie-Addo J.[2], Asare E.[2], Adu-Dapaah H.[3] and Kombiok M. J.[4]
[1]Cocoa Research Institute of Ghana (CRIG), New Tafo-Akim, Ghana
[2]Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
[3]Crop Research Institute, Kumasi, Ghana
[4]Savanna Agricultural Research Institute, Nyankpala, Ghana
E-Mail: Sampson.konlan@gmail.com

ABSTRACT

An experiment was conducted at Anwomaso in the Ashanti Region to investigate the response of groundnut varieties to spacing arrangement in the humid forest agro-ecological zone of Ghana. The experiment was laid in randomized complete block (RCB) design with three replicates. Six groundnut varieties (Adepa, Azivivi, Jenkaar, Kpanieli, Nkosuor and Manipintar) were studied using three spacing arrangements (30 cm x 15 cm), (40 cm x 10 cm) and (50 cm x 10 cm). The Adepa and Kpanieli varieties significantly improved pod yield by 6.3 and 10.2 % respectively in 2006 and 2007 while the 30 cm x 15 cm spacing significantly increased pod yields by 16.8 and 0.6 % respectively, in 2006 and 2007. In both years, the 50 cm x 10 cm spacing arrangement increased mean seed weight by 4.1 and 3.7 %, respectively. Stover N (kg N ha^{-1}) was improved by Jenkaar (4.1 %) and Kpanieli (6.4 %) while the 30 cm x 15 cm spacing improved stover N by 4.4 and 7.4 %, respectively, in 2006 and 2007. Based on the results, the recommended groundnut varieties for adoption and further research in the humid forest agro-climate were Adepa and Kpanieli with the 30 cm x 15 cm as the promising spacing arrangement.

Keywords: climate, symbiotic, humid forest, optimum, spatial.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is an annual soil enriching, self pollinated legume, cultivated widely in the arid and semi-arid regions of the world (40^{o} N and 40^{o} S), from warm temperate to equatorial climates. It is an important oilseed crop of the semi-arid tropics (Fletcher *et al*., 1992; Tarimo, 1997; ICRISAT, 2008). The crop ranks thirteenth (13th) in importance among world crops (Hatam and Abbasi, 1994). Groundnut shows high sensitivity to soil salinity, tolerating a wide range of pH values, but prefers neutral to slightly acidic soils (Tsigbey *et al*., 2003). Seed germination is inhibited if the temperature falls below 15°C or rises above 45°C. In the semi-arid tropics, optimum daylight temperatures for vegetative and reproductive growth and development in groundnut ranges from 25°C to 36°C and from 25°C to 26°C (Cox, 1979; Wood, 1968). Very low temperatures early or late in the growing period can lead to immature pods at harvest while high temperatures retard growth and may lead to moisture stress (Vara Prasad *et al*., 1998). Although groundnut is generally tolerant to drought, its sensitivity varies at different growth stages (ICRISAT, 1992, Boote and Ketring, 1990). Rainfall of 500-1000 mm per annum is normally enough for successful cash cropping if well distributed (Gram, 1958; Shilling and Gibbons, 2002).

As a deep rooting legume enjoying symbiotic association with *rhizobia* and *mycorrhizae*, groundnut responds to starter nitrogen at the early stages but it is able to provide for its own nitrogen needs through symbiotic nitrogen fixation after six weeks of growth (Gibbons and Martin, 1980). Groundnut is also known to provide an equivalent of 60 Kg N ha^{-1} to the subsequent non-legume crop or cereal through biological nitrogen fixation (Ghosh *et al*., 2007; Rwamugira and Massawe, 1990). The crop also benefits its intercrop partner through nitrogen sparing and soil solubilisation (Ghosh *et al*., 2007; Nair *et al*., 1979). The additions of Phosphorus, Calcium, Potassium and Magnesium have been shown to improve yield performance (Peanut CRSP, 1997; Piggott, 1960).

For new crop varieties, different aspects of plant population and spatial arrangement need to be understood, as well as their performance in different climatic zones (Ntare, 1990). Several reports on groundnut research indicate that climate and plant spacing were related to growth habit with closer spacing giving higher pod yield (Patel, 1988; Piggott, 1960; Tarimo, 1997). Factors promoting vegetative growth such as high soil nitrogen, available soil moisture and low plant population density have all been found to greatly reduce pod yield (Bullock *et al*., 1998; Kang Young Kil *et al*., 1998; Tarimo, 1997). High plant population density in groundnut results in rapid canopy closure that significantly minimizes competition from weeds (Ahmad *et al*., 2007; Bradley, 2006; Lee *et al.*, 1994; Thellen, 2006), occurrences and spread of tomato spotted wilt virus (Branch *et al*., 2004; Brown *et al*., 2005; Gorbet and Shokes, 1994; Jadhav, 2006; McGriff *et al*., 1999; Wehtje *et al*., 1994) and groundnut rosette virus (Gibbons and Martins, 1980; Mahmoud *et al*., 1992; Schilling and Gibbons, 2002). Close spacing is also known to give compact and higher pod yield (Ahmad *et al*., 2007; Buchanan and Hauser, 1980; Duke and Alexander 1964; Norden and Lipscomb 1974; Schilling, 2002). The establishment of sole groundnut crop using unsuitable varieties in wide rows, which often lead to lower pod yields $ha^{-1,}$ has been attributed to sub-optimum plant population densities that poorly utilizes labour, crop growth resources and scarce land in the face of pressing need for cash income by the farm family (Kafiriti, 1994; Schilling and Masari, 1992).

Faced by numerous production obstacles such as access to land, poor seed and agronomic practices and non-supportive small scale policies, Farm families in Ghana cultivate groundnut on small scales, both in pure stands and in crop mixtures, especially with cereals (Naab *et al.*, 2005; Tsigbey *et al.*, 2003; Atuahene-Amankwa *et al*., 1990). Despite the numerous problems facing groundnut cultivation, it ranks as the number one grain legume grown, especially in the Guinea savanna zone of Ghana by about 90 % of farm families (Naab *et al.*, 2005). The cultivation of the crop in the forest-savanna transition and humid forest agro-ecologies is however beginning to attract farmer attention because of its cash value. The crop is grown on flats in these agro-ecologies mostly with untested varieties, non-recommended spacing arrangements and no fertilizer and pesticides use (Tsigbey *et al*., 2003). To meet the varietal and spacing needs of farmers in the hunid forest agro-ecological zone, there is the need to come up with groundnut varieties and spacing arrangement that will enable them to cultivate the crop on profitable and sustainable basis.

The objective of this study was therefore to assess and compare the effects of spatial arrangement on the growth, yield and nitrogen fixing abilities of six new groundnut varieties at Anwomaso within the humid forest agro-ecological zone of Ghana.

MATERIAL AND METHODS

Experimental site

The experiment was conducted in 2006 and 2007 on the Kwame Nkrumah University and Science and Technology (KNUST) Agricultural Research Station, Anwomaso. Anwomaso (Lat 6° 41.850' N and Long 1° 31.545' W at 292 metres above sea level) is a peri-urban town located about 2.5 km off the main Kumasi-Accra highway. Farming activity is the dominant occupation as in most other similar towns in Ghana. The land is greatly undulating with signs of strong disturbance, especially in the cultivated areas where sheet and gulley erosion are prominent. The climate of Anwomaso site is warm, moist with bimodal annual rainfall. The site experiences the major season from March-August, and the minor season from September-November. The average annual rainfall is about 2, 056.3 mm. The bulk of the rainfall however, is received during the major season. The minor season receives less rain comparatively but is often long enough and well distributed for the cultivation of short season crops. Following the minor season is a short dry season from early December to March. Average monthly atmospheric temperatures range from a minimum of 16.3 ^oC to a maximum of 35 ^oC with an annual mean temperature of 26.8 ^oC. The total amount of rainfall during the period of the experiment in 2006 was 1,998.3 mm which was lower and less evenly distributed than the rainfall of 2, 114.3 mm received during the same period in 2007.

Experimental design and treatments

The field experiment in both years was laid out in Randomized Complete Block (RCB) design with three replicates. Each gross plot measured 6 m x 6 m. A net plot which measured 4 m x 4 m was taken for crop growth and yield data analysis. The factors tested were crop variety and spacing. Treatments comprised six groundnut varieties made up of Adepa, Azivivi, Jenkaar and Nkosuor, obtained from Crop Research Institute (CRI), and Manipintar and Kpanieli from the Savanna Agricultural Research Institute (SARI). The different spacing arrangements used were 30 cm x 15, 40 cm x 10 cm and 50 cm x 10 cm. Maize crop variety (*Dorke* SR) planted at 75 cm x 40 cm was used as the reference crop for nitrogen estimation. Initial weed control operation was carried out using hand hoe three weeks after planting (3 WAP). Hand pulling was subsequently used to achieve effective weed control at 6 WAP following canopy closure.

Plant measurements

Measurement of growth parameters

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^{th} to 8^{th} week weeks after sowing. The height of each plant was measured using a measuring tape. Measurement was done from the ground level to the last terminal leaf of each plant at 4, 6 and 8 WAP. The average height per groundnut plant was then calculated. The canopy spread of the five plants selectively tagged for height measurement was also monitored. The 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, and the average canopy width determined.

Yield and yield components

Harvest from five consecutive groundnut plants were counted and the average of this taken as the number of pods plant^{-1}. The harvests from the 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}. Five sets of hundred seeds were then weighed and the average of these determined as the mean (100) seed weight. The total weight of groundnut from the respective net plots were recorded after plugging and drying to a moisture content of 13 % determined using a moisture meter. The weights of groundnuts harvest from each net plot were 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 (%), determined as the weight of groundnut seed divided by weight of pods as shown below.

Shelling outturn (%) = Ws / Wp x 100

Where;

Ws = weight of groundnut seed
Wp = weight of groundnut pods

Stover yield and estimation of nitrogen fixed

Groundnut haulms after harvest were dried and weighed. This was then added to the weight of the empty shells after shelling to obtain the total stover weight from each net plot. The values were then converted to stover yield ha^{-1} for each treatment. The technique used to estimate N_2-fixed was the Total Nitrogen Difference (TND) method as described by Hanssen (1994). The groundnut varietal trial was compared to a single treatment of maize per replicate, grown as the reference crop. The difference between the two crops on per plant basis was regarded as the quantity of N provided by biological nitrogen fixation (BNF).

Thus N_2- fixed = $Nyield_{fix}$ - $Nyield_{ref}$
% Ndfa = 100 ($Nyield_{fix}$ - $Nyield_{ref}$) / $Nyield_{fix}$

Where;

% Ndfa = percentage of plant nitrogen derived from atmosphere
$Nyield_{fix}$ = nitrogen yield by N_2-fixing system (groundnut)
$Nyield_{ref}$ = nitrogen yield by reference crop (maize)

Nitrogen yield (kg N ha^{-1}) was then estimated as the product of plant total dry matter yield (t ha^{-1}) and nitrogen concentrations.

Statistical methods

Data collected was subjected to statistical analysis using Genstat Discovery software (2011). The analysis of variance procedure for multifactor experiments was followed to determine whether differences existed among treatments. All treatments were compared using the Least Significant Difference (LSD) at 5 % probability level. 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 which recognizes negative one (-1) as perfect negative correlation, positive one (+1) as perfect positive correlation and zero (0) as no correlation (Allan, 2001; Pelosi and Sandifer, 2003).

RESULTS

Rainfall and temperature

The results of rainfall data in 2006 and 2007, and mean monthly rainfall from 1953 to 2007 at Anwomaso are presented in Figure-1.

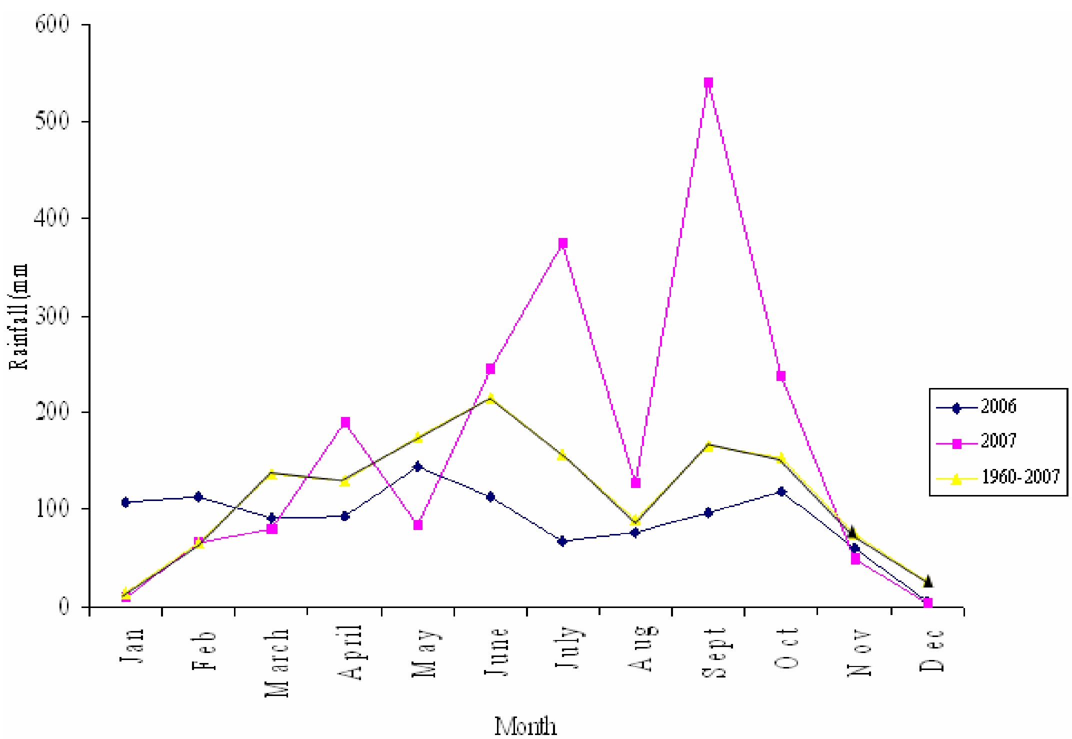

Figure-1. Mean monthly rainfall at Anwomaso in 2006 and 2007 compared to national mean monthly rainfall from 1960-2007.

The mean monthly rainfall in April, then from June to October 2007 were all higher than both their respective mean values in 2006, as well as the national mean monthly values from 1953 to 2007. The total annual rainfall (2, 114.3 mm) and mean monthly rainfall (178.69 mm) in 2007 were also higher than the 2006 values (1, 998.3 mm and 166.5 mm, respectively). Data on temperature (Table-1) show that there were no wide fluctuations in mean (Tmean), minimum (Tmin) and maximum (Tmax) temperatures in both years. Also, the general mean temperatures (26.7 ^{o}C and 26.8 ^{o}C) in 2006 and 2007 respectively did not show wide fluctuations.

Table-1. Minimum, mean and maximum temperatures at Anwomaso in 2006 and 2007.

Month	2006				2007	
	Tmin	**Tmean**	**Tmax**	**Tmin**	**Tmean**	**Tmax**
January	21.2	26.9	32.6	16.5	25.3	34.0
February	22.5	28.8	35.0	22.4	28.5	35.2
March	21.8	27.4	32.9	22.6	28.9	34.0
April	22.5	28.4	34.2	21.8	27.9	32.9
May	22.0	27.1	32.2	22.2	27.6	31.6
June	20.6	26.0	31.4	22.6	27.1	29.6
July	20.8	25.6	30.3	22.9	26.3	29.9
August	20.5	24.9	29.2	22.1	26.0	30.2
September	21.1	25.6	30.1	22.0	26.1	30.9
October	21.7	26.6	31.5	21.9	26.4	31.4
November	21.8	27.1	32.3	22.1	26.8	32.1
December	21.4	24.1	32.7	19.9	26.0	32.1
Mean	21.4	26.7	32.0	21.5	26.8	32.0

Note: Tmin (minimum temperature), Tmean (mean temperature), Tmax (maximum temperature)

Growth parameters

There were no significant influences of variety and plant spacing on groundnut height in 2006 (Table-2). Also, groundnut variety did not significantly influence canopy widths in 2006. Plants of the Manipintar variety which was the only indeterminate variety were significantly taller (P<0.05) than the rest of the varieties in 2007. Canopy widths of the Manipintar variety were also significantly wider at 4 and 6 WAP in 2007 (Table-2). The 30 cm x 15 cm spacing resulted in significantly taller plants than the 40 cm x 10 cm and 50 cm x 10 cm spacing in 2007. The 40 cm x 10 cm plant spacing also resulted in significantly taller (P<0.05) plants than the 30 cm x 15 cm spacing at 4, 6 and 8 WAP in 2007. Canopy widths were however, significantly reduced (P<0.05) by the 30 cm x 15 cm plant arrangement in both years (Table-2).

Table-2. Plant height and canopy widths at 4, 6 and 8 weeks after planting as affected by groundnut variety and spacing.

	Plant height (cm) **- WAP**						**Canopy width** (cm) **- WAP**					
	2006			**2007**			**2006**			**2007**		
Variety	4	6	8	4	6	8	4	6	8	4	6	8
Adepa	15.6	24.9	34.5	14.2	19.9	29.9	18.9	35.1	45.9	16.7	22.4	44.0
Azivivi	14.6	23.6	33.3	15.4	22.3	30.9	19.4	34.6	48.1	16.6	21.2	44.1
Jenkaar	14.0	24.7	33.9	15.7	23.1	33.3	17.3	36.1	49.5	17.5	21.9	47.8
Kpanieli	*	*	*	16.3	23.8	31.6	*	*	*	16.9	22.6	41.6
Nkosuor	15.5	23.1	32.6	15.3	22.3	30.9	19.7	34.0	45.2	16.7	20.9	43.4
Manipintar	*	*	*	19.8	33.4	39.9	*	*	*	19.2	27.4	43.0
Lsd $_{0.05}$	ns	ns	ns	0.7	2.8	3.3	ns	ns	ns	1.5	2.3	ns
Spacing												
30 cm x 15 cm	15.1	23.8	32.9	16.7	25.6	34.1	17.6	31.4	48.5	15.4	20.3	36.7
40 cm x 10 cm	15.1	24.5	34.4	16.0	23.9	32.6	18.2	34.2	48.5	16.8	22.3	45.9

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50 cm x 10 cm	14.6	23.9	33.4	15.7	22.9	31.1	20.8	39.3	54.5	18.9	26.0	49.3
Lsd $_{0.05}$	ns	ns	ns	0.7	2.0	2.4	1.5	3.5	4.2	1.0	1.7	2.9
CV (%)	2.5	5.4	6.0	3.1	9.9	7.1	5.3	3.8	4.7	3.2	4.3	8.9

Note: cm (centimetres), WAP (weeks after planting), *data not taken in that year, ns (no significant differences at P<0.05)

Yield and yield components

Groundnut variety did not significantly (P<0.05) influence the number of pods per plant and seeds per pod in both years, as well as mean seed weight in 2006 (Table-3). In 2007, The Kpanieli and Manipintar varieties supported significantly (P<0.05) higher number of pods per plant, seeds per pod and mean seed weight, hence higher shelling outturn although the differences in shelling outturn among varieties were not significant (Table-3). There was also no significant varietal influence on pod yield although yield of the Adepa and Kpanieli varieties were higher in 2006 and 2007, respectively. Plant spacing did not significantly influence pod yield in both years although yield obtained from groundnut established at 30 cm x 15 cm was relatively higher (Table-3). Mean seed weight was significantly (P<0.05) improved by the 30 cm x 15 cm and 50 cm x 10 cm spacing in 2006 and by the 50 cm x 10 cm spacing in 2007 (Table-3).

Table-3. Pod yield and yield components as affected groundnut variety and spacing arrangement.

Variety	**Pod yield** (tha^{-1})		**Number of pods per plant**		**Number of seeds per pod**		**Mean seed weight** (g)		**Shelling**	**Out turn** (%)
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Adepa	1.02	3.65	13.0	10.8	1.6	1.5	39.3	36.1	60.0	61.3
Azivivi	0.92	3.91	15.2	11.5	1.5	1.6	40.2	38.4	59.2	60.3
Jenkaar	0.90	3.51	14.0	13.5	1.5	1.5	38.5	35.9	59.3	59.2
Kpanieli	*	4.01	*	34.8	*	1.6	*	50.5	*	64.6
Nkosuor	0.99	3.15	21.3	11.1	1.7	1.6	39.7	38.3	60.4	58.6
Manipintar	*	3.58	*	21.3	*	1.5	*	46.1	*	65.0
Lsd $_{0.05}$	ns	ns	ns	3.6	ns	ns	ns	17.3	ns	ns
Spacing										
30 cm x 15 cm	1.18	3.59	15.2	16.9	1.6	1.6	40.0	41.1	56.6	60.4
40 cm x 10 cm	0.90	3.71	11.8	17.1	1.5	1.5	36.7	39.1	60.6	61.7
50 cm x 10 cm	0.94	3.40	15.2	17.7	1.5	1.5	40.8	42.4	60.0	62.4
Lsd $_{0.05}$	ns	ns	ns	ns	ns	ns	2.9	2.1	ns	ns
CV (%)	4.1	3.5	23.4	13.1	5.3	3.2	7.5	6.3	1.6	1.4

Note: t ha^{-1}(tons per hectare), g (grams), *data not taken in that year, ns (no significant differences at P<0.05)

Stover yield and estimation of nitrogen fixed

Both variety and spacing arrangement did not significantly (P<0.05) influence residue, seed and total nitrogen (%), as well as the stover yield in both years (Table-4). Also, there were no significant influences of variety on stover N (kg N ha^{-1}) in both years and by plant spacing in 2006 (Table-4). Stover N (kg N ha^{-1}) of the 30 cm x 15 cm plant spacing was however significantly higher (P<0.05) than the 40 cm x 10 cm and 50 cm x 10 cm spacing in 2007.

Correlation analysis

The correlation coefficients in 2006 and 2007 (Table-5) show that pod yield was positive and significantly correlated with stover N (r = 0.46, P<0.05). However, pod yield was negative and highly correlated with canopy width (r = -0.67, P<0.01). The number of pods per plant was also negative and significantly correlated with mean seed weight (r=0.86, P<0.01). Mean seed weight and shelling outturn were positive and significantly correlated (r=0.72, P<0.01). Canopy width was positive and highly correlated with stover yield (r=0.65, P<0.01) and stover N (r=0.75, P<0.01). Stover N was also found to be positive and significantly correlated with plant height (r=0.52, P<0.05) and stover yield (r=0.65, P<0.05).

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Table-4. Percent nitrogen, stover yield and stover N as affected by groundnut variety and spacing arrangement.

Variety	**Residue N** (%)		**Seed N** (%)		**Total N** (%)		**Stover yield** (tha^{-1})		**Stover N** (kg N ha^{-1})	
	2006	2007	2006	2007	2006	2007	2006	2007	2007	2007
Adepa	1.45	1.73	4.05	4.00	5.50	5.73	5.10	6.50	55.7	53.8
Azivivi	1.72	1.88	3.77	3.26	5.49	5.14	5.00	6.68	58.9	58.0
Jenkaar	2.09	2.15	3.47	3.97	5.56	6.12	6.41	7.05	61.2	55.1
Kpanieli	*	1.85	*	2.97	*	4.87	*	6.74	*	55.8
Nkosuor	2.43	1.97	3.48	3.11	5.91	4.08	4.98	6.01	59.4	56.8
Manipintar	*	2.13	*	3.66	*	5.79	*	6.67	*	60.2
Lsd $_{0.05}$	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Spacing										
30 cm x 15 cm	2.14	1.89	3.59	3.53	5.73	5.32	5.95	7.40	61.4	60.8
40 cm x 10 cm	1.84	2.17	4.02	3.64	5.84	5.81	5.90	6.31	60.1	55.8
50 cm x 10 cm	1.78	1.79	3.46	3.32	5.44	5.11	5.70	6.14	54.9	53.2
Lsd $_{0.05}$	ns	ns	ns	ns	ns	ns	ns	ns	ns	4.8
CV (%)	8.10	13.17	8.81	2.12	7.50	5.01	5.70	8.70	9.7	21.7

Note: t ha^{-1}(tons per hectare), kg N ha^{-1} (Nitrogen in kilograms per hectare), *data not taken in that year, ns (no significant differences at $P<0.05$).

Table-5. Correlations among some growth parameters and yield components.

	Cnpy	**Pdplt**	**Pdyld**	**Msw**	**RsdN**	**StvrY**	**StvrN**	**Shlng**
Hght	-0.29	0.23	0.24	0.26	0.34	0.09	0.52*	0.34
Cnpy		-0.16	-0.67*	-0.18	0.10	0.65*	-0.75*	0.11
Pdplt			0.04	0.86**	-0.09	-0.17	0.04	0.69*
Pdyld				0.01	0.43	0.45	0.46*	-0.09
Msw					-0.02	-0.18	0.13	0.72**
RsdN						0.03	0.01	0.06
StvrY							0.65**	-0.35
StvrN								-0.18
Shlng								-
*p<0.05	**P<0.01							
Hght	Plant height (cm)							
Cnpy	Canopy width (cm)							
Pdplt	Number of pods per plant							
Msw	Mean seed weight (g)							
RsdN	Percent residue nitrogen (%)							
StvrY	Stover yield (tha^{-1})							
Stvr N	Stover nitrogen (kg N ha^{-1})							
Shlng	Shelling outturn (%)							

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DISCUSSIONS

Growth parameters

With the exception of Manipintar, the rest of the varieties did not show variation in height in both years. This behaviour was probably due to genetic similarities with regard to the potential height the varieties could attain under similar environmental conditions. The Manipintar variety however showed significant difference mainly due to its indeterminate growth habit. In 2007, intense competition for light by close spacing, compared to wide spacing, and the subsequent rapid depletion of growth resources by closely spaced crop probably resulted in decreased growth at the later stages (Farnham, 2001; Porter *et al.,* 1997). The indeterminate growth habit of the Manipintar variety was largely to explain for its wider canopies during the 4^{th} and 6^{th} week sampling occasions in 2007. The lack of variation in canopy widths among the varieties at 8 WAP were probably due to closed canopies that promoted vertical growth as plants competed for space and light. The reduction in canopy width among groundnut planted at 30 cm x 15 cm and 40 cm x 10 cm were probably due to lack of space for horizontal growth. The close spacing arrangements which resulted in completely closed canopies 6 WAP was therefore more efficient in minimizing weed growth, allowing for the second weeding operation to be carried out by hand pulling (Tillman *et al.*, 2006; Baldwin *et al.*, 2001; Brown *et al.*, 2003 and 2005; Naab *et al.*, 2005).

Yield and yield components

The variations in number of pods plant^{-1} observed during this study confirm the findings of earlier scientific studies. Ahmad and Mohammad (1997) and Virk *et al*., (2005) both reported significant variations in pod number. Abdullah *et al*., (2007) reported between 18-24 pods plant^{-1}, and Virender and Kandhola (2007) reported 24.1-28.7 pods plant^{-1}. The general variation in number of pods plant^{-1} observed within seasons was probably due largely to the genotypes of the groundnut varieties (Wright and Bell, 1992). The higher pod yields in 2007 were probably as a result of relatively higher rainfall (2, 114.3 mm) compared to the lower rainfall of 2006 (1, 607.2 mm). Pod yield of the varieties in 2006 were therefore lower than that reported in earlier studies (Shambharkar *et al*., 2006; Abdullah *et al*., 2007; and Virender and Kandhola, 2007) and consistent with the reports of Mayeux and Maphanyane (1989). The 50 cm x 10 cm plant spacing produced the highest number of pods plant^{-1}. However, relatively close spacing (30 x 15 cm and 40 x 10 cm) recorded the greatest pod yields in both years. This was probably because the additional plants in the closely spaced crop more than compensated for the reduced number of pods plant^{-1}, giving higher pod yields in both years. Virk *et al*., (2005) had earlier reported more efficient utilization of solar energy and other growth resources by closely spaced groundnut crop which translated into higher pod yield. Establishment of groundnut at 30 cm x 15 cm increased pod yield by 10.3 % and 16.7 % respectively, in 2006 and 2007, confirming research reports by Ahmad *et al*., (2007) who found out that pod yield was 16 % higher in narrow-row plantings when compared with traditional wide-row crop. Norden and Lipscomb (1974) and Duke and Alexander (1964) had earlier reported pod yield among narrow-row groundnut to be 14 % higher than wide-row groundnuts. The lack of variations in number of seeds pod^{-1} in both years with regard to variety and plant spacing was probably attributable to lack of environmental influence on this trait (Ahmad and Mohammed, 1997; Ogundele, 1988). Mean seed weights of all treatments in both years were lower than the 61- 67.8 g reported by Virender and Kandhola (2007). The higher mean seed weight values of groundnut established at 50 cm x 10 cm both years confirms the research findings of Sumarnno and Adie (1995) who concluded that narrow plant spacing that result in high plant densities significantly reduced mean seed weight. The lower mean seed weight values recorded in 2007 for all treatments compared to 2006 were probably as a result of the relatively higher rainfall received during that year that might have encouraged continued vegetative growth at the expense of pod filling (Shilling and Gibbons, 2002).

Stover yield and estimation of nitrogen fixed

The establishment of groundnut in narrow rows (30 cm x 15 cm and 40 cm x 10 cm) supported smaller shoot dry matter (g plant^{-1}). However, the reduced shoot dry matter was more than compensated for by the additional plants m^{-2}, resulting in higher stover yield among narrow row groundnut compared to wide row (50 cm x 10 cm) crop. The stover yield by varieties and different plant spacing in 2006 were lower than in 2007 probably due to the adverse effects of the relatively lower rainfall during the 2006 cropping season. The observed relatively higher percent residue, seed and total N in 2007 was therefore probably due to the favourable climatic conditions that encouraged vegetative growth and production of sufficient dry matter that was used to support the process of N_2-fixation (Giller, 2001). In both years, stover N decreased with increasing row spacing, being hugely influenced by the amount of crop stover (t ha^{-1}). Groundnut varieties supporting large stover yield did not support the largest stover N in both years. However, establishment at 30 cm x 15 cm plant spacing supported the largest stover yield and stover N in both years. Stover N obtained from this study was similar to the reported 60 kg N ha^{-1} (Ghosh *et al*., 2007), 54-58 kg N ha^{-1} (Singh *et al*., 1988; Hedge and Dwivedi, 1993) values by earlier studies. Stover N of some treatments however were well below values reported by these studies. These differences could be attributed to both plant and environmental factors controlling N concentration in the residue, and varietal size that determines the overall stover yield (t ha^{-1}).

Correlation analysis

An increase in the number of pods per plant led to a decrease in the mean seed weight probably because of insufficient dry matter to fill all the pods formed. The corresponding increase in shelling outturn with increase in mean seed weight matches earlier observations by Boote *et al*., (1992) and Lapang *et al*., (1980). Increasing canopy size was also found to significantly reduce pod number since dry matter was diverted to support vegetative growth at the expense of pod formation. It however, led to increases in stover yield (t ha^{-1}) and stover N (kg N ha^{-1}) because of the increased amount of N assimilated into the vegetative structures (Bell *et al*., 1993).

CONCLUSIONS

The performance of the groundnut varieties in both years point clearly to the fact that optimum plant spacing is required to maximize returns to inputs and labour in groundnut production in the humid forest. The selection of the right varieties and achievement of this optimum spacing is essential in reducing weed competition and maximizing the use of soil, light and farm inputs. The Adepa and Kpanieli varieties produced the largest pod yield respectively, in 2006 and 2007 while the 30 cm x 15 cm plant spacing was found to give the largest pod yield per unit area. In addition, the 30 cm x 15 cm plant spacing resulted in the production of large crop stover and subsequently, large amounts of stover N in both years. Farmers in the humid forest zone therefore, can potentially benefit more from high pod production and stover N that would be made available to the succeeding crop by planting Adepa and Kpanieli at 30 cm x 15 cm.

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