International Journal of Plant & Soil Science
3(9): 1069-1082, 2014; Article no. IJPSS.2014.9.004

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Growth and Yield Performance of Groundnuts (*Arachis hypogaea* L.) in Response to Plant Density

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Authors' contributions

This work was carried out in collaboration between all authors. Authors HKD and RTA designed the study, wrote the protocol and analyzed the data. Author HKD wrote the first draft. Author RTA edited manuscript. Author IM was involved in the design of the study, carried out the field work, collected and compiled data. All authors read and approved the final manuscript.

Original Research Article

Received 10th February 2014
Accepted 31st March 2014
Published 18th June 2014

ABSTRACT

A field study was conducted at the University of Education, Winneba, Mampong-Ashanti campus during the 2009 and 2010 seasons to determine the effects of different sowing densities on the growth and yield of three groundnut cultivars. Azivivi, Nkosour and Shitaochi groundnut cultivars were sown at four sowing densities [Low (14.29 plants m^{-2}), Medium (16.67 plants m^{-2}), Control (20.0 plants m^{-2}) and High (33.33 plants m^{-2})] in a 3 x 4 factorial arranged in a randomized complete block design with three replications. Azivivi and Nkosour are improved 120-day maturing Virginia bunch types, while Shitaochi is a widely grown local 95–100-day maturing Spanish type. In 2009, Nkosour and Azivivi produced similar, but greater haulm (11-30%), pod (83-113%) and seed (71-95%) yield than the Shitaochi cultivar. The high plant density generally produced greater haulm, pod and seed yields in 2009 under adverse low rainfall environment. In 2010, Nkosour and Shitaochi produced similar haulm and seed yields, which were 12-17% and 9-17%,

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respectively, higher than the yields produced by Azivivi; and the low and medium sowing densities produced intermediate haulm and slightly greater pod and seed yields in 2010. It is recommended that Nkosour at high plant density be sown during the minor season; and Nkosour or Shitaochi at low or medium plant density during the major season for dual purpose haulm and seed production.

Keywords: Plant height; total dry matter accumulation; haulm; pod and seed yields; plant density; Arachis hypogaea.

1. INTRODUCTION

Groundnut or peanut (*Arachis hypogaea* L.) is an increasingly popular and valuable food, feed and cash crop in Ghana, especially in the Guinea savanna and forest-savanna transition agro-ecological zones, which account for about 85% of groundnut production in the country [1,2]. It is grown mostly by smallholder farmers as a main food or cash crop in the major season (March–July) or as a secondary food crop in the minor season (August–December) often planted after maize. In both seasons, the haulms (i.e. the stalks or stems of the crop without the pods) serve as a valuable indispensable source of feed, especially for cattle, sheep and goats.

Despite estimated yearly increases in total acreage cultivated, there has not been a corresponding increase in the total annual production, because of the generally low average yields on farmers' fields [3,4]. On the average, yields on farmers' fields are estimated to be about 900 kg ha^{-1} compared with the potential yields of 1800-2800 kg/ha for the improved cultivars recommended for production by farmers [5,6]. A major or significant contributor to these low yields on farmers' fields is the low or sub-optimum plant population densities often recorded by farmers. Typical plant population densities on farmers' fields range from 8 to 10 plants m^{-2} compared with the recommended plant population density of 20 plants m^{-2} [2,4,5,7]. Most small-holder farmers either plant their groundnuts randomly on the flat land without any defined plant spacing or on mounds constructed haphazardly. In both practices, the plant spacings adopted are usually very wide. Planting groundnut in wide rows or spacing is reported to lead to sub-optimum plant population densities and lower yields [8,9]. Few farmers plant the crop in well defined (spaced) rows or ridges, which when adopted tend to achieve optimum plant populations. Generally, altering plant population densities can affect crop growth and development, yield, quality factors and pest development in groundnut [10,11,12]. Attaining optimum plant population densities, particularly when close or narrow row spacings are adopted, can lead to early and complete canopy closure, greater LAI, increased solar radiation interception and utilization, reduced weed/crop competition, reduced incidence and severity of some diseases (e.g. groundnut rosette virus), increased crop growth rates and yields [10,13,14,15,16].

Several authors have reported that decreasing or narrowing row spacing from 80 to 40 to 20 cm [17] and higher plant population density: 22 to 33 plants m^{-2} [18]; 18 to 30 plants m^{-2} [19]; 4 to 12 to 24 plants m^{-2} [20] and 3.7 to 16.6 plants m^{-2} [21] have resulted in maximum or optimum yields of groundnuts. The objective of this study was to evaluate the growth and yield performance of three groundnut cultivars in response to different sowing densities when grown under rain-fed conditions.

2. MATERIALS AND METHODS

2.1 Site Description

The experiments were conducted during the 2009 minor (October, 2009 to January, 2010) and 2010 major (April to July, 2010) cropping seasons at the research fields at the Mampong-Ashanti campus of the University of Education, Winneba. Mampong-Ashanti (07^o 8'N, 01^o 24'W; 456 m altitude) is located in the forest-savanna transition agro-ecological zone of Ghana. The soils at the experimental site belong to the Bediase series (deep sandy-loam with pH of about 5.5-6.5) and are classified as Chromic Luvisol [22,23]. The monthly total rainfall, mean monthly minimum and maximum temperatures and humidity at the site in both seasons are provided in Table 1.

Table 1. Weather conditions at the experimental site during the 2009 and 2010 growing seasons

Month	Total monthly rainfall (mm)	Mean monthly temperature(ºC)		Mean monthly relative humidity(%)	
		Min.	Max.	6h	15h
		2009 minor growing season			
Oct 2009	138.6	22.0	31.0	98	67
Nov	45.2	22.0	32.0	98	60
Dec	33.4	23.0	33.0	97	56
Jan 2010	14.7	22.9	33.6	95	50
Total	231.9				
	2010 major growing season				
Apr	77.3	23.4	33.8	94	56
May	108.8	23.3	32.4	96	63
Jun	225.8	22.3	30.9	97	68
Jul	83.0	21.7	29.6	97	69
Total	494.9				

2.2 Experimental Design and Treatments

The experiment was laid out in a 3x4 factorial arranged in a randomized complete block design (RCBD) with three replications. Three groundnut cultivars (Azivivi, Nkosour and Shitaochi) were sown at four sowing densities [low (14.29 plants m^{-2}), medium (16.67 plants m^{-2}), control (20.0 plants m^{-2}) and high (33.33 plants m^{-2})]. The plant spacing used, which correspond with the above sowing densities were 70x20cm, 60x20cm, 50cmx20cm and 60 cmx10cm, respectively. Each plot size consisted of six ridges, with each ridge measuring 4 m long. Azivivi and Nkosour are improved 120-day maturing Virginia bunch type groundnut cultivars (reportedly tolerant to the rosette virus disease), while Shitaochi is a widely grown local 95–100-day maturing Spanish type groundnut cultivar (reportedly susceptible to the rosette virus disease) [5,6].

2.3 Crop Management Practices

Land preparation before sowing in each season consisted of slashing, disc ploughing and construction of ridges. Three to four seeds per hill were sown at a planting depth of about 3-5cm on the 3 October, 2009 and 10 April, 2010 for the two seasons, respectively. The emerged seedlings were later thinned to two plants per hill. Weeds were controlled manually using hoes at 3 and 6 weeks after planting (WAP) in the first season and 2, 4 and 6 WAP in the second season. Earthen up (i.e covering the base of the plant with soil) was done during the last weeding to protect developing pegs and pods from being exposed. As a result of intermittent drought in the first season, each plot received three supplemental irrigation applications of 34 litres of water each time per month in November and December, 2009.

2.4 Data Collected

Plant height and number of branches per plant were estimated from five randomly selected and tagged plants within the two middle harvestable rows at 10 days interval from 21 days after planting (DAP) up to 71 DAP. Data on total above ground dry matter production were measured at 30, 40, 50, 60, 70, 80 DAP and at harvest from five plants randomly selected and cut at ground level from the second and fifth rows of each plot. The samples were oven-dried at 75^{o}C for 72 hours and weighed. The number of pods per plant was measured from five plants selected from the harvestable area of each plot. In both seasons, maturity was estimated from visual observation of the onset of senescence characterized by the yellowing and browning of leaves. The two middle rows of each plot were harvested at maturity for haulm, pod and seed yield determination. Harvesting was done manually by hoe digging and hand pulling of dug plants. Pods were removed from plants, sun-dried for 10 and 14 days in 2009 and 2010, respectively, and weighed. The pods were then shelled and the seeds weighed for seed yield determination. The moisture level of seeds was taken using a GE Protimeter Grainmaster moisture meter after sun-drying in both seasons and was about 10-13 % for all samples.

2.5 Data Analysis

All data were analyzed using standard analysis of variance technique for a factorial RCBD experiment with the SAS/STAT statistical package [24]. The significantly different means were separated using the Least Significant Difference (LPD) at the 5% significance level ($P<0.05$). Correlation analysis between yield and yield components, pod and haulm yield was done.

3. RESULTS AND DISCUSSION

3.1 Plant Height

The effects of cultivar and plant density on groundnut plant height were significant in both 2009 and 2010 seasons. In both seasons, Shitaochi cultivar consistently had taller plants after 30 DAP than Azivivi and Nkosour, which produced similar plant heights (Figs. 1a and b). Plant height as a quantitative growth parameter is a genetic attribute, but can be influenced by environmental factors, mainly soil moisture and weeds. This is a genetic trait since Shitaochi is a semi-erect bunch Spanish type groundnut, whereas Azivivi and Nkosour, even though Virginia bunch types, showed slight spreading features. Konlan et al. [25] similarly observed that indeterminate spreading Manipintar and Kpanieli cultivar produced taller plants than other four groundnut varieties, which were of the bunch semi-erect types.

The plant density also influenced plant height in both seasons, with the high plant density treatment generally producing the tallest plants, the medium and control plant density treatments producing intermediate plant heights, while the low plant density had shorter plant heights (Figs. 1c and d). At the high plant density, plants compete for light and grow taller, a phenomenon common with crowded plants. This agrees with [26], who indicated that there is increased competition for light by closely spaced crops compared to widely spaced crops. Mozingo and Steele [11] also reported that increasing intra-row spacing among five groundnut cultivars resulted in decreased main stem height and lateral branch length obviously decreasing plant height. They further reported that main stems were taller for each increment in plant spacing.

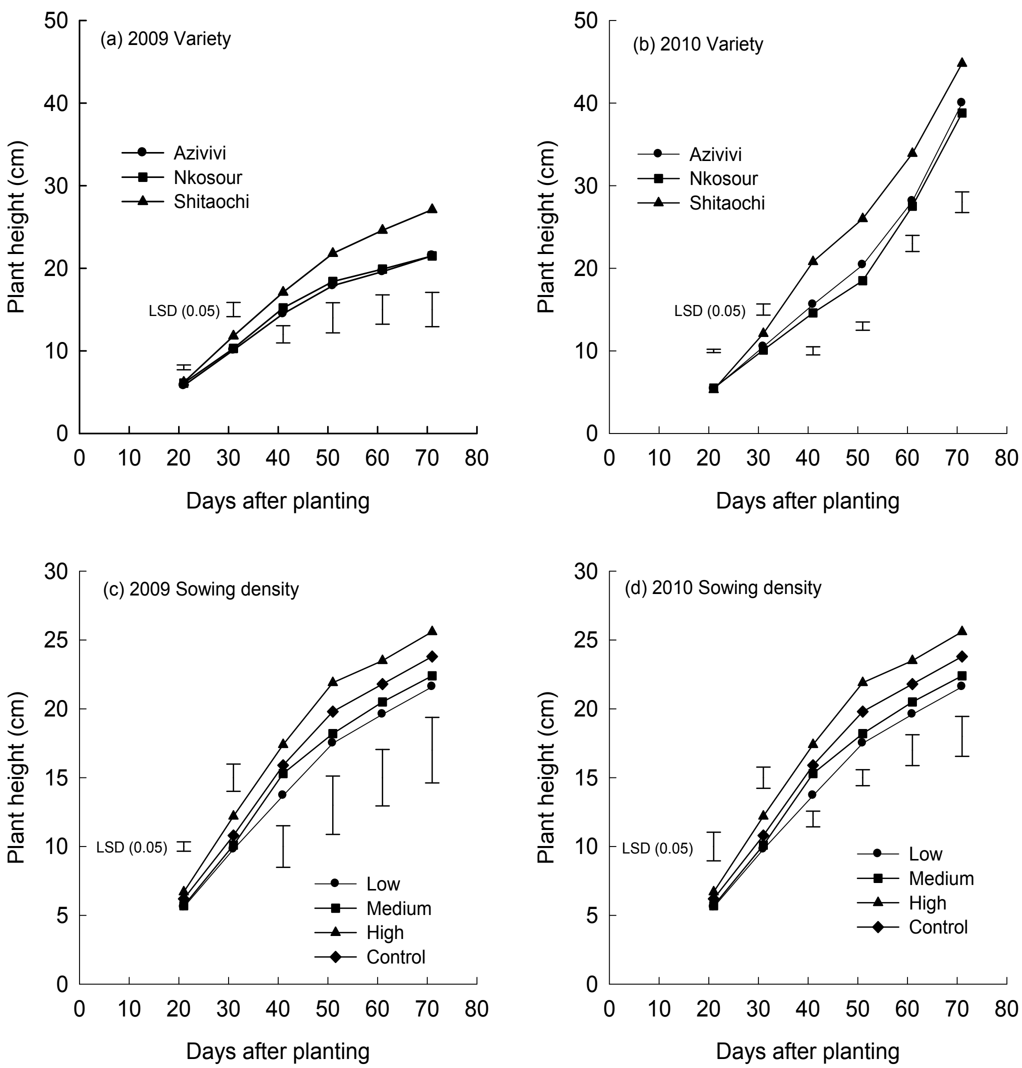

Fig. 1. Plant height of groundnut as affected by cultivar and plant density in 2009 and 2010

Generally, plant height was almost two times more in the 2010 season crops when compared with plant height in the 2009 season crops. High soil moisture due to high and well distributed rainfall, fast bushy growth of crops reducing weed competition, might have contributed to the improved plant height in 2010; as shown by [27] that adequate or excess soil moisture during the first two months after planting can trigger excessive vine growth in groundnuts.

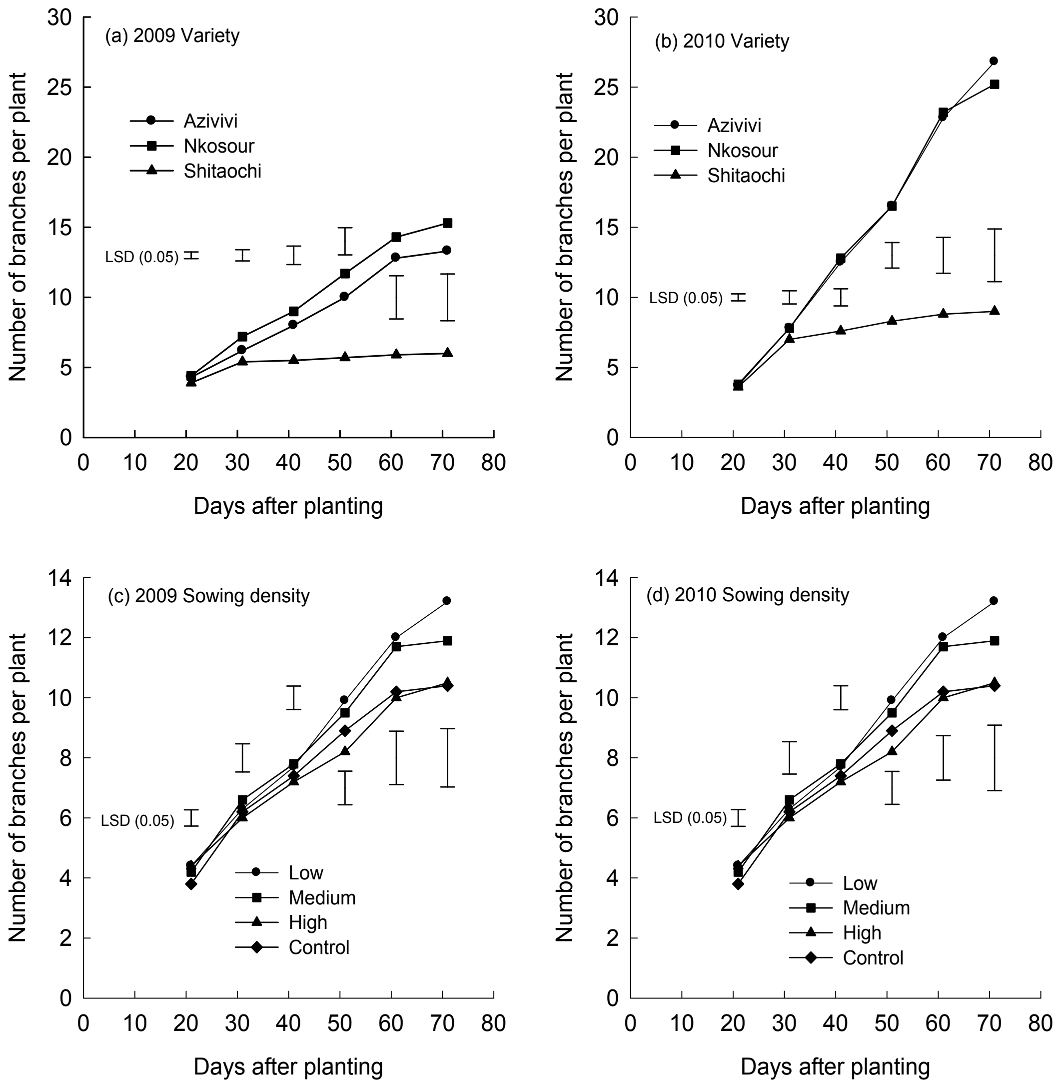

Fig. 2. Number of branches per plant of groundnut as affected by cultivar and plant density in 2009 and 2010

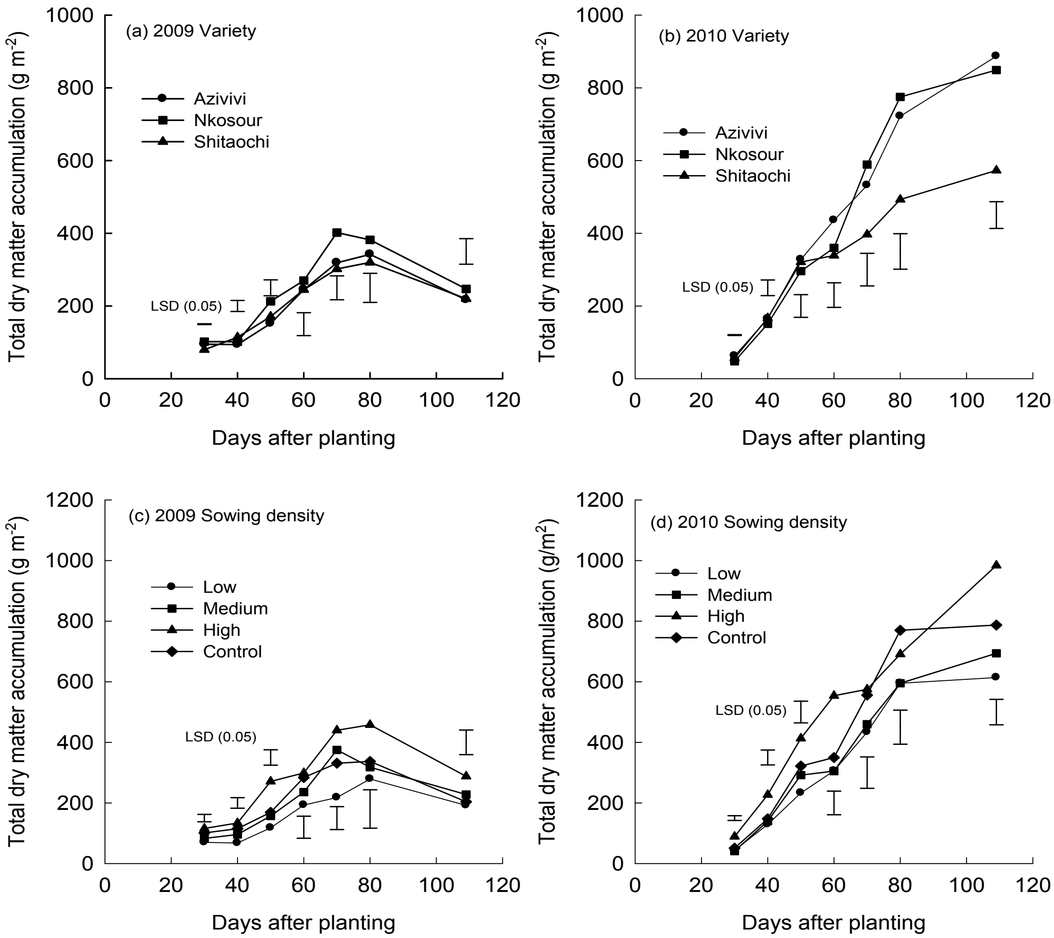

Fig. 3. Total dry matter accumulation of groundnut as affected by cultivar and plant density in 2009 and 2010

3.2 Number of Branches Per Plant

In 2009 and 2010, there were highly significant differences in the number of branches per plant produced among the cultivars after 31 DAP. Nkosour and Azivivi produced similar but significantly higher number of branches per plant than Shitaochi in both seasons (Figs. 2a and b). Branching in groundnuts may impact positively on yield since the branches bear the leaves and also determine the canopy spread and closure and solar radiation interception and utilization. In addition, the nodes of branches are potential sites for peg development and subsequent pod formation. Azivivi and Nkosour produced higher branches per plant than Shitaochi because of the slightly spreading nature of these two cultivars compared with the semi-erect bunch type Shitaochi cultivar. Konlan et al. [25] also observed in northern Ghana that the improved varieties Jenkar, Adepa, Nkosour and Azivivi had greater number of branches than the local variety Kpanieli. Similarly, they noted that Jenkar had significantly higher canopy spread or width than Azivivi, Kpanieli and Manipintar because of more number of branches per plant produced.

Plant density did not significantly influence branching in groundnut cultivars up to 40 DAP in both seasons (Figs. 2c and d). However, after 50 DAP, the low and medium sowing densities had slightly higher number of branches per plant than the control and high sowing densities (Figs. 2c and d). Wider spacing or lower plant density supported more branches per plant probably because of more available space for horizontal or lateral growth compared to close spaced or higher plant density crops. Closer spacing or higher plant density reduced branching as plants competing for space and light were compelled to grow taller. This phenomenon, according to [25,26,28], could be attributed to limited space available to closer spaced plants for branching or competition for light, leading to increase in height at the expense of branching. In contrast, [9] observed that close spacing or high plant density produced higher number of branches per plant in peanut. The greater branching trends observed in 2010 than in 2009 was due to the well distributed and higher rainfall experienced during the 2010 growing season.

3.3 Total Dry Matter Accumulation

In 2009, total dry matter (TDM) accumulation did not differ significantly among the groundnut cultivars, although Nkosour had slightly higher TDM after 60 DAP (Fig. 3a). However, in 2010, Azivivi and Nkosour produced significantly higher TDM accumulation than Shitaochi after 60 DAP (Fig. 3b). Azivivi and Nkosour are slightly spreading cultivars, which produced higher number of branches per plant than Shitaochi (Fig. 2b), and therefore, might have had larger and faster canopy formation and spread enabling them to intercept more solar radiation necessary for photosynthesis thus contributing to more TDM accumulation.

The TDM accumulation among the plant density treatments did not differ significantly in 2009, although the high plant density showed slightly higher TDM after 70 DAP (Fig. 3c). In 2010, the control and high sowing densities produced significantly higher TDM accumulation than the low and medium sowing densities after 60 DAP (Fig. 3d). The ability of plants to suppress weeds at high density and make maximum use of growth resources might have enhanced more TDM accumulation. These results agree with [7], who reported lower total DM in low plant density regimes than in medium and high regimes in groundnut. Lanier et al [10] also reported that closely spaced crops resulted in increased shoot dry matter, even at very high plant density due to a reduction in weed competition and efficient interception and utilization of solar radiation. The TDM accumulated in both variety and plant density treatments were higher in the 2010 than in the 2009, and reflected the more conducive environmental and edaphic conditions prevailing in the 2010 season.

3.4 Number of Pods Per Plant

The study showed varying number of pods per plant among varieties, sowing densities as well as between seasons. In both cropping seasons, varietal influence on the number of pods per plant was significant. In 2009, Azivivi and Nkosour produced on the average 8-9 pods per plant compared with 6 pods per plant for Shitaochi. However, in 2010, Shitaochi produced 33 pods per plant, 32% greater than the number of pods per plant produced by Azivivi and Nkosour (*c.* 25 pods per plant) (Table 2). The differences in number of pods among the varieties could be attributed to genotypic differences and their response to adverse environmental effects. Azivivi and Nkosour could be said to be more tolerant to water and heat stress than Shitaochi, as experienced in 2009. In 2010, when favourable environmental conditions were obtained, Shitoachi produced more number of pods than

Azivivi and Nkosour. Virk et al [29] reported that groundnut varieties differ significantly in the number of pods per plant.

Table 2. Yield and yield components of three groundnut cultivars as affected by plant density in 2009 and 2010.

Treatment	No. of pods per plant		100 seed wt.(g)		Shelling percentage (%)	
	2009	2010	2009	2010	2009	2010
Variety (V)						
Azivivi	7.8	25.9	34.3	46.8	62.5	66.8
Nkosour	8.8	25.1	36.7	49.3	61.2	69.6
Shitaochi	6.0	33.0	29.0	43.5	66.9	73.0
LPD (0.05)	1.8	2.9	3.9	2.9	3.0	2.0
Plant density (PD)						
Low	9.1	35.4	32.4	45.8	62.2	69.2
Medium	8.3	31.8	32.6	46.7	63.9	69.4
High	5.5	17.0	36.4	47.5	62.3	70.8
Control	7.2	27.8	31.8	46.2	63.1	70.4
LPD (0.05)	2.1	3.1	NS	NS	NS	NS
V x PD interaction	NS	NS	NS	NS	NS	NS

In 2009, the number of pods per plant for the sowing densities ranged from 5.5 to 9.1, with the high plant density producing the lowest number of pods per plant, while the low plant density produced the greatest. The medium and control sowing densities produced intermediate number of pods per plant (Table 2). In 2010, similar trends were obtained with the high plant density producing the least number of pods per plant (17 pods plant^{-1}), while the low plant density had the highest pod numbers per plant (35.4 pods plant^{-1}) (Table 2). The lower number of pods per plant produced by the high plant density may be attributed to increased intra-specific competition for growth resources compared to the low sowing densities. Increases in pods per plant with reduced plant densities have also been reported by [11] and [27]. Generally, extremely low number of pods per plant was recorded in 2009 due to the combined effects of low soil moisture and heat stress [30,31]. However, the number of pods per plant in 2010 season was high as a result of the high and well distributed rainfall during the season.

3.5 Mean Seed Weight

In both seasons, variations in mean seed weight (MSW), which ranged from 29-37 g and 44-49 in 2009 and 2010, respectively, was significantly influenced by cultivar (Table 2). Nkosour recorded the highest MSW, while Shitaochi produced the least MSW in both seasons. The varietal differences in MSW were mainly genotypic manifestation, since the seeds of Nkosour were generally larger and bigger. Nkosour and Azivivi also produced greater TDM accumulation than Shitaochi after 60 DAP when seed-filling might have commenced and thus improved MSW. Similarly, variations in mean seed weight were reported by [32] and [33] to be strongly influenced by groundnut varietal differences.

The different sowing densities did not have any significant effects on MSW in both seasons, similar to observations made by [25] in the Guinea savanna zone of Ghana. However, generally the high plant density tended to have slightly higher MSW, perhaps due to the lower number of pods per plant produced in both seasons (Table 2). With few pods per plant, more assimilates might have been partitioned to the seeds to produce slightly heavier mean seed weight. In this study, low MSW was recorded in all the cultivars and sowing densities in the 2009 growing season compared with the 2010 season; and might be attributed to the adverse effects of the relatively low rainfall received and water stress at the pod-filling stage in 2009 [25,34]

3.6 Shelling Percentage

The results showed high shelling percentage values among all the treatments in both seasons. Shelling percentage which ranged from *c.* 61-73% among the varieties differed significantly in both seasons, with Shitaochi recording the highest shelling percentage in 2009 and 2010 (Table 2). Azivivi and Nkosour had similar shelling percentages in both years. Shelling percentage is an index of the percentage of grains or seeds in groundnut pods on the basis of weight. Thus, although Shitaochi produced lower mean seed weight, its pod shells were very light and easier to crack compared with the thick, hard and heavier pod shells of Azivivi and Nkosour. This might have accounted for the higher shelling percentages in Shitaochi. Other studies have reported similar shelling percentage (66–70%, 48–61% and 54–66%) as this study [25,33,35]. The plant density did not influence significantly the shelling percentage of groundnuts in both seasons. However, generally, shelling percentage was about 13% higher in the 2010 season than 2009, and could be due to varietal responses to the erratic nature of rainfall in 2009.

3.7 Haulm Yield

There were significant effects of cultivar and plant density on haulm yield in both seasons (Table 3). However, pod and seed yield differed significantly only among the cultivars. Plant density did not affect both pod and seed yields in the two seasons. There was also no significant effect of cultivar x plant density interaction on haulm, pod and seed yields (Table 3). In 2009, Azivivi and Nkosour cultivars produced 24.3-28.4 t/ha, 488-567kg ha^{-1} and 305-347 kg ha^{-1} of haulm, pod and seed yield, respectively, which were 11-30%, 83-113% and 72-95%, respectively, higher than that produced by the Shitaochi (Table 3), because of the higher number of branches per plant, total dry matter accumulation, number of pods per plant and mean seed weight produced. Naab et al. [7] and [25] also reported that improved Manipintar, Nkosour, and Jenkaar cultivars yielded about 23-62% higher pod or seed yield than local Chinese or Kpanieli cultivars in the northern Guinea savanna zone of Ghana. However, in 2010, Nkosour and Shitaochi produced similar haulm and seed yields, which were 12-17% and 9-17%, respectively, higher than the yields produced by Azivivi, also as a result of higher number of pods per plant, mean seed weight and shelling percentage. Generally, the results indicated that Nkosour performed well under both erratic adverse low rainfall effects as well as favourable rainfall conditions and therefore quite stable, Azivivi had intermediate adaptability, whereas Shitaochi was adapted to more favourable rainfall conditions.

The high plant density produced the highest haulm yield, which was about 22-30 % greater than that produced at the medium and control sowing densities in 2009. The low plant density had intermediate haulm yield (Table 3). In 2010, the control and high densities produced similar haulm yields, which were 11-15 % greater than the haulm yield at low plant density. The high plant density tended to produce high haulm yield in both seasons because of the high TDM accumulation resulting from early canopy closure, efficient interception and utilization of solar radiation and reduced weed competition [36].

Table 3. Haulm, pod and seed yields of groundnut as affected by cultivar and plant density in 2009 and 2010

Treatment	Haulm yield ($t\ ha^{-1}$)		Pod yield ($kg\ ha^{-1}$)		Seed yield ($kg\ ha^{-1}$)	
	2009	2010	2009	2010	2009	2010
Variety (V)						
Azivivi	24.3	34.4	488	2785	305	1860
Nkosour	28.4	38.6	567	2911	347	2028
Shitaochi	21.8	40.4	266	2980	178	2176
LPD (0.05)	0.36	2.83	155.5	NS	101.6	211.5
Plant density (PD)						
Low	26.6	35.2	423	2917	263	2020
Medium	23.1	36.5	418	3009	267	2088
High	28.2	39.2	547	2824	341	2000
Control	21.4	40.4	374	2806	236	1978
LPD (0.05)	0.41	3.23	NS	NS	NS	NS
V x PD interaction	NS	NS	NS	NS	NS	NS

Table 4. Correlation coefficients of yield and yield components in 2009 and 2010

Parameters †	2	3	4	5	6
		2009			
1. 100 seed weight	0.48***	-0.05	0.55***	0.80***	0.80***
2. No. pods per plant		-0.24	0.48**	0.75***	0.73***
3. Shelling percentage			-0.14	-0.15	-0.05
4. Haulm weight				0.67***	0.64***
5. Pod yield					0.99***
6. Seed yield					-
		2010			
1. 100 seed weight	-0.28	0.21	-0.29	0.22	0.14
2. No. pods per plant		0.09	-0.09	0.43**	0.42*
3. Shelling percentage			0.15	0.06	0.36*
4. Haulm weight				0.08	0.21
5. Pod yield					0.95***
6. Seed yield					-

† Numbers against the parameters in columns correspond with variables in rows.
** =Significant at P=0.05; ** =Significant at P=0.01; *** =Significant at P<0.001*

3.8 Pod and Seed Yields

Although, pod and seed yields were similar among the sowing densities, the high plant density in 2009 (a lower rainfall season), produced pod and seed yields of 547 and 341kg ha^{-1}, respectively, which were about one and half times the pod and seed yields at the control plant density (374 and 236kg ha^{-1}) (Table 3). The low and medium sowing densities, on the average, produced 418-423 kg ha^{-1} and 263-267kg ha^{-1} pod and seed yields, respectively. In 2010, the low and medium sowing densities had similar, but slightly higher pod and seed yields than the control plant density. Several authors have also reported that haulm, pod and seed yields of peanuts increased with increased plant population or plant density [7,18,21,25,37,38].

The correlation analysis results in 2009 showed high, positive and highly significant correlation between seed yield and mean seed weight ($r=0.80$, $p<0.0001$); number of pods per plant ($r=0.73$, $p<0.0001$); haulm yield ($r=0.64$, $p<0.0001$) and pod yield ($r=0.99$, $p<0.0001$) (Table 4). Similarly in 2010, seed yield was positive and significantly correlated with number of pods per plant ($r=0.42$, $p=0.05$); shelling percentage ($r=0.36$, $p=0.05$), but high, positive and highly significantly correlated with pod yield ($r=0.95$, $p<0.0001$). Pod yield was also highly significantly correlated with mean seed weight ($r=0.80$), number of pods per plant ($r=0.75$) and haulm yield ($r=0.67$), especially in 2009 (Table 4). Strong and highly significant positive correlations between yield and yield components in peanuts have also been reported by [25,27,33,37,39].

4. CONCLUSION

In conclusion, groundnuts can be grown for its seed and haulm in both the major and minor seasons in the transition zone of Ghana. The study showed that Nkosour produced higher TDM accumulation, haulm, pod and seed yields in the adverse low rainfall minor season, as well as the well favourable rainfall major season. Shitaochi also performed significantly well with high haulm, pod and seed yields in the well favourable rainfall major season. Therefore, Nkosour is recommended for adoption by farmers in both the minor and major seasons for improved haulm and seed production of the crop in the transition zone or similar agro-ecological zones in Ghana. Shitaochi may also be adopted for haulm, pod and seed yields during the major season. The high plant density (33.3 plants m^{-2} produced high haulm, pod and seed yields under the erratic adverse low rainfall conditions and is also recommended for adoption under those conditions. Under well favourable rainfall conditions, the low (14.29 plants m^{-2}) and medium (16.67 plants m^{-2}) sowing densities are recommended for dual purpose haulm and seed production.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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