

Full Length Research Paper

Growth and yield response of two groundnut cultivars to row pattern in the forest-Savannah Transition Zone of Ghana

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Two field trials (2017 and 2018) were conducted at the research field of the University of Education, Winneba, Mampong Campus from May to August to determine the growth and yield response of groundnut to row pattern. The experimental design was a 2 x 4 factorial arranged in a randomized complete block design (RCBD) with three replications. The factors studied included: (A) Cultivar [(i) *Yenyawoso* and (ii) *Adepa*] and (B) Row pattern [(i) 50 cm x 10 cm, (ii) 60 cm x 10 cm single row, (iii) 50 cm x 20 cm x 20 cm (iv) 60 cm x 20 cm x 20 cm twin row]. The result revealed that *Adepa* produced taller plants, higher number of branches at 86 DAP, taller plants, 100 - seed weight and number of pods/plant than *Yenyawoso*. The 50 cm x 20 cm x 20 cm twin row pattern produced higher number of branches, taller plants, number of plants harvested and pod yield than other row pattern. The 60 cm x 20 cm x 20 cm twin row pattern produced higher 100 - seed weight and higher number of pods/plant than 50 cm x 10 cm and 60 cm x 10 cm single row pattern. Interaction effect between variety x row pattern was significant with number of branches at 58 and 86 DAP in 2018 cropping season. In conclusion groundnut farmers are to grow *Adepa* cultivar of groundnut using 50 cm x 20 cm x 20 cm twin row pattern for high yield and vegetative biomass. For heavy seeds farmers should grow *Adepa* using 60 cm x 20 cm x 20 cm twin row pattern.

Key words: Groundnut, *Adepa*, *Yenyawoso*, single row pattern, twin row pattern.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is one of the world most popular crops grown in tropical and sub-tropical

regions. The crop belongs to the family Fabaceae. It originated from South American, but it is now widely

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cultivated throughout the tropical, sub-tropical and temperate countries, and in Africa, Asia, North and South America. Due to its high protein, oil, fatty acid, carbohydrates, vitamins and minerals content, the crop has high commercial and nutritional values. Groundnut seeds are a rich source of oil (35-56%), protein (25-30%), carbohydrate (9.5-19%) and minerals (Gulluoglu et al., 2016a); Gulluoglu et al., (2016c). In Ghana, the paste obtained after the oil has been extracted can be moulded into different shapes and fried as "krukli". The crop is intercropped with other cereal crops such as pearl millet, maize, sorghum and cassava. Its cake is used as feed and haulms provide quality fodder (Martey et al., 2015).

Groundnut production in Africa covers 31.3% land area and 18.6% production. Ghana is one of the top six countries producing groundnut in Africa (FAO, 2008). Groundnut total production in Ghana range from 209,000 tons in 2000 to 530887 tons in 2010 and it is mostly produced by smallholder farmers (Angelucci and Bazzuchi, 2013). It is estimated that more than 70% of farmers in the three northern regions of Ghana grow groundnuts and together account for over 85% of the national output. Groundnut is an important legume crop grown and marketed by farmers in the study area. The crop provides substantial income which has helped to improve their livelihoods over the years. Most of the grains are transported to large market centres where they are sold and used for food and oil preparations. However, production has been on subsistence level with low crop yield. This is due to inappropriate use of agronomic factors such as row planting pattern. In addition farmers have been using local groundnut varieties for cultivation which usually give low yield. Single row planting pattern has been a traditional cultivation method used by groundnut farmers in the forest-savannah transitional agro-ecological zone of Ghana. For improved groundnut varieties it is important to accommodate the most appropriate row planting pattern and number of plants per unit area to obtain better yield (Gulluoglu et al., 2016b). Understanding the proper planting pattern is very important to increase crop yield (Knezevic et al., 2003). A particular planting pattern for a specific leguminous crop may provide an optimum space to maximize vegetative parts which will receive higher solar energy and results in maximum yield. Adjusting row planting pattern is one of the important agronomic practices for increasing yield of row crop and reducing competition in environmental and soil resources. The response of groundnut to single -row and twin-row pattern has been investigated by many researchers. Gulluoglu et al. (2016) reported that twin row pattern increased yield (4906 kg ha⁻¹) from 80 cm x 25 cm x 80 cm x 30 cm (63.2 plants m⁻¹) than single row pattern with yield (35.7 plants m⁻¹).. The yield increase was however, 24.4% in twin row pattern than conventional single row pattern (standard). There is however, limited research conducted and little information available to compare the performance of newly released groundnut cultivars in terms of growth

and yield as influenced by single and twin row pattern in the study area. The study therefore seeks to determine the effect of row pattern on growth, yield and yield components of two cultivars of groundnut in the forest-savannah transition zone of Ghana.

MATERIALS AND METHODS

Description of study area

Two field experiments were carried out at College of Agriculture Education of the University of Education, Winneba, Asante Mampong campus during 2017 and 2018 cropping seasons. The experimental site is gently incline and is well drained. The climatic conditions at the experimental sites for 2017 and 2018 cropping seasons is presented in Table 1. The climatic conditions during the field research periods show that differences in environmental factors (rainfall, temperature and relative humidity) were shown in both cropping seasons. The overall monthly rainfall during the 2017 cropping season was 512.4 mm and it occurred from May to August, 2017 with the peak in May and June (Meteorological Department- Mampong-Ashanti, 2017). The average monthly temperature of the experimental site for the 2017 cropping season was between 21.7 to 32.4°C, with the highest daily of 32.4°C occurring in May. The mean monthly relative humidity ranged from 63% to 97% with the highest occurring between June and July. In the 2018 cropping season, the overall monthly rainfall was 568.0 mm and it occurred from May to August with the peak in May and June (Meteorological Department- Mampong- Ashanti, 2018). The average monthly temperature of the experimental site for the 2018 cropping season was between 21.2 to 31.1°C, with the highest daily of 31.1°C occurring in May. The mean monthly relative humidity ranged from 65% to 92% with the highest occurring between May and June.

The soil at the experimental site has been categorized as Chronic Luvisol and locally as the Bediesi series with a pH range of 4.0-6.5 suitable for root, cereal, vegetable and legume crops production (Asiamah, 1988; FAO/UNESCO, 1988) legume.

Experimental design and planting

The experimental design was a 2x4 factorial arranged in a Randomized Complete Block Design (RCBD) with three replications. The factors studied included: (A) Variety (*Yenyawoso* and *Adepa*) and (B) Row pattern and spacing (i) 50 cm x 10 cm single, (ii) 60 cm x 10 cm single row, (50 cm x 20 cm) x 20 cm twin row and (iv) (60 cm x 20 cm) x 20 cm twin row.

The total field size of 28.8 m x 13 m (374.4 m²) was demarcated, cleared, lined and pegged and ridges prepared. Each experimental plot measured 2 m x 2 m, 2.4 m x 2 m, 2.8 m x 2 m and 3.2 m x 2 m, respectively based on the respective treatment. Each experimental plot had 120 plants based on row planting spacing and pattern. A space of 2 m was left between blocks with 1 m interval between plots. Two cultivars *Yenyawoso* and *Adepa* seeds obtained from Crops Research Institute (CSIR) in Kumasi, Ghana were used as a plant material in the study. Both cultivars have a semi-erect growth form with high oil content in the seed, high yield capacity and a growing period of between 60 to 115 days. Three seeds of *Yenyawoso* and *Adepa* were planted per hill at a depth of 3-4 cm according to planting spacing and row patterns. Seedlings were thinned to 1 plant per hill 8 days after emergence. Each treatment plot had 4 rows on single row pattern with thirty plants on each row and eight rows on twin row pattern with fifteen plants on each row.

Table 1. Climatic data for 2017 and 2018 experimental periods.

Month	Total monthly rainfall (mm)		Mean monthly relative humidity (%) (Hours GMT)				Mean monthly temperature (°C)			
			06.00		15.00		Minimum		Maximum	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
May	161.2	184.6	95	91	63	65	23.6	22.9	32.4	31.1
June	175.0	185.5	97	92	70	73	23.0	22.5	30.6	29.7
July	139.3	157.2	97	89	75	73	21.8	22.0	29.2	29.8
August	51.8	40.7	96	86	73	71	21.7	21.2	27.2	28.3
Total	512.4	568.0								

Meteorological Department- Mampong-Ashanti, Ghana (2017, 2018).

Data collection and analysis

Data were collected on sixty plants from the two middle rows and the means were taken. The quantitative traits measured were number of branches per plant, plant height, number of plants harvested, number of pods per plant, 100-seed weight and pod yield ($t\ ha^{-1}$). Number of branches per plant was counted from the two harvestable areas. Plant height was measured on three plants from the two middle rows with meter rule. Number of plants harvested and number of pods per plant were counted from the two middle rows on the day of harvest. The 100-seed weight was determined by randomly sampling 100 - seeds from the two middle rows and the weight determined using electronic weighing scale. Data collected were subjected to ANOVA using GenStat Statistical Package, version 11.1. Least significant difference (LSD) was used to separate means at 5% level of probability.

RESULTS

Vegetative growth

Number of branches per plant

There was a significant difference between Adepa from Yenyawoso in terms of number of branches per plant for the entire 2017 and 2018 cropping seasons (Table 2a and b). The 50 cm x 10 cm and 60 cm x 10 cm single row pattern produced the same number of branches per plant at 30 days after planting (DAP) during the 2017 cropping season (Table 2a). The 50 cm x 10 cm and 60 cm x 10 cm single row pattern differed significantly from 50 cm x 20 cm x 20 cm and 60 cm x 20 cm x 20 cm twin row pattern in number of branches per plant at 30 DAP during the 2017 cropping season (Table 2a). The 60 cm x 10 cm single row pattern differed significantly from those planted on 50 cm x 20 cm x 20 cm and 60 cm x 20 cm x 20 cm twin row pattern in number of branches per plant for the entire growing period during the 2017 cropping season (Table 2a). There was no significant difference between variety x row pattern interaction in number of branches per plant in 2017 cropping season (Table 2a). The 50 cm x 10 cm differed significantly from other spacing at 30 DAP and 58 DAP in number of branches during the 2018 cropping season (Table 2b). There was no significant difference between single row and twin row

pattern in number of branches per plant at 44, 72 and 86 DAP during the 2018 cropping season (Table 2b). There was a significant difference between variety x row planting spacing and pattern in number of branches per plant at 58 DAP and 86 DAP during the 2018 cropping season (Table 2b).

Plant height

There was a significant difference between Yenyawoso from Adepa in plant height at 44 DAP during the 2017 cropping season (Table 3a). However, Adepa had significantly taller plants from Yenyawoso at 86 DAP in the same cropping season. There was no significant difference between variety at 30 DAP and from 58 DAP to 72 DAP in plant height in 2017 cropping season (Table 3a). The 50cm x 10 cm single row pattern produced significantly taller plant than 50 cm x 20 cm x 20 cm and 60 cm x 20 cm x 20 cm twin row pattern at 30 DAP during the 2017 cropping season (Table 3a). There was no significant difference between row pattern in plant height from 44 DAP to 86 DAP at the same cropping period (Table 3a). There was no significant difference between variety x row pattern interaction in plant height for the entire 2017 growing period (Table 3a). There was a significant difference between Adepa from Yenyawoso in plant height at 30 DAP during the 2018 cropping season (Table 3b). However, Yenyawoso had significantly taller plants than Adepa from 44 DAP to 86 DAP in the same cropping season. There was no significant difference between single row pattern as well as with twin row pattern in plant height for the entire 2018 growing period (Table 3b). The 60 cm x 10 cm single row pattern produce significantly taller plants than 50 cm x 20 cm x 20 cm twin row pattern for the entire 2018 growing season. There was no significant difference between variety x row pattern interaction in plant height for the entire growing period in 2018 (Table 3b).

Yield and yield components

Number of plants harvested

Yenyawoso and Adepa had the same number of plants

Table 2a. Number of branches per plant as influenced by variety and row pattern- 2017 cropping season.

Treatment	30 DAP	44 DAP	58 DAP	72 DAP	86 DAP
Variety					
Adepa	6	8	10	12	13
Yenyawoso	5	6	8	10	10
Mean	5.5	7	9	11	11.5
LSD ($P \leq 0.05$)	0.85	0.98	0.86	0.86	0.86
Row pattern					
50 cm x 10 cm	7	7	9	11	12
60 cm x 10 cm	7	8	10	12	13
50 cm x 20 cm x 20 cm	5	6	8	10	11
60 cm x 20 cm x 20 cm	5	6	8	10	11
Mean	6	7	9	11	11.7
LSD ($P \leq 0.05$)	1.2	1.39	1.22	1.22	1.22
Variety x Row Pattern Interaction	NS	NS	NS	NS	NS

Table 2b. Number of branches per plant as influenced by variety and row pattern- 2018 cropping season.

Treatment	30 DAP	44 DAP	58 DAP	72 DAP	86 DAP
Variety					
Adepa	10	18	31	37	36
Yenyawoso	7	9	10	8	9
Mean	8.5	13.5	20.5	22.5	22.5
LSD ($P \leq 0.05$)	1.48	2.22	1.83	3.47	2.75
Row pattern					
50 cm x 10 cm	10	14	20	20	22
60 cm x 10 cm	9	14	17	22	20
50 cm x 20 cm x 20 cm	7	12	20	24	25
60 cm x 20 cm x 20 cm	8	13	23	25	23
Mean	8.5	13.3	20	22.7	22.5
LSD ($P \leq 0.05$)	2.09	NS	2.6	NS	NS
Variety x Row Pattern Interaction	NS	NS	3.67	NS	5.51

harvested and were not significantly different during the 2017 cropping season (Table 4). The 60 cm x 10 cm single row pattern and 50 cm x 20 cm x 20 cm twin row pattern had the same number of plants harvested and not significantly different in 2017 cropping season (Table 4). There was a significant difference between Yenyawoso from Adepa in number of plants harvested during the 2018 cropping season (Table 4). The 60 cm x 10 cm single row pattern differed significantly from 50 cm x 20 cm x 20 cm and 60 cm x 20 cm x 20 cm twin row pattern in number of plants harvested during the 2018 cropping season. There was no significant difference between

variety x row pattern interaction in number of plants harvested.

Number of pods per plant

There was no significant difference between Adepa and Yenyawoso in number of pods per plant during the 2017 cropping season (Table 4). There was no significant difference between row pattern in number of pods per plant during the 2017 cropping season although differences exist between treatment (Table 4). Adepa

Table 3a. Plant height as influenced by variety and row pattern- 2017 cropping season.

Treatment	30 DAP	44 DAP	58 DAP	72 DAP	86 DAP
Variety					
Adepa	10.3	18.9	33.6	45.2	58
Yenyawoso	10	21.2	36.4	45.5	54.6
Mean	10.1	20	35	45.3	56.3
LSD ($P \leq 0.05$)	NS	1.77	NS	NS	3.35
Row pattern					
50 cm x 10 cm	11.6	20	36.4	45.4	56
60 cm x 10 cm	10.6	19.4	35.2	46.7	56.3
50 cm x 20 cm x 20 cm	9.7	20.2	35.3	45.6	57.1
60 cm x 20 cm x 20 cm					
Mean	8.7	18.6	33.3	43.7	55.8
LSD ($P \leq 0.05$)					
Variety x Row Pattern Interaction	10.1	20	35	45.3	56.3
	2.01	NS	NS	NS	NS
	NS	NS	NS	NS	NS

Table 3b. Plant height as influenced by variety and row pattern- 2018 cropping season.

Treatment	30 DAP	44 DAP	58 DAP	72 DAP	86 DAP
Variety					
Adepa	8.2	15	25.8	26.6	29.1
Yenyawoso	7.3	19.7	31.6	33.2	35.7
Mean	7.7	17.3	28.7	29.9	32.4
LSD ($P \leq 0.05$)	0.77	1.58	4.49	2.88	3.12
Row pattern					
50 cm x10 cm	8.9	19.5	31.6	31.4	35.1
60 cm x10 cm	8.7	18.8	33.3	34	36.3
50 cm x 20 cm x 20 cm					
60 cm x 20 cm x 20 cm	7.2	17	27	29.3	31.4
Mean	6.3	14.2	22.8	24.9	26.9
LSD ($P \leq 0.05$)					
Variety x Row Pattern Interaction	7.7	17.3	28.7	29.9	32.4
	1.09	2.24	6.35	4.07	4.42
	NS	NS	NS	NS	NS

differed significantly from Yenyawoso in number of pods per plant during the 2018 cropping season. There was no significant difference between 50 cm x 20 cm x 20 cm from 60 cm x 20 cm x 20 cm twin row pattern as well as between 50 cm x 10 cm and 60 cm x 10 cm single row pattern. There was a significant difference between 60 cm x 20 cm x 20 cm twin row pattern from 50 cm x 10 cm and 60 cm x 10 cm single row pattern. There was no significant difference between variety x row pattern interaction in number of pods per plant during the 2018 cropping season (Table 4).

100 - Seed weight

There was a significant difference between Adepa and Yenyawoso in 100 - seed weight in both 2017 and 2018 cropping seasons (Table 5). There was no significant difference between row pattern in 100 - seed weight although differences exist among treatments in both 2017 and 2018 cropping seasons (Table 5). There was no significant difference between variety x row pattern interaction in 100 - seed weight in both 2017 and 2018 cropping seasons (Table 5). Yenyawoso and Adepa

Table 4. Number of plants harvested and number of pods per plant as influenced by variety and row pattern- 2017 and 2018 cropping seasons.

Treatment	Number of plants harvested		Number of pods per plant	
	2017	2018	2017	2018
Variety				
Adepa	50	32	30	86
Yenyawoso	50	38	34	64
Mean	50	35	32	75.5
LSD ($P \leq 0.05$)	NS	4	NS	11
Row pattern				
50 cm x 10 cm	48	38	27	64
60 cm x 10 cm	51	40	32	70
50 cm x 20 cm x 20 cm	51	34	35	82
60 cm x 20 cm x 20 cm				
Mean	50	29	34	86
LSD ($P \leq 0.05$)				
Variety x Row Pattern Interaction	50	35.2	32	75.5
	NS	5.67	NS	15.5
	NS	NS	NS	NS

Table 5. 100 - seed weight (g) and Yield ($t ha^{-1}$) as influenced by variety and row pattern- 2017 and 2018 cropping seasons.

Treatment	100 - seed weight (g)		Yield ($t ha^{-1}$)	
	2017	2018	2017	2018
Variety				
Adepa	70.4	76	3.94	5.86
Yenyawoso	56.4	69.2	3.73	5.12
Mean	63.4	72.6	3.83	5.49
LSD ($P \leq 0.05$)	7.85	5.45	NS	NS
Row pattern				
50 cm x 10 cm	67.5	71.2	4.3	4.88
60 cm x 10 cm	62.2	70.5	4.04	4.81
50 cm x 20 cm x 20 cm	63.7	73.3	3.71	6.7
60 cm x 20 cm x 20 cm				
Mean	60.3	75.3	3.29	5.58
LSD ($P \leq 0.05$)				
Variety*Row Pattern Interaction	63.4	72.6	3.83	5.49
	NS	NS	NS	NS
	NS	NS	NS	NS

planted on both single and twin row pattern during the 2018 cropping season had heavier 100 - seed weight than those planted on same during the 2017 cropping season (Table 5).

Yield ($t ha^{-1}$)

The yield varies between 3.73 - 3.94 $t ha^{-1}$ and 5.12 - 5.86

$t ha^{-1}$ in variety and 3.29 - 4.30 $t ha^{-1}$ and 4.81 - 6.70 $t ha^{-1}$ in row pattern during 2017 and 2018 cropping seasons respectively (Table 5). There was no significant difference between variety, row pattern and their interaction in yield during 2017 and 2018 cropping seasons although differences exist among treatment (Table 5). Adepa and Yenyawoso planted on both single and twin row pattern during the 2018 cropping season had higher yield than those planted on same during the 2017 cropping season

(Table 5).

DISCUSSION

Number of branches per plant

The significant difference between Adepa from Yenyawoso in number of branches per plant in both 2017 and 2018 cropping seasons could be due to differences in genetic traits. Onat et al. (2016) reported that peanut cultivars vary in growth habit and branching patterns ranging from the erect, semi-erect and runner types. The highest number of branches per plant in Adepa could also be attributed to presence of both primary and secondary branches produced coupled with more spreading nature of Adepa than Yenyawoso cultivar. This agrees with Konlan et al. (2013) in an observation made in northern Ghana that the improved variety, Adepa produced more number of branches per plant compared to other local varieties. The significantly higher number of branches per plant produced by 50 cm × 10 cm and 60 cm × 10 cm single row pattern than 50 cm × 20 cm × 20 cm and 60 cm × 20 cm × 20 cm twin row pattern and with 50 cm × 10 cm single row pattern than the other row patterns at 30 DAP and 58 DAP in 2017 and 2018 cropping seasons respectively could be due to narrow intra row spacing and pattern. Plant density is an important factor in plant growth. The closed intra row spacing and single row pattern might have led to early canopy closure at the early growth stage of plants resulting in vigorous plant growth with less competition for light and nutrients (Hamakareem et al., 2016). This is in disagreement with El Naim et al. (2010) Ansa (2016) that at close spacing the branches develop less in number than at wider spacing and that there is reduced vegetative and lateral development with closely spaced groundnut plants. Similar observation was made by Onat et al. (2016) that at low plant density, existing plants developed more branches because of reduced in competition. The significant effect between variety × row pattern interaction at 58 DAP and 86 DAP in number of branches during the 2018 cropping season could probably be due to row pattern effect on variety coupled with higher rainfall and lower temperature experienced during the 2018 growing period compared to 2017 cropping period. Groundnut can be influenced by environmental factors such as soil moisture, temperature and plant density and that the growth and development is determined by the efficiency with which plant population uses available resources.

Plant height

The significant effect of Adepa and Yenyawoso in plant height during 2017 and 2018 cropping seasons could be

attributed to differences in genetic characteristics of cultivars. Plant height is a growth parameter and can be influenced by both genetic and environmental factors such as soil moisture, nutrient, light and plant spacing. Both groundnut cultivars are semi-erect type as a genetic characteristics and their response to the environmental resources might have affected their growth differently. The variations in plant height observed in this study confirm the findings of Dapaah et al. 2014 and Konlan et al. (2013), who reported variations among cultivars in plant height. The significantly taller plants produced by 50 cm × 10 cm and 60 cm × 10 cm single row pattern than 50 cm × 20 cm × 20 cm and 60 cm × 20 cm × 20 cm twin row pattern at 30 DAP and for the entire growing season in 2017 and 2018 respectively could be attributable to close intra row spacing and single row pattern. This could be that the narrow spaced plants did not get enough space for lateral growth thereby compelled to grow more in vertical position to intercept light. Dapaah et al. (2014) similarly reported that at the high plant density, plants compete for light and grow taller, a phenomenon common with crowded plants. Under high planting density the competition for photosynthesis and nutrient absorption among plants become severe and the stem grows tall (Gulluoglu et al., 2016).

Number of plants harvested

The study revealed varying number of plants harvested among varieties, row pattern as well as between cropping seasons. In 2017 cropping season, Adepa and Yenyawoso produced the same (50.0) and higher number of plants harvested compared to 32 – 38 plants harvested during the 2018 cropping season. The higher number of plants harvested in 2017 cropping season could probably be influence of environmental conditions like plant population, soil moisture and light on cultivars. The efficiency with which plants use available environmental resources may determine the growth and yield (Onat et al., 2016). The significantly higher number of plants harvested with Yenyawoso than Adepa during the 2018 cropping season could be due to differences in genetic traits and its response to initial high rainfall experienced during the growing period. The significantly higher number of plants harvested by 60 cm × 10 cm single row pattern than 50 cm × 20 cm × 20 cm and 60 cm × 20 cm × 20 cm twin row pattern during the 2018 cropping season could be attributed to narrow spaced and, single row pattern. Narrow spacing probably encouraged upward growth of groundnut to intercept light for utilization and growth while single row probably minimized intra plant competition for water uptake, soil moisture and nutrient compared to twin row pattern with high population density per plot. This is in contrast with Konlan et al. (2013) and Dapaah et al. (2014) that

groundnut grown on low plant densities, benefit from more water, solar energy and nutrition. The higher number of plants harvested during the 2017 cropping season than during the 2018 cropping season could be linked to tall plants produced in 2017. The close and positive relationship between the two groundnut varieties, row patterns in number of plants harvested and plant height during the 2017 growing season might have contributed to this observation. The tall plants produced might have enhanced light interception and utilization, hence high number of plants surviving until harvesting. Light interception is highly influenced by different planting patterns, and the more efficient capture and use of light contribute to yield advantages (Wang et al., 2017).

Number of pods per plant

The non-significant difference between varieties and row pattern in number of pods per plant during the 2017 cropping season could be that row pattern had no effect on variety. The significantly higher number of pods per plant produced by Adepa over Yenyawoso in 2018 cropping season could be due to differences in genetic trait and its response to high rainfall experienced during the growing period. The significant difference between 60 cm x 20 cm x 20 cm twin row pattern from 50 cm x 10 cm and 60 cm x 10 cm single row pattern in number of pods per plant could be attributed to wider spacing and twin row pattern. As the number of plants per unit area decrease, thus at low plant density competition for growth resources such as water, nutrient and light decrease. This is in conformity with earlier findings by Arioglu et al. (2017); Dapaah et al. (2014) and Konlan et al. (2013). Jaiswal et al. (2018) reported that wider spacing of 30 cm x 15 cm proved superior in increasing number of pods per plant than closer spacing of 22.5 cm x 10 cm. Wider spacing might have decreased inter and intra-specific competition for crop growth resources compared to narrow spaced plant. Crop yield is determined by the efficiency with which plant population use available environmental resources such as nutrient, light and water for growth (Onat et al., 2016; Angelucci and Bazzuchi, 2013).

Total yield (t ha⁻¹)

The higher yield produced in both cultivars and row pattern during the 2018 cropping season than in 2017 could be due to high rainfall experienced during the 2018 cropping period. Seasonal changes to rainfall could lead to changes in soil water content, which is likely to affect plant growth and yield. The higher rainfall experienced in 2018 than in 2017 cropping seasons might have enhanced plants to produce more leaves, large leaf area and canopy spread to maximize light interception during

growth and reproductive stages for high yield. Lack or inadequate rainfall during flowering and pod setting causes substantial decrease in yield. The production of high yield in Adepa than Yenyawoso in both 2017 and 2018 cropping seasons may be linked to high production of number of branches per plant in Adepa at 86 DAP. This agrees with Dapaah et al. (2014) that nodes of branches are potential sites for peg development and subsequent pod formation and that branching characteristics is an important agronomic traits for crop yield. Konlan et al. (2013) reported higher yield in Adepa than other four groundnut varieties in northern Ghana. The higher yield in 50 cm x 20 cm x 20 cm twin row pattern during the 2018 cropping season than same during the 2017 cropping season and the other row patterns may be attributed to wider spacing and twin row pattern. Wider spacing might have decreased inter and intra plant competition for resources such as moisture, nutrient and light. This agrees with Arioglu et al. (2017) and Onat et al. (2016). Planting spacing, row pattern, plant density and branching are some of the most important factors that may have direct influence on crop yield. There was a close and positive relationship with number of branches per plant at 86 DAP and pod yield with 50 cm x 20 cm x 20 cm twin row pattern in 2018 cropping season. Branching in groundnut may impact positively on yield since the branches bear the leaves and also determine the canopy spread and closure and solar interception and utilization (Dapaah et al. (2014). This is in support of Onat et al. (2016) that at low plant density, existing plants developed more branches and pegs because of reduction in competition.

100 - Seed weight

Adepa produced significantly higher 100 - seed weight than Yenyawoso in both cropping seasons. This might be due to differences in genetic characteristics. Konlan et al. (2013) earlier reported that Adepa with bunch semi-erect growth habit produced heavier 100- seed weight than other local varieties which were of the bunch semi-erect types. The 50 cm x 20 cm x 20 cm and 60 cm x 20 cm x 20 cm twin row pattern produced heavier 100 - seed weight than 50 cm x 10 cm and 60 cm x 10 cm single row pattern during the 2018 cropping season. This might probably be due to the highest number of pods per plant produced. There was a close and positive relationship between number of pods per plant and 100 - seed weight during the 2018 cropping season. The low plant density might have contributed to decreased inter and intra-specific competition for growth resources and compensated for by the increased pods number per plant giving high 100 - seed weight. Increased in 100 - seed weight with decreased plant density with wider spacing have also be reported by Dapaah et al. (2014) and Konlan et al. (2013). The variety x row pattern interaction

effects for 100 - seed weight was not significant in both years.

Conclusion

In conclusion groundnut can be cultivated in the forest-savannah transition zone of Ghana for high vegetative biomass, pod yield and heavy seeds. Farmers are encouraged to grow preferably Adepa cultivar of groundnut under initial high rainfall condition for proper crop growth in terms of high number of branches and tall plants and also for high yield. Groundnut should be planted using 50 cm x 20 cm x 20 cm and 60 cm x 20 cm x 20 cm twin row pattern for high vegetative biomass, yield and quality seeds in terms of heavy seeds. Interaction effect between variety x row pattern was significant with number of branches per plant at 58 DAP and 86 DAP during the 2018 cropping season. This is an indication that row pattern had effect on variety and with higher rainfall and lower temperature experienced during the 2018 growing period compared to 2017 cropping period the growth of more branches per plant was enhanced. Nodes on branches are the potential sites for peg development and subsequent pod formation hence high yield in groundnut. Groundnut can be influenced by environmental factors such as soil moisture, temperature and plant density and that the growth and development of a crop is determined by the efficiency with which plant population uses available resources.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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