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Research Article
Influence of Row Spacing and NPK Fertilizer on the Growth and Yield of Two Groundnut (*Arachis hypogaea* L.) Varieties under Rain-Fed Condition in the Transitional Zone of Ghana

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Abstract

Background and Objective: Two field experiments (2018 and 2019) were conducted at the research field of the University of Education, Winneba, Mampong, Ashanti campus from May to August to determine the influence of row spacing and NPK fertilizer on growth and yield of groundnut under rain-fed condition in transitional zone of Ghana. **Materials and Methods:** The experimental design was a 2×3×2 factorial laid in a randomized complete block design with 3 replications. The factors studied included: (A) Variety [(i) Yenyawoso and (ii) Adepa], (B) Row spacing [(i) 30×15 cm, (ii) 40×15 cm, (iii) 50×15 cm] and (C) Fertilizer rates [(i) 20 kg ha^{-1} NPK 15-15-15 and (ii) No fertilizer (control)]. **Results:** The result according to the two year cropping seasons showed that Yenyawoso groundnut was found promising to produce high vegetative biomass and Adepa groundnut for high yield and heavy seeds. The 30×15 and 50×15 cm spacing produced heaviest pod weight and high yield respectively. Interaction effect between variety×spacing and variety×spacing×fertilizer was significant with number of branches, yield and haulm weight at harvest. **Conclusion:** Farmers are encouraged to grow Yenyawoso and Adepa groundnut varieties using 30×15 and 50×15 cm spacing for taller plants, highest number of branches, wider canopy spread and high yield and quality seeds with regard to weight respectively as well as apply NPK 15-15-15 at 20 kg ha^{-1} at the initial growth stage to boost groundnut growth and development.

Key words: Interaction effect, Adepa, Yenyawoso, variety, rain-fed condition, NPK fertilizer, Ghana

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Competing Interest: The author has declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is cultivated in tropical, sub-tropical and warm temperate regions between 40°N and 40°S latitude. The production is largely confined to Asian and African countries[1]. Groundnut is the most important food legume in Ghana in terms of consumption and area under cultivation[2]. Groundnut is a major crop in the Guinea and Sudan savannah zones of Ghana[3] and also produced in the forest savannah transition zone of Ghana. The forest savannah transition zone of Ghana is traditionally characterized by a multiplicity of uncertainties, to which farmers respond by cultivating a diversity of crop including leguminous crops[4]. The developing countries account for about 94% of the world groundnut production grown mostly under rain-fed conditions. In West Africa groundnut is usually grown under rain-fed conditions[5]. In the forest savannah transition zone of Ghana groundnut is usually grown under rain-fed conditions. Its production is highly vulnerable to intermittent drought conditions that may cause decreased yield of groundnut. To sustainably lessen the water deficit effects and improve groundnut production and yield, it is important to develop and release drought-tolerant varieties. Groundnut breeders at Crops Research Institute of CSIR in Ghana have selected and released new varieties improved for high yield, high oil content and adapted to grow well in the forest savannah transitional zone of Ghana.

Despite the availability of improved groundnut varieties, the full production potential is still not realized with grain yield on farmers' fields being still low. The decline in yield may be due to improper use of agronomic practices such as planting spacing, plant density and misuse/underuse of NPK fertilizer on the crop. The management of planting spacing dimensions as well as fertilizer application to groundnut in the field has been the subject of considerable discussion among agronomists for many years. The response of groundnut to spacing has been investigated worldwide. However, under local and rain-fed conditions, there is little information on the optimum row plant spacing for newly released varieties in the forest savannah transition zone of Ghana. Groundnut varietal response to spacing has been reported by Konlan *et al.*[6] in the humid forest zone of Ghana. Six different groundnut varieties studied using 30×15, 40×10 and 50×10 cm spacing showed that 30×15 cm spacing significantly increased pod yield by 16.8 and 0.6%, respectively in 2006 and 2007 in Anwomaso in the Ashanti Region of Ghana[6]. Earlier studies by Parameshwarareddy *et al.*[1] on effect of plant spacing (30×10, 30×7.5 and 30×5 cm) and three fertilizer levels (100, 125 and 150% RDF) on growth and yield of summer groundnut in Dharwad showed that combination of 30×10 cm with 125% RDF produced significantly higher pod yield compared to other combination. Fertilizer management is another core factor in improving groundnut yield[1]. In some developed countries like United States, groundnut is commercially grown and fertilized. However, in parts of Africa where most of the crop is used for local consumption, fertilizer application is not a common practice[7]. Supplying nutrients is required to increase the potential of crop cultivars. Groundnut responds rather well to fertilizers and produce high pod yield and vine biomass. In early stages of groundnut growth, nitrogen is very much in demand when the plants are in the initial stages of nitrogen fixation. Nitrogen plays an important role for good growth and development of groundnut and also controls the efficient utilization of phosphorus and potassium. A good strategy for nitrogen management in groundnut cultivation is to apply a starter dose of 15-20 kg N ha^{-1} and that the starter dose of nitrogen is side dressed along with phosphorus and potassium application just before sowing[8]. Phosphorus is an important nutrient for groundnut and that most of the groundnut production regions in Africa are deficient in P whilst in semiarid regions of Africa the crop can respond to application of K[7]. Therefore the appropriate row planting spacing and effective use of NPK fertilizer on groundnut is required for better utilization of growth resources like light, moisture and nutrients which will increase yield. The objective of the study was to determine the effect of row spacing and NPK fertilizer on the growth and yield of two varieties of groundnut under rain- fed condition in the transitional zone of Ghana.

MATERIALS AND METHODS

Description of study area: Two field experiments were conducted at the research field at the College of Agriculture Education of the University of Education, Winneba, Asante Mampong campus during 2018 and 2019 major rainy seasons. The experimental site is gently incline and is well drained. The climatic conditions at the experimental sites were determined during 2018 and 2019 cropping seasons. The result is shown 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 2018 cropping season was 568.0 mm and it occurred from May to August, 2018 with the peak in May and June[9]. The average monthly temperature of the experimental site for the 2018 cropping season was between 21.2-31.1°C, with the highest daily of 31.1°C occurring in May. The mean monthly relative humidity ranged from 65-92% with the highest occurring between May and June. In the 2019 cropping season, the overall monthly rainfall was 636.1 mm and it occurred from May to August with the peak in May and June[10].

Table 1: Climatic data for 2018 and 2019 experimental periods

	Total monthly rainfall (mm)		Mean monthly relative humidity (%) (GMT h)				Mean monthly temperature (°C)			
			06:.00		15:00		Minimum		Maximum	
Months	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
May	184.6	174.4	91	90	65	65	22.9	22.2	31.1	31.3
June	185.5	214.3	92	96	73	73	22.5	22.6	29.7	29.5
July	157.2	157.5	89	89	73	73	22.0	21.2	29.8	28.0
August	40.7	89.9	86	88	71	71	21.2	21.0	28.3	27.7
Total	568.0	636.1								

Source: Meteorological Department[9,10]

Table 2: Soil chemical properties at the experimental sites for 2018 and 2019 cropping seasons

Properties	2018	2019
pH (1: 2.5)	5.45	6.05
Organic carbon (%)	0.71	0.85
Total nitrogen (%)	0.07	0.10
Organic matter (%)	1.28	1.63
Exchangeable cations (me/100 g)		
Ca (mg/100 g)	3.52	4.82
Mg (mg/100 g)	1.96	2.36
K (mg/100 g)	0.14	0.20
Na (mg/100 g)	0.08	0.13
Total exchangeable bases	5.70	7.51
Effective cation exchange capacity	5.67	8.17

Source: SRI[14,15]

The average monthly temperature of the experimental site for the 2019 cropping season was between 21.0-31.3°C, with the highest daily of 31.3°C occurring in May. The mean monthly relative humidity ranged from 65-96% 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[11,12] legend. Soil samples were taken prior to inorganic fertilizer application for chemical analyses. Soil sample analysis was carried out at the Soil Research Institute of CSIR laboratory in Kumasi, Ghana. The characteristics analyzed for included pH in (1:1 soil:distilled water ratio) and measured by the potentiometric method on a pH meter manufactured by Veb Pracitron in Dresden, Germany. Organic matter was determined by the Walkey and Black[13] method and total nitrogen was determined by the micro Kjeldahl method. Exchangeable cations were determined by flame emission photometry. Extraction was carried out by filtration or centrifugation. Ca and Mg were determined using an atomic absorption or spectrometry (AAS) after the removal of ammonium acetate and organic matter at pH 7.0. The result on soil chemical properties is shown in Table 2. The soil of the experimental sites was acidic to slightly acidic, low to moderate in Organic matter content and Total Nitrogen levels and low in exchangeable calcium and potassium for the top soil in both 2018 and 2019 experimental periods.

Experimental design and planting: The experimental design was a 2×3×2 factorial laid in a randomized complete block design (RCBD) with 3 replications. The factors studied included: (A) Variety (Yenyawoso and Adepa), (B) Row spacing [(i) 30×15 cm, (ii) 40×15 cm and (iii) 50×15 cm], (C) Fertilizer rates [(i) 20 kg ha^{-1} NPK (15-15-15) and (ii) no fertilizer (control). The total field size of 19.2 m×13 m (249.6 m^2) was demarcated, cleared, lined and pegged and ridges prepared. Each experimental plot measured 4.8×3, 6.4×3 and 8.0×3 m, respectively as per the row planting spacing. Each experimental plot had 160 plants. A space of 2m was left between blocks. 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 varieties have a semi-erect growth habit with a maturity period of between 60-115 days. Three seeds of Yenyawoso and Adepa were planted per hill at a depth of 3-4 cm. Seedlings were thinned to 2 plants per hill 8 days after emergence. Each treatment plot had 4 rows with 40 plants on each row and 80 plants in the harvest area. The inorganic fertilizer, NPK (15-15-15) was applied two weeks after planting at 20 kg ha^{-1} as per treatment.

Data collection and analysis: Data were collected on seventy two plants from the two middle rows and the means were taken. The quantitative traits measured were percentage plant establishment, days to 50% pegging, days to 50% podding, number of branches, plant height, canopy spread, number of plants harvested, number of pods per plant, 100-seed weight, pod yield (t ha^{-1}) and haulm weight at harvest. The number of branches was counted from 6 tagged plants from the two middle rows. Plant height and canopy spread was measured on 6 tagged plants from the two middle rows with a meter rule. Number of plants harvested and number of pods/plant were counted from the two middle rows on the day of harvest. The100-seed weight was determined by randomly sampling100-seeds from the two middle rows and the weight determined using electronic weighing scale. Haulm weight at harvest was determined by taking the weight of haulm from the two middle rows and the weight

determined using electronic weighing scale. Data collected were subjected to ANOVA using GenStat Statistical Package, version11.1. Least significant difference (LSD) was used to separate means at 5% level of probability.

RESULTS

Phenology

Percentage plant establishment (%): There was no significant difference between varieties in percentage plant establishment in both 2018 and 2019 cropping seasons although Adepa produced higher (76.0) percent plant establishment than Yenyawoso (75.4) in 2018 cropping season whilst in 2019 cropping season Yenyawoso had the highest percent plant establishment (98.6) (Table 3 and 4). The 30×15 and 40×15 cm spacing performed better than other spacing in percent plant establishment in 2018 and 2019 cropping seasons, respectively. In both cropping seasons NPK amended plots performed better than the control in percent plant establishment (Table 3 and 4). There was no significant effect of variety×fertilizer interaction in percentage plant establishment in both cropping seasons (Table 3 and 4). There

Table 3: Percentage plant establishment (%), days to 50% pegging, days to 50% podding and haulm weight at harvest as affected by variety, row spacing and fertilizer during the 2018 cropping season

Treatments	Percentage plant establishment (%)	Days to 50% pegging	Days to 50% podding	Haulm weight at harvest (kg)
Varieties				
Adepa	76.0	55.00	69.00	2.26
Yenyawoso	75.4	45.00	59.00	2.85
Mean	75.7	50.00	64.00	2.55
LSD (p = 0.05)	Non-significant	3.36	3.36	0.57
Row spacing				
30×15 cm	75.4	50.00	64.00	2.41
40×15 cm	78.1	49.00	63.00	2.53
50×15 cm	73.5	51.00	65.00	2.70
Mean	75.7	50.00	64.00	2.55
LSD (p = 0.05)	Non-significant	Non-significant	Non-significant	Non-significant
Fertilizer				
NPK	76.7	50.00	64.00	2.62
Control	74.7	50.00	64.00	2.49
Mean	75.7	50.00	64.00	2.55
LSD (p = 0.05)	Non-significant	Non-significant	Non-significant	Non-significant
Variety×Fertilizer	Non-significant	Non-significant	Non-significant	Non-significant
Variety×Spacing	Non-significant	Non-significant	Non-significant	Non-significant
Fertilizer×Spacing	Non-significant	Non-significant	Non-significant	Non-significant
Variety×Fertilizer×Spacing interaction	Non-significant	Non-significant	Non-significant	Non-significant

Table 4: Percentage plant establishment (%), days to 50% pegging, days to 50% podding and haulm weight at harvest as affected by variety, row spacing and fertilizer during the 2019 cropping season

Treatments	Percentage plant establishment (%)	Days to 50% pegging	Days to 50% podding	Haulm weight at harvest (kg)
Varieties				
Adepa	83.8	45.3	58.3	3.72
Yenyawoso	98.6	44.8	57.7	2.60
Mean	91.2	45.0	58.0	3.16
LSD (p = 0.05)	Non-significant	Non-significant	Non-significant	0.49
Row spacing				
30×15 cm	95.8	45.5	58.5	3.07
40×15 cm	95.8	45.1	57.8	3.18
50×15 cm	82.0	45.5	57.7	3.22
Mean	91.2	45.3	58.0	3.16
LSD (p = 0.05)	Non-significant	Non-significant	Non-significant	Non-significant
Fertilizer				
NPK	91.4	45.2	57.6	3.18
Control	91.0	45.4	58.4	3.14
Mean	91.2	45.3	58.0	3.16
LSD (p = 0.05)	Non-significant	Non-significant	Non-significant	Non-significant
Variety×Fertilizer	Non-significant	Non-significant	Non-significant	Non-significant
Variety×Spacing	Non-significant	Non-significant	Non-significant	Non-significant
Fertilizer×Spacing	Non-significant	Non-significant	Significant	Non-significant
Variety×Fertilizer×Spacing interaction	Non-significant	Non-significant	Non-significant	Significant

was high percent plants established with variety, spacing and fertilizer in both 2018 and 2019 cropping seasons although during the 2019 cropping season higher percentage plants was established than those established during the 2018 cropping season (Table 3 and 4).

Days to 50% pegging: Yenyawoso pegged 10 days earlier than Adepa during the 2018 cropping season (Table 3). The 40×15 cm spacing pegged a day or two earlier than the other spacing whilst the NPK amended plots was at par with the control in days to 50% pegging in 2018 season (Table 3). In 2019 cropping season the 30×15, 40×15 and 50×15 cm spacing, NPK amended plots and the control had averagely the same days to 50% pegging (45.3) (Table 4). There was no significant ($p>0.05$) effect between row spacing×fertilizer interaction in days to 50% pegging in both cropping seasons (Table 3 and 4). The variety, spacing and fertilizer pegged between 1-6 days earlier during the 2019 cropping season than those pegged during the 2018 cropping season (Table 3 and 4).

Days to 50% podding: Yenyawoso podded 10 days earlier than Adepa during the 2018 cropping season (Table 3). The 30×15, 40×15 and 50×15 cm spacing, NPK amended plots and the control had averagely the same days to 50% podding (64.0) in 2018 season (Table 3). There was no significant ($p>0.05$) difference between variety×spacing×fertilizer interaction in days to 50% podding in 2018 cropping season (Table 3). In 2019 cropping season variety, spacing and fertilizer had averagely the same days to 50% podding (58.0) (Table 4). There was a significant ($p< 0.05$) difference between fertilizer×spacing interaction in days to 50% podding in 2019 cropping season (Table 4). The variety, spacing and fertilizer podded between 2-11 days earlier during the 2019 cropping season than those podded during the 2018 cropping season (Table 3 and 4).

Vegetative growth

Haulm weight at harvest (kg): Yenyawoso produced significantly higher haulm weight at harvest than Adepa during the 2018 cropping season (Table 3). In 2019 cropping season Adepa produced significantly higher haulm weight at harvest than Yenyawoso (Table 4). The 50×15 cm spacing and NPK amended plots produced the highest haulm weight at harvest in both 2018 and 2019 cropping seasons (Table 3 and 4). There was a significant ($p\leq0.05$) difference between variety×spacing×fertilizer interaction in haulm weight at harvest during the 2019 cropping season (Table 4). Adepa groundnut variety, spacing and fertilizer produced higher haulm weight at harvest during the 2018 cropping season than those produced during the 2019 cropping season (Table 3 and 4).

Number of branches: The number of branches increased progressively for the entire growing period in variety, spacing and fertilizer during the 2018 cropping season (Table 5). There was a significant ($p<0.05$) difference between the two varieties with Yenyawoso performing better than Adepa in number of

Table 5: Number of branches as affected by variety, row spacing and fertilizer during the 2018 cropping season

	Number of branches(Days after planting)				
Treatments	28	42	56	70	84
Varieties					
Adepa	4.20	8.8	13.30	15.40	14.90
Yenyawoso	5.40	10.8	17.10	19.10	20.40
Mean	4.80	9.8	15.20	17.20	17.60
LSD (p = 0.05)	1.01	2.0	3.11	3.45	3.45
Row spacing					
30×15 cm	6.10	10.8	16.70	18.30	19.60
40×15 cm	5.40	10.5	16.20	18.30	18.70
50×15 cm	5.20	8.2	12.80	15.20	14.80
Mean	5.50	9.8	15.20	17.20	17.70
LSD (p = 0.05)	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant
Fertilizer					
NPK	6.40	9.8	14.80	17.40	17.80
Control	5.40	9.8	15.60	17.10	17.60
Mean	5.90	9.8	15.20	17.20	17.70
LSD (p = 0.05)	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant
Variety×Fertilizer	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant
Variety×Spacing	Non-significant	Non-significant	Non-significant	Non-significant	Significant
Fertilizer×Spacing	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant
Variety×Fertilizer×Spacing interaction	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant

Table 6: Number of branches as affected by variety, row spacing and fertilizer during the 2019 cropping season

	Number of branches (Days after planting)				
Treatments	28	42	56	70	84
Varieties					
Adepa	7.00	9.00	11.00	11.00	12.00
Yenyawoso	6.00	7.00	8.00	9.00	9.00
Mean	6.50	8.00	9.50	10.00	10.50
LSD (p = 0.05)	Non-significant	1.24	1.31	1.98	1.72
Row spacing					
30×15 cm	8.00	9.00	11.00	11.00	11.00
40×15 cm	6.00	8.00	10.00	10.00	10.00
50×15 cm	6.00	8.00	9.00	10.00	10.00
Mean	6.60	8.30	10.00	10.30	10.30
LSD (p = 0.05)	1.17	Non-significant	Non-significant	Non-significant	Non-significant
Fertilizer					
NPK	7.00	8.00	10.00	10.00	10.00
Control	7.00	8.00	9.00	10.00	10.00
Mean	7.00	8.00	9.50	10.00	10.00
LSD (p = 0.05)	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant
Variety×Fertilizer	Non-significant	Non-significant	Significant	Significant	Non-significant
Variety×Spacing	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant
Fertilizer×Spacing	Non-significant	Significant	Non-significant	Non-significant	Non-significant
Variety×Fertilizer×Spacing interaction	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant

branches for the entire 2018 growing period (Table 5). There was no significant (p>0.05) difference between row spacing in number of branches although 30×15 cm had the highest number of branches for the entire growing period during the 2018 cropping season (Table 5). The fertilizer amended plot had higher number of branches than the control at 30 DAP and from 70-84 DAP during the 2018 cropping season (Table 5). There was a significant effect between variety×spacing interaction in number of branches at 84 DAP during the 2018 cropping season (Table 5).

In the 2019 cropping season Adepa produced significantly higher number of branches than Yenyawoso from 42-84 DAP except at 30 DAP (Table 6). The 30×15 cm spacing had higher number of branches for the entire growing period during the 2019 cropping season than 40×15 and 50×15 cm spacing (Table 6). The NPK amended plot was at par with the control in number of branches for the entire growing period during the 2019 cropping season except at 56 DAP where it performed better than the control (Table 6). There was a significant effect between variety×fertilizer interaction from 56-70 DAP and with fertilizer×spacing interaction at 42 DAP in number of branches during the 2019 cropping season (Table 6). The variety, spacing and fertilizer produced higher number of branches during the 2018 cropping season than those produced during the 2019 cropping season (Table 5 and 6).

Canopy spread (sm): Yenyawoso produced significantly wider canopy spread than Adepa for the entire growing period during the 2018 cropping season except at 70 DAP where no significant (p>0.05) difference exist between varieties (Table 7). There was no significant (p>0.05) difference between row spacing although 40×15 cm spacing produced the widest canopy spread for the entire growing period during the 2018 cropping season (Table 7). The NPK amended plot performed better than the control at 56 DAP and 84 DAP. There was a significant effect between variety×spacing interaction in canopy spread from 28-56 DAP in canopy spread during the 2018 cropping season (Table 7).

In the 2019 cropping season Yenya woso produced wider canopy spread than Adepa for the entire growing season (Table 8). The 30×15 cm spacing produced the widest canopy spread for the entire growing season except at 56 DAP during the 2019 cropping season (Table 8). The NPK amended plot performed better than the control in canopy spread for the entire growing period in the same season. There was a significant ($p \leq 0.05$) effect between variety×fertilizer×spacing interaction at 56 DAP during the 2019 cropping season (Table 8). The variety, spacing and fertilizer produced wider canopy spread during the 2019 cropping season than those produced during the 2018 cropping season (Table 7 and 8).

Plant height (cm): There was no significant (p>0.05) difference between varieties in plant height for the entire growing period during the 2018 cropping season although Yenyawoso had taller plants than Adepa (Table 9). There was no significant (p>0.05) difference between row spacing in plant height for the entire growing period in 2018 cropping season although the 40×15 cm spacing had the tallest plants from 56-70 DAP (Table 9).

Table 7: Canopy spread (cm) as affected by variety, row spacing and fertilizer during the 2018 cropping season

	Canopy spread (cm) (Days after planting)				
Treatments	28	42	56	70	84
Varieties					
Adepa	19.2	25.70	35.90	42.5	44.40
Yenyawoso	20.9	29.30	40.50	45.8	49.50
Mean	20.0	27.50	38.20	44.1	46.90
LSD (p = 0.05)	1.6	3.06	3.49	Non-significant	4.66
Row spacing					
30×15 cm	20.1	27.60	38.40	42.8	46.20
40×15 cm	20.2	28.50	40.00	45.4	49.00
50×15 cm	19.9	26.40	36.20	44.2	45.70
Mean	20.0	27.50	38.20	44.1	46.90
LSD (p = 0.05)	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant
Fertilizer					
NPK	19.7	27.50	39.40	43.9	47.30
Control	20.1	27.60	37.00	44.5	46.70
Mean	20.0	27.50	38.20	44.2	47
LSD (p = 0.05)	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant
Variety×Fertilizer	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant
Variety×Spacing	Significant	Significant	Significant	Non-significant	Non-significant
Fertilizer×Spacing	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant
Variety×Fertilizer×Spacing interaction	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant

Table 8: Canopy spread as affected by variety, row spacing and fertilizer during the 2019 cropping season

	Canopy spread (cm) (Days after planting)				
Treatments	28	42	56	70	84
Varieties					
Adepa	26.1	48.4	59.3	74.9	77.0
Yenyawoso	27.7	52.7	64.9	79.9	82.0
Mean	26.9	50.5	62.1	77.4	79.5
LSD (p = 0.05)	Non-significant	Non-significant	4.6	Non-significant	Non-significant
Row spacing					
30×15 cm	28.0	51.3	61.4	78.2	80.9
40×15 cm	26.3	51.2	62.8	77.3	78.8
50×15 cm	26.4	49.2	62.1	76.8	78.9
Mean	26.9	50.5	62.1	77.4	79.5
LSD (p = 0.05)	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant
Fertilizer					
NPK	27.0	51.4	62.9	78.8	81.4
Control	26.9	49.7	61.3	76.1	77.6
Mean	26.9	50.5	62.1	77.4	79.5
LSD (p = 0.05)	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant
Variety×Fertilizer	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant
Variety×Spacing	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant
Fertilizer×Spacing	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant
Variety×Fertilizer×Spacing interaction	Non-significant	Non-significant	Significant	Non-significant	Non-significant

In the 2019 cropping season Yenyawoso performed better than Adepa in plant height for the entire growing period (Table 10). Yenyawoso produced significantly taller plants than Adepa from 70-84 DAP during the 2019 cropping season (Table 10). There was no significant ($p<0.05$) difference between row spacing although 30×15 cm spacing produced tallest plants for the entire growing period except at 56 DAP (Table 10). The NPK amended plots performed better than the control for the entire growing period in the same cropping season (Table 10). There was no significant ($p>0.05$) effect between variety, spacing, fertilizer and their interaction for the entire 2019 growing period (Table 10). The variety, spacing and fertilizer produced taller plants during the 2019 cropping season than those produced during the 2018 cropping season (Table 9 and 10).

Table 9: Plant height as affected by variety, row spacing and fertilizer during the 2018 cropping season

	Plant height (cm) (Days after planting)				
Treatments	28	42	56	70	84
Varieties					
Adepa	7.8	16.5	21.0	22.4	23.3
Yenyawoso	8.4	16.6	21.3	23.2	24.7
Mean	8.1	16.5	21.2	22.8	24.0
LSD (p = 0.05)	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant
Row spacing					
30×15 cm	7.3	16.1	20.7	22.1	23.4
40×15 cm	8.7	17.1	21.7	22.8	24.2
50×15 cm	8.8	16.5	21.2	23.4	24.5
Mean	8.2	16.5	21.2	22.8	24
LSD (p = 0.05)	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant
Fertilizer					
NPK	7.9	16.6	21.0	22.5	23.6
Control	8.7	16.5	21.4	23.0	24.4
Mean	8.3	16.5	21.2	22.8	24.0
LSD (p = 0.05)	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant
Variety×Fertilizer	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant
Variety×Spacing	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant
Fertilizer×Spacing	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant
Variety×Fertilizer×Spacing interaction	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant

Table 10: Plant height as affected by variety, row spacing and fertilizer during the 2019 cropping season

	Plant height (cm) (Days after planting)				
Treatments	28	42	56	70	84
Varieties					
Adepa	7.3	16.30	24.2	25.70	27.1
Yenyawoso	7.4	17.60	25.8	28.90	30.4
Mean	7.3	16.90	25.0	27.30	28.7
LSD (p = 0.05)	Non-significant	Non-significant	Non-significant	2.51	2.6
Row spacing					
30×15 cm	7.7	18.10	24.8	28.30	29.9
40×15 cm	7.1	16.50	25.1	27.00	28.4
50×15 cm	7.2	16.20	25.0	26.60	28.0
Mean	7.3	16.90	25.0	27.30	28.7
LSD (p = 0.05)	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant
Fertilizer					
NPK	7.5	17.90	25.2	28.20	29.5
Control	7.1	15.90	24.7	26.40	28.0
Mean	7.3	16.90	25	27.30	28.7
LSD (p = 0.05)	Non-significant	1.77	Non-significant	Non-significant	Non-significant
Variety×Fertilizer	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant
Variety×Spacing	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant
Fertilizer×Spacing	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant
Variety×Fertilizer×Spacing interaction	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant

Yield and yield components

Number of plants harvested: Yenyawoso, 30×15 cm spacing and fertilizer performed better by producing higher number of plants harvested than Adepa, 40×15 cm and 50×15 cm spacing and the control respectively during the 2018 cropping season (Table 11). There was a significant ($p \leq 0.05$) effect between variety×spacing interaction in number of plants harvested during the 2018 cropping season (Table 11).

In the 2019 cropping season, Adepa, 40×15 cm spacing and fertilizer performed better by producing higher number of plants harvested than Yenyawoso, 30×15 and 50×15 cm spacing and the control, respectively (Table 12). There was no significant ($p>0.05$) effect between variety, spacing and fertilizer interactions in number of plants harvested during the 2019 cropping season (Table 12).

Table 11: Number of plants harvested, number of pods/plant, pod weight/plot (g), 100-seed weight (g) and yield (t ha^{-1}) as affected by variety, row spacing and fertilizer during the 2018 cropping season

Treatments	Number of plants harvested	Number of pods/plant	Pod weight /plot (g)	100-seed weight (g)	Yield (t ha^{-1})
Varieties					
Adepa	64	18.8	462	39.5	1.39
Yenyawoso	72	21.8	558	44.7	1.56
Mean	68	20.3	510	42.1	1.48
LSD (p = 0.05)	Non-significant	2.82	56	Non-significant	Non-significant
Row spacing					
30×15 cm	72	23.8	579	41.7	1.59
40×15 cm	68	19.0	500	43.7	1.43
50×15 cm	60	18.2	452	40.8	1.40
Mean	68	20.3	510	42.1	1.48
LSD (p = 0.05)	Non-significant	3.46	72	Non-significant	Non-significant
Fertilizer					
NPK	70	20.6	548	43.1	1.62
Control	66	20.0	470	41.1	1.34
Mean	68	20.3	509	42.1	1.48
LSD (p = 0.05)	Non-significant	Non-significant	56	Non-significant	Non-significant
Variety×Fertilizer	Non-significant	Non-significant	Significant	Non-significant	Non-significant
Variety×Spacing	Significant	Non-significant	Significant	Non-significant	Significant
Fertilizer×Spacing	Non-significant	Significant	Significant	Non-significant	Non-significant
Variety×Fertilizer×Spacing interaction	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant

Table 12: Number of plants harvested, number of pods/plant, pod weight/plot (g), 100-seed weight (g) and yield (t ha^{-1}) as affected by variety, row spacing and fertilizer during the 2019 cropping season

Treatments	Number of plants harvested	Number of pods/plant	Pod weight /plot (g)	100-seed weight (g)	Yield (t ha^{-1})
Varieties					
Adepa	72	30.1	1161	73.1	3.23
Yenyawoso	68	36.1	767	52.4	2.13
Mean	70	33.1	964	62.7	2.68
LSD (p = 0.05)	Non-significant	Non-significant	287	6.82	0.79
Row spacing					
30×15 cm	70	32.6	950	62.9	2.64
40×15 cm	72	32.7	883	61.5	2.45
50×15 cm	70	33.9	1058	63.8	2.94
Mean	70	33.0	964	62.7	2.68
LSD (p = 0.05)	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant
Fertilizer					
NPK	70	34.0	978	63.0	2.72
Control	70	32.0	950	62.4	2.64
Mean	70	33.0	964	62.7	2.68
LSD (p = 0.05)	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant
Variety×Fertilizer	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant
Variety×Spacing	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant
Fertilizer×Spacing	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant
Variety×Fertilizer×Spacing interaction	Non-significant	Non-significant	Non-significant	Non-significant	Non-significant

Number of pods per plant: Yenyawoso and 30×15 cm spacing produced significantly higher number of pods/plant than Adepa and 40×15 and 50×15 cm spacing respectively during the 2018 cropping season (Table 11). There was no significant ($p>0.05$) difference between NPK amended plot from the control in number of pods per plant although the amended plot performed better than the control (Table 11). There was a significant ($p\leq0.05$) effect between fertilizer×spacing interaction in number of pods per plant in the same cropping season (Table 11).

In the 2019 cropping season Yenyawoso, 50×15 cm spacing and NPK amended plot performed better in number of pods per plant than Adepa, 30×15 and 40×15 cm spacing and the control respectively (Table 12). There was no significant ($p>0.05$) effect between variety, spacing and fertilizer interactions in number of pods/plant in 2019 cropping season (Table 12). The variety, spacing and fertilizer produced higher number of pods per plant during the 2019 cropping season than those produced during the 2018 cropping season (Table 11 and 12).

Pod weight/plot (g): Yenyawoso, 30×15 cm spacing and NPK amended plot produced significantly higher pod weight/plot than Adepa, 40×15 and 50×15 cm spacing and the control respectively during the 2018 cropping season (Table 11). There was a significant ($p \leq 0.05$) difference between variety×fertilizer, variety×spacing and fertilizer×spacing interactions in pod weight per plot during the 2018 cropping season (Table 11).

In the 2019 cropping season Adepa produced significantly higher pod weight/plot than Yenyawoso (Table 12). The 50×15 cm spacing and NPK amended plot performed better in pod weight per plot than 30×15 and 40×15 cm spacing and the control respectively during the 2019 cropping season (Table 11). The variety, spacing and fertilizer produced higher pod weight per plot during the 2019 cropping season than those produced during the 2018 cropping season (Table 11 and 12).

100-seed weight (g): Yenyawoso, 40×15 cm spacing and NPK amended plot performed better by producing heavier 100-seed weight than Adepa, 30×15 and 50×15 cm spacing and the control respectively during the 2018 cropping season (Table 11). In the 2019, cropping season Adepa produced significantly higher 100-seed weight than Yenyawoso (Table 12). The 50×15 cm spacing and NPK amended plot performed better by producing heavier 100-seed weight than 30×15 and 40×15 cm spacing and the control respectively during the 2019 cropping season (Table 12). There was no significant ($p>0.05$) effect between variety, spacing and fertilizer interaction in 100-seed weight in both 2018 and 2019 cropping seasons (Table 11 and 12). The variety, spacing and fertilizer produced heavier 100-seed weight during the 2019 cropping season than those produced during the 2018 cropping season (Table 11 and 12).

Yield (t ha^{-1}): Average yield ranged from 1.39-1.56 t ha^{-1} and 2.13-3.23 t ha^{-1} for Adepa and Yenyawoso during the 2018 and 2019 cropping seasons respectively (Table 11 and 12). Yenyawoso, 30×15 cm spacing and NPK amended plot performed better by producing higher yield than Adepa, 40×15 and 50×15 cm spacing and the control respectively during the 2018 cropping season (Table 11). There was a significant ($p<0.05$) effect between variety×spacing interaction in yield during the 2018 cropping season (Table 11).

In the 2019, cropping season Adepa produced significantly higher yield than Yenyawoso (Table 12). The 50×15 cm spacing and NPK amended plot performed better by producing higher yield than 30×15 and 40×15 cm spacing and the control respectively during the 2019 cropping season (Table 12). The variety, spacing and fertilizer produced higher yield (t ha^{-1}) during the 2019 cropping season than those produced during the 2018 cropping season (Table 11 and 12).

DISCUSSION

The higher percentage plants establishment, earliest days to 50% pegging and podding with variety, spacing and fertilizer during the 2019 cropping season than those produced during the 2018 cropping season might be due to high rainfall experienced during the 2019 cropping season. This might have increased soil moisture to enhance seed germination with initial vigorous seedling growth, early pegging and podding than those in 2018 cropping season with less rainfall. Groundnut requires adequate moisture in the soil during the pegging stage as the pegs enter the soil and the pod begins to develop. The significant difference between Yenyawoso from Adepa in days to 50% pegging and podding during the 2018 cropping season could be due to differences in variety.

The significant effect of varieties in haulm weight at harvest in both years could be attributed to the fact that both varieties have semi-erect growth habit and probably responded positively to fertilizer, spacing and rainfall and temperature conditions experienced during the growing periods hence high haulm weight. The significant effect of variety×spacing×fertilizer interactions in haulm weight at harvest during the 2018 cropping season could be linked to higher number of branches produced in the same cropping season than in 2019. The greater number of branches might have resulted in efficient interception and utilization of solar radiation for assimilates development[16]. The application of NPK fertilizer might have improved plant growth and thence haulm production. This is because these elements can stimulate roots, strengthen plant stems and increase photosynthesis rates and that nitrogen element contributes for high growth and production of plant leaves[17].

The significant effect of varieties in number of branches for the entire growing period in both 2018 and 2019 except at 28 DAP in 2019 cropping seasons might be due to differences in genetic characteristics of varieties and their response to rainfall, temperature, spacing and nutrients during the growing period. The significantly higher number of branches with 30×15 cm spacing than 40×15 and 50×15 cm spacing at 28 DAP during the 2019 cropping season might be attributed to narrow inter row spacing. This might have led to early canopy closure due to vigorous plant growth with

less competition for light and nutrients[18]. This disagrees with El Naim *et al.*[19] and Ansa[20] 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. The significant effect of variety×fertilizer interaction from 56-70 DAP and with fertilizer×spacing interaction at 42 DAP in number of branches during the 2019 cropping season could probably due to adequate nutrient supply of NPK fertilizer effect on row spacing, variety coupled with high rainfall experienced during the growing period. This agrees with Kabir *et al.*[21] that phosphorus application significantly increased number of branches/plant of groundnut thus enables plants to absorb more water and nutrients from depth of the soil and hence enhance lateral growth of plants.

The significantly wider canopy spread between the two varieties could probably be due to the varieties ability to respond to its environmental conditions since both have semi-erect growth habit. The significant effect of variety×spacing interaction in canopy spread from 28-56 DAP during the 2018 cropping season could probably due to row spacing effect on variety.

The significantly taller plants produced by Yenyawoso over Adepa from 70-84 DAP during the 2019 cropping season could be due to differences in variety and its responds to spacing and fertilizer. The tallest plants produced in 30×15 cm (closed spaced) are in conformity with Ansa[20] and Gadade *et al.*[22]. This could be that plants from narrow spacing did not get enough space for lateral growth therefore compelled to grow more in upward position to intercept light for photosynthesis. Under fertilizer, plants improved their height over the control although there was non significant difference between fertilizer amended plots and the control in both years.

The highest number of plants harvested with Yenyawoso, 30×15 cm spacing, fertilizer amended plots and significant effect of variety×spacing interaction during the 2018 cropping season could be due to Yenyawoso response to narrow spacing and NPK fertilizer. Narrow spacing probably encouraged vertical growth of groundnut for efficient interception of light and utilization. Fertilizers promote vegetative growth for efficient utilization of solar radiation to enhance photosynthesis as well as root growth for exploitation of soil moisture.

The variations in number of pods per plant observed in this study confirm the findings and reported significant variations in pod number per plant[6,19,23]. The significantly higher number of pods per plant with Yenyawoso, 30×15 cm spacing and fertilizer×spacing interaction during the 2018 cropping season could be due to differences in genotypes of varieties and their response to narrow spacing and NPK fertilizer. This is in line with Jaiswal *et al.*[24] who reported that 30×15 cm spacing proved superior in increasing number of pods per plant than closer spacing of 22.5×10 cm. The earlier report showed that significant interaction effect existed between planting spacing×fertilizer levels in respect of number of pods per plant of groundnut[22]. Fertilizers promote vegetative growth as well as root growth and increase the yield of groundnut[25].

The significantly higher pod weight per plot in varieties in both years could be due to genotypes of groundnut varieties. The significantly higher pod weight/plot in 30×15 cm spacing than 40×15 and 50×15 cm spacing, fertilizer over the control and their interactions in 2018 (a lower rainfall season) could attributable to narrow spacing of crops with high soil nutrition. The narrow spacing of crops compensated for the reduced number of pods/plant giving higher pod weight. This is in agreement with Konlan *et al.*[6], Waghmode *et al.*[23] that with closely spaced (30×15 cm spacing) crops pod weight per plot increased. Significant effect in interaction between 30×15 cm spacing and fertilizer level of 125% has been reported[23]. The higher pod weight per plot in 2019 than in 2018 cropping season could be due to higher rainfall experienced during the growing period (636.1 mm) compared to lower rainfall (568.0 mm) in 2018. The early phase of pod setting is sensitive to any soil moisture deficit and this reflects on decreased pod weight. The variety, spacing, fertilizer and interaction effects for 100-seed weight was found to be non significant in both years. This is in line with Jaiswal *et al.*[24] and Yousif and Hussain[26].

Although there were variations in yield (t ha^{-1}), there was no significant difference between variety, spacing, fertilizer and their interactions except variety×spacing interaction in 2018 and variety in 2019 which was significant. The higher yield produced with widely spaced (50×15 cm) than more closely spaced (30×15 and 40×15 cm) in 2019 cropping season could be linked to high haulm weight at harvest, wider spacing and higher rainfall experienced during the growing period. With increasing inter row spacing haulm weight and yield had increased. This disagrees with Akpalu *et al.*[27] that in Bambara groundnut crop intensification especially, legumes planted at higher density may increase crop yield due to the fact that they fix nitrogen for growth and yield. The higher yield in variety, spacing and fertilizer during the 2019 cropping season than those produced during the 2018 cropping season could be due to variation in rainfall. High soil moisture content during the vegetative phase generally improves flowering and maturity and also increases the crop growth and yield.

CONCLUSION

Yenyawoso pegged and podded significantly earlier than Adepa during the 2018 cropping season. Yenyawoso was found promising to produce higher vegetative biomass than Adepa in terms of producing significantly taller plants, significantly higher number of branches and wider canopy spread compared to Adepa during the 2019 cropping season. For yield and yield attributes, Adepa produced significantly heavier 100-seed weight and higher yield than Yenyawoso during the 2019 cropping season. The 30×15 cm spacing produced significantly higher number of plants harvested and heavier pod weight/plot, wider canopy spread and taller plants compared to 40×15 and 50×15 cm spacing in 2018 and 2019 cropping seasons respectively. The 50×15 cm spacing produced the highest yield. Interaction effect between variety × spacing, spacing × fertilizer, variety × fertilizer and variety×spacing×fertilizer was significant with number of branches, number of plants harvested, yield, number of pods/plant, pod weight per plot and haulm weight at harvest in 2018 and 2019 cropping seasons respectively. For groundnut production to be sustainable, the cropping season should inform the soil and crop management practices as climatic conditions that prevail in the experimental area significantly influence the success of soil nutrient management practices.

SIGNIFICANCE STATEMENT

This study discovers the influence of row spacing and NPK fertilizer on the growth and yield of two groundnut (*Arachis hypogaea* L.) varieties under rain-fed condition in the transitional zone of Ghana that can be beneficial for both researchers and farmers. This study will help the researcher to compare the performance of two groundnut varieties, appropriate row spacing and whether or not NPK fertilizer use is critical in groundnut production that many researchers were not able to explore. Thus, best agronomic practice to employ on newly improved groundnut varieties during production that may boost their growth and subsequent yield may be arrived at.

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