Agricultural Sciences, 2024, 15, 54-70
https://www.scirp.org/journal/as
ISSN Online: 2156-8561
ISSN Print: 2156-8553

Effect of Variety and Plant Spacing on Growth and Yield of Groundnuts (*Arachis hypogaea* L.)

Abukari Iddrisu[1], Eric Adjei[2*], Samuel Kwesi Asomaning[3], Kwadwo Gyasi Santo[3], Adu Poku Isaac[4], Alexander Danson-Anokye[2]

[1]Cocoa Health and Extension Division, Huni Valley, Ghana
[2]Department of Agriculture, Berekum East Municipal Assembly, Berekum, Ghana
[3]Department of Horticulture and Crop Production, School of Agriculture and Technology, University of Energy and Natural Resources, Sunyani, Ghana
[4]Glenn High School, Winston Salem, USA
Email: *przyeric@yahoo.com

How to cite this paper: Iddrisu, A., Adjei, E., Asomaning, S.K., Santo, K.G., Isaac, A.P. and Danson-Anokye, A. (2024) Effect of Variety and Plant Spacing on Growth and Yield of Groundnuts (*Arachis hypogaea* L.). *Agricultural Sciences*, **15**, 54-70.
https://doi.org/10.4236/as.2024.151004

Received: November 25, 2023
Accepted: January 12, 2024
Published: January 15, 2024

Abstract

A field experiment was carried out to determine the effect of variety and plant spacing on yield and growth of groundnuts. The field experiment was laid in a 3 × 3 factorial experiment in a Randomized Complete Block Design (RCBD) with three (3) replications. The factor A included three (3) groundnut varieties (Nkatie Sari, Sum Nutt 22 and Yenyawoso) and Factor B was the three (3) spacing of 30 cm × 15 cm, 30 cm × 30 cm and 30 cm × 40 cm. All recommended agronomic practices were followed. Data was collected from eight (8) tagged plants. Growth data were recorded on plant height, number of branches, number of leaves, and the number of flowers while yield data were collected on the number of flowers, number of pods per plant, 100 seeds weight and the pod yield (kg/ha). The plant spacing significantly influenced ($P < 0.05$) the growth and yield parameters. Groundnut grown at a spacing of 30 cm × 15 cm produced the maximum plant height, whereas the maximum number of leaves, number of branches and number of flowers were produced from 30 cm × 40 cm. Yenyawoso variety with a wider plant spacing performed better vegetatively among all the varieties. The Yenyawoso variety produced the highest number of pods, 100 seeds weight and pod yield as compared to the other varieties. Also, Yenyawoso at 30 cm × 40 cm spacing and Nkatie Sari at 30 cm × 15 cm spacing produced the maximum pod yield.

Keywords

Groundnut, Variety, Yield, Spacing, Plant Height

1. Introduction

Groundnut is the most important grain legume in Ghana in terms of area under cultivation [1]. The Guinea savanna ecology of Ghana accounts for over 70% of total groundnut produced in the country [1], making it the most important groundnut region in the country. In Ghana, groundnut is a crucial crop for both cash crops and domestic use [2]. Ghana produced 2.5 times as much groundnuts in 2010 as it did at the start of the decade. The rapid growth in output is the result of a 75% increase in harvested area and a 50% increase in yield during the same ten-year period [3]. Groundnut production was constrained at the start of the decade by a number of biotic and abiotic challenges, such as pests, the Rosette virus, and aflatoxin [4].

It is a highly profitable oilseed and cash crop that is widely farmed in the world's semi-arid tropical regions. It is grown for both direct human use and industrial purposes. The crop's production is predominantly concentrated in Asia and Africa's semi-arid tropical regions, which account for approximately 96 percent of worldwide groundnut acreage and 92 percent of total global groundnut output [5] [6]. According to [7], groundnut is regarded as the world second most significant cultivated food grain legume as well as the fourth largest producing edible oilseed crop. The nuts are crushed to remove the kernels that are a source of protein, cakes vegetable oil, and other industrial product. As a rich source of edible oils and a superior source of fat, protein, carbohydrates, minerals, and some vitamins compared to other nuts, groundnut seeds are also frequently the least priced [8]. Variety recommendations for the three growing locations in the region have been made as part of the Peanut Germplasm Project, mostly from International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), taking into account their earliest maturity, resistance to harmful diseases, and yield [9].

One of the important agronomic techniques that affect groundnut development, yield, and quality is plant density. In order to maximize grain seed yield, optimal density guarantees that there is less interspecies competition and that growth resources are efficiently captured and used both above and below ground [10]. [11] states that closer spacing (30 cm × 10 cm) can enhance the yield of erect type of groundnuts, whereas a spacing of 40 cm × 20 cm will maximize the output of spreading or semi-spreading type of groundnuts. One of the groundnut cultivars used by smallholder farmers in Malawi, CG7, has suggested plant density of 89,000 plants per hectare (75 cm × 15 cm × 1 seed) [12]. The theoretical yield for CG7 at this spacing is 2500 kg/ha. One of the many factors that affect groundnut production, proper row spacing is essential in plantings. Planting density is one of the main factors that influence the development, productivity, and quality of peanuts. [13] observed that plant dry matter accumulation and branch formation were increased when the crop is cultivated with optimum spacing, and yield parameters like number of pod/plant, yield/plant, and

1000-grain weight were at their highest. A recent study revealed that yield increased continuously when row spacing decreased and multiplied when chemical fertilizers were added [14]. When compared to a normal broad row crop, close-spaced groundnut has also been proven to provide more ground cover, better canopy light interception, crop growth rates, leaf area indices, and eventually higher pod yields [15].

Rainfall is the most significant climatic factor affecting groundnut production, as 70% of the crop area under semi-arid tropics is characterized by low and erratic rainfall. Low rainfall and prolonged dry spells during crop growth period were reported to be main reasons for low yields in most of the regions of Asia and Africa [8]. [16] reported that persistent droughts and insufficient rainfall represent one of the greatest constraints on groundnut crop. [17] reported that groundnut production is significantly determined by rainfall. Appropriate soil moisture management is crucial to achieve early germination, uniform plant establishment and high productivity in the crop. [18] reported that nodulation and nitrogen fixation show rapid decline under drought conditions and maintained that prolonged desiccation could lead to nodule loss with partial inability to further form nodules. At harvest, traits such as seed weight are the sum of development and responses to stresses over the growing season and particularly during the reproductive phase of growth [19]. Although groundnut has the ability to fix atmospheric nitrogen, balanced nutrition can enhance crop development and further increase yield. To achieve optimum yield and sustained production, attention should be given to the rate of nutrient removal based on soil analytical data. Optimum production of groundnut production requires balanced nutrition as nutrient deficiencies can have adverse effects on crop growth development and yield. [20] suggested 10 - 20 kg N/ha, 18 kg P/ha and 33 kg K/ha under rain-fed condition and 20 kg N/ha, 18 - 40 kg P/ha and 17 - 33 kg K/ha under irrigated condition.

The major challenge inhibiting the production of groundnut is as a result of poor cultural practices especially the practice of wide spacing [21]. Weeds cannot effectively compete with groundnut, especially in the first three to six weeks after sowing, therefore it is crucial to get rid of them before flowering and while the plant is still in the pegging stage [22]. One of the most notable pests that significantly reduce plant yield, raise production costs, and, in certain situations, make farmland unfit for farming purposes are weeds [23] [24]. Crop output is increased by increasing planting density (by close spacing) per hectare, according to [25]. Additionally, the majority of studies have discussed the effects of weeding practices and spacing, but there is no study or literature on how spacing affects groundnut growth and production. In order to increase crop output, this research aims to explore the likelihood of high groundnut yield under various spacing conditions. This study investigated the effect of variety and plant spacing on yield and growth of groundnuts.

2. Materials and Methods

2.1. Research Location

The study was carried out at Huni Valley in the Prestea Huni Valley Municipality in the Western Region of Ghana during the major and minor seasons of 2020. The study area lies within latitude 5˚28'0" North of the Equator and 1˚55'0" West of the Greenwich meridian. It has two rainfall patterns usually from March to July (major season) and from September to November (minor season). The District experiences high rainfall with a mean annual rainfall of 187.83 mm. Temperatures are high all year round with significant daily and seasonal variations. The annual average temperatures range between 26˚C and 30˚C. Humidity varies from 75 - 80 percent in the wet season and 70 - 80 percent in the dry season. The soil is deep, open and acidic in many places due to heavy leaching of base from the top soil because of high rainfall, humidity and temperatures [26].

2.2. Experimental Design and Treatments

The field experiment was laid out in a 3 × 3 factorial experiment in a Randomized Complete Block Design (RCBD) with three (3) replications. Factor A was three groundnut varieties (Yenyawoso, Nkatie Sari and Sum Sutt 22) and factor B was the planting distance with three different spacing of 30 cm × 30 cm, 30 cm × 15 cm, and 30 cm × 40 cm. The treatment combination is shown in **Table 1**.

2.3. Source of Planting Materials

The groundnut seeds were sourced from the Savannah Agricultural Research Institute (SARI) Nankpala Station Tamale. The varieties collected were Yenyawoso (Early), Samnut 23 (Early) and Nkatie Sari (Late).

2.4. Land Preparation and Weed Control

The land was slashed with no burning. The land was ploughed manually using a hoe in October, 2019. Lining and pegging of the field was then done. The sowing of the groundnut seeds was carried out in November, 2019. The seeds were sown at one (1) seed per hill. After 7 days, refilling was done. Weed control was carried out manually by hand hoeing and pulling of the weeds when they were tender. The control of the weeds on the field began exactly two weeks after planting up to flowering and the formation of pegs, in order to ensure that the pegs are not damaged.

Table 1. Treatment combinations.

Factors	**varieties**		
Spacing	**V_1 (Nkatie Sari)**	**V_2 (Sum Nutt 22)**	**V_3 (Yenyawoso)**
S_1 (30 × 15 cm)	S_1V_1	S_1V_2	S_1V_3
S_2 (30 × 30 cm)	S_2V_1	S_2V_2	S_2V_3
S_3 (30 × 40 cm)	S_3V_1	S_3V_2	S_3V_3

2.5. Data Collection

2.5.1. Soil Sampling

Before the study began, surface (0 - 20 cm) soil samples were taken from each plot. The samples were bulked and air-dried for standard analysis. [27] used the Walkley-Black dichromate digestion method to measure organic matter (O.M.) and the Kjeldahl method to measure total soil nitrogen [28]. Bray-1 technique was used to determine the available P. [29]. Using ammonium acetate, exchangeable K^+, Ca^{2+}, and Mg^{2+} were removed. The flame photometer was used to measure potassium, and Ca and Mg were measured using an EDTA titration. A glass electrode was used to measure the pH of the soil in 0.01 M $CaCl_2$. Results of the soil's physical and chemical characteristics of the soil before planting are displayed in Table 2.

2.5.2. Growth Parameters

Eight plants were randomly selected from each plot and tagged for the data collection on plant height. The plant height was taken every two weeks with a measuring tape/meter rule. Plant height was measured from the ground level to the topmost point, and the average for each plot was calculated and recorded. The number of leaves of the eight tagged plants from each treatment was counted and the average calculated for each treatment plot. Data collection for the number of leaves started from two weeks after planting (2 WAP) at two-weeks interval. The number of flowers of the eight tagged plants was counted and the average calculated for each plot. This was done four weeks after planting (4 WAP) at two-weeks interval. The number of branches of the eight tagged plants was counted and the average calculated for each plot. This was done four weeks after planting (4 WAP) at two-weeks interval.

2.5.3. Yield Parameters

The total number of pods on each plot was harvested and counted. The mean number of pods per plants was recorded. A total of randomly sampled 100 seeds from the harvested plants were air dried at 15% moisture content. The seeds were weighed and the average was recorded for each treatment. The groundnut plants from the two middle rows of each treatment plot were harvested pods and

Table 2. Physical and chemical characteristics of the soil before planting.

Physical Property	Value	Chemical Property	Value
Sand (%)	62	Soil pH (H_2O) 1:2.5	4.07
Silt (%)	30	Organic Carbon (%)	1
Clay (%)	8	Available P (mg/kg)	6.42
Texture	Sandy Loam	Total N (%)	0.12
		Sulphur (%)	
		Exchangeable Ca ($cmol_c \cdot kg^{-1}$)	1.49
		Exchangeable Mg ($cmol \cdot kg^{-1}$)	0.85

were separated from plants and sundried for seven days at an average temperature of 23˚C, at 15% moisture and weighed to record pod yield per plot. The value obtained was then converted into pod yield (kg/ha^{-1}) using the formula as follow:

$$\text{Pod yield } (\text{kg/ha}) = \frac{\text{pod yield}(\text{kg}) \times 10000\text{m}^2}{\text{Harvested area}(\text{m}^2)}$$

2.5.4. Data Analysis

The data collected were subjected to analysis of variance (ANOVA) using GenStat Twelth Edition. ANOVA was used to calculate the differences between the means for the treatments and the treatment means were compared using Least Significant Difference (LSD) at $p < 0.05$. The results were presented in Tables.

3. Results

3.1. Influence of Different Planting Density on the Growth of Different Varieties of Groundnut

3.1.1. Plant Height

During the 2020 major cropping season, plant height results showed significant differences ($p < 0.05$) among the treatments at 2, 6 and 10 weeks after planting (WAP) during the 2020 major cropping season. At 2 WAP, the highest (12.70 cm) plant height was recorded from Yenyawoso at a spacing of 30 × 15 cm while the least (8.13 cm) was recorded from Nkatie Sari at a spacing of 30 × 30 cm. Also, at 4 WAP, Yenyawoso at spacing of 30 × 15 cm recorded the highest plant height (14.27 cm), whereas Nkatie Sari at Plant Spacing of a spacing of 30 × 40 cm recorded the lowest plant height (11.67 cm). Further, at 6 WAP, the highest plant height (16.63 cm) was recorded from Yenyawoso at a spacing of 30 × 15 cm whilst the lowest plant height (14.17 cm) was recorded from Nkatiee Sari at a spacing of 30 × 40 cm. Yenyawoso at 30 × 15 cm spacing recorded the highest plant height (21.10 cm and 42.07 cm), while Nkatie Sari at spacing of 30 × 40 cm recorded the least plant height (16.10 cm and 32.50 cm) for 8 and 10 WAP, respectively (Table 3).

There was a significant difference ($P < 0.05$) among the treatments during 2, 4, 6, 8 and 10 weeks after planting (WAP) during the 2020 minor cropping season. At 2 WAP, the highest (12.73 cm) plant height was recorded from Yenyawoso at a spacing of 30 × 15 cm while the least (8.13 cm) was recorded from Nkatie Sari at a spacing of 30 × 30 cm. Also, at 4 WAP, Yenyawoso at spacing of 30 × 15 cm recorded the highest plant height (14.27 cm) whereas Nkatie Sari at Plant Spacing of a spacing of 30 × 40 cm recorded the lowest plant height (11.67 cm). Further, at 6 WAP, the highest plant height (16.62 cm) was recorded from Yenyawoso at a spacing of 30 × 15 cm, whilst the lowest plant height (14.17 cm) was recorded from Nkatie Sari at a spacing of 30 × 40 cm. Yenyawoso at 30 × 15 cm spacing recorded the highest plant height (21.10 cm and 42.08 cm), while Nkatie Sari at a spacing of 30 × 40 cm recorded the least plant height (16.10 cm and 32.49 cm) for 8 and 10 WAP, respectively (Table 3).

Table 3. Effect of plant spacing on plant height of different varieties of groundnut during.

Spacing (cm)	Variety	2020 Major Season					2020 Minor Season				
		2 WAP	4 WAP	6 WAP	8 WAP	10 WAP	2 WAP	4 WAP	6 WAP	8 WAP	10 WAP
	Nkatie Sari	8.43^{d}	12.47^{cd}	14.93^{bcd}	16.87^{b}	36.30^{cd}	8.42^{d}	12.46^{cd}	14.91^{bcd}	16.87^{b}	36.30^{cd}
30 × 15	Sum Nut 22	11.47^{ab}	13.47^{b}	16.00^{ab}	20.47^{a}	41.73^{ab}	11.47^{ab}	13.47^{b}	16.01^{ab}	20.46^{a}	41.71^{ab}
	Yenyawoso	12.70^{a}	14.27^{a}	16.63^{a}	21.10^{a}	42.07^{a}	12.73^{a}	14.27^{a}	16.62^{a}	21.10^{a}	42.08^{a}
	Nkatie Sari	8.13^{d}	12.00^{de}	14.43^{cd}	16.20^{b}	32.07^{d}	8.13^{d}	12.01^{de}	14.43^{cd}	16.20^{b}	32.09^{d}
30 × 30	Sum Nut 22	11.00^{abc}	13.13^{bc}	15.27^{bc}	18.53^{ab}	36.10^{cd}	11.19^{abc}	13.13^{bc}	15.26^{bc}	18.52^{ab}	36.11^{cd}
	Yenyawoso	11.30^{ab}	12.90^{bc}	15.00^{bcd}	18.40^{ab}	37.17^{bc}	11.30^{ab}	12.91^{bc}	15.03^{bcd}	18.40^{ab}	37.18^{bc}
	Nkatie Sari	8.83^{cd}	11.67^{e}	14.17^{d}	16.10^{b}	32.50^{cd}	8.84^{cd}	11.67^{e}	14.17^{d}	16.10^{b}	32.49^{cd}
30 × 40	Sum Nut 22	10.40^{bcd}	12.83^{bc}	15.17^{bcd}	18.33^{ab}	35.93^{cd}	10.40^{bcd}	12.82^{bc}	15.18^{bcd}	18.32^{ab}	35.92^{cd}
	Yenyawoso	11.87^{ab}	12.53^{cd}	14.80^{cd}	18.20^{ab}	36.43^{cd}	11.88^{ab}	12.52^{cd}	14.80^{cd}	18.20^{ab}	36.43^{cd}
LSD (p = 0.05)		**0.93**	**0.39**	**0.68**	**0.61**	**2.99**	**0.04**	**0.01**	**0.02**	**0.02**	**0.02**

3.1.2. Number of Leaves

The number of leaves showed significant differences, ($p < 0.05$) among the treatment interactions at 2, 4, 6 and 8 WAP during the 2020 major cropping season. At 2 WAP, Yenyawoso at a plant spacing of 30 cm × 40 cm recorded the mean highest number of leaves (50.67), whereas Nkatie Sari at 30 cm × 15 cm recorded the minimum number of leaves (30). At 4 WAP, Yenyawoso at a plant spacing of 30 × 40 cm recorded the mean maximum number of leaves (62.67), followed by Yenyawoso at a spacing of 30 cm × 15 cm (60), whereas the minimum number of leaves was recorded for Nkatie Sari at a spacing of 30 cm × 15 cm (38.67). At 6 WAP, Yenyawoso at a spacing of 30 cm × 40 cm recorded the mean highest number of leaves (71.67), whilst Nkatie Sari at a spacing of 30 cm × 15 cm recorded the least number of leaves (53). However, at 8 WAP, Sum Nut 22 at a spacing of 30 cm × 40 cm maintained the highest number of leaves (127.33), while Nkatie Sari at a spacing of 30 cm × 15 cm produced the lowest mean number of leaves (91.33) (**Table 4**).

The number of leaves showed significant differences ($p < 0.05$) among the treatments at 2, 4, 6 and 8 WAP during the 2020 minor growing season. At 4 WAP, Yenyawoso at a spacing of 30 cm × 30 cm recorded the mean highest number of leaves (42), followed by Sum Nutt 22 at a spacing of 30 cm × 15 cm (39.33) whereas the lowest mean number of leaves was recorded for Nkatie Sari at a spacing of 30 cm × 30 cm (22). At 6 WAP, Yenyawoso at a spacing of 30 cm × 40 cm recorded the mean highest number of leaves (62), whilst Nkatie Sari at a spacing of 30 cm × 15 cm recorded the least number of leaves (43). However, at 8 WAP, Yenyawoso at a spacing of 30 cm × 40 cm maintained the highest number of leaves (127.33), while Nkatie Sari produced the lowest mean number of leaves (62) (**Table 4**).

Table 4. Effect of plant spacing on number of leaves of different varieties of groundnut.

Spacing (cm)	Variety	2020 Major Season				2020 Minor Season			
		2 WAP	4 WAP	6 WAP	8 WAP	2 WAP	4 WAP	6 WAP	8 WAP
30 × 15	Nketi Sari	30.00^{a}	38.67^{a}	53.00^{a}	91.33^{a}	16.67^{b}	24.00^{b}	43.00^{c}	62.00^{e}
	Sum Nut 22	37.33^{bc}	47.67^{bc}	61.33^{c}	99.33^{ab}	14.00^{a}	26.00^{b}	49.33^{bc}	105.00^{c}
	Yenyawoso	40.00^{bcd}	50.67^{bcd}	64.00^{cd}	99.33^{ab}	18.00^{bc}	39.33bc	50.67^{bc}	110.00^{bc}
30 × 30	Nketi Sari	36.33^{b}	42.67^{a}	54.33^{ab}	106.67^{bc}	18.00^{bc}	22.00^{b}	48.67^{bc}	81.33^{d}
	Sum Nut 22	42.33^{def}	52.33^{cd}	67.00^{de}	114.67^{cd}	16.00^{b}	24.00^{b}	46.33^{c}	118.67^{ab}
	Yenyawoso	46.67^{fg}	60.00^{e}	69.00^{ef}	111.67^{c}	20.00^{cd}	42.00c	55.33^{ab}	126.00^{a}
30 × 40	Nketi Sari	41.67^{cde}	47.33^{b}	57.33^{b}	114.33^{cd}	17.33^{a}	25.33^{b}	48.67^{bc}	89.33^{d}
	Sum Nut 22	46.00^{ef}	55.00^{d}	71.00^{ef}	126.67^{e}	16.67^{b}	24.00^{b}	49.33^{bc}	123.33^{a}
	Yenyawoso	50.67^{g}	62.67^{e}	71.67^{f}	122.00^{de}	21.33^{d}	36.67^{a}	62.00^{a}	127.33^{a}
LSD (p = 0.05)		**4.42**	**4.5**	**3.98**	**8.04**	**1.96**	**3.78**	**5.5**	**5.64**

3.1.3. Number of Branches

There was a significant difference ($p < 0.05$) among the treatments for the number of branches at 4, 6, 8 and 10 WAP during the 2020 major cropping season. At 4 WAP, Yenyawoso at a plant spacing of 30 cm × 40 cm produced significantly the highest mean number of branches (15.67), whereas Yenyawoso at a spacing of 30 × 15 cm produced the least mean number of branches (9). Also, at 6 WAP, the highest mean number of branches (30) was recorded from Sum Nut 22 at a spacing of 30 cm × 40 cm, while the lowest number of branches (15.33), was produced from Yenyawoso at plant spacing of 30 cm × 15 cm. Further at 8 WAP, Sum Nut 22 at a spacing of 30 cm × 40 cm recorded the highest number of branches (37.33) whereas Yenyawoso at a spacing of 30 cm × 15 cm recorded the least value (21.33). However, at 10 WAP, Yenyawoso at a plant spacing of 30 cm × 40 cm produced the mean maximum number of branches (47.33), whereas Sum Nut 22 and Nketi Sari at a spacing of 30 cm × 15 cm produced the mean minimum number of branches (30.67) (Table 5).

There was a significant difference ($p < 0.05$) among the treatments for the number of branches at 4, 6, 8 and 10 WAP during the minor season. At 2 WAP, Sum Nut 22 at a plant spacing of 30 × 15 cm produced significantly the highest mean number of branches (16.33), whereas Nkatie Sari at a plant spacing of 30 × 15 cm produced the least mean number of branches (11.00). Also, at 6 WAP, the highest mean number of branches (26.00) was recorded from Yenyawoso at plant spacing of 30 × 15 cm while the lowest number of branches (19.33) was produced from Nkatie Sari at plant spacing of 30 cm × 15 cm. Further, at 8 and 10 WAP, Yenyawoso at a plant spacing of 30 cm × 15 cm, recorded the highest number of branches (36.00 and 54.33), whereas Nkatie Sari at plant spacing of 30 × 15 cm recorded the least value (20.00 and 32.00) (Table 5).

Table 5. Effect of plant spacing on the number of branches of different varieties of groundnut.

Spacing (cm)	Variety	2020 Major Season				2020 Minor Season			
		4 WAP	6 WAP	8 WAP	10 WAP	4 WAP	6 WAP	8 WAP	10 WAP
30 × 15	Nketi Sari	10.00[a]	18.00[abc]	23.33[a]	30.67[a]	11.00[a]	19.33[a]	20.00[a]	32.00[a]
	Sum Nut 22	9.67[a]	16.67[ab]	22.67[a]	30.67[a]	16.33[b]	23.00[ab]	32.00[cd]	44.00[c]
	Yenyawoso	9.00[a]	15.33[a]	21.33[a]	32.67[a]	14.33[ab]	26.00[b]	36.00[de]	54.33[f]
30 × 30	Nketi Sari	14.00[b]	26.00[def]	31.00[bc]	39.33[b]	14.00[ab]	24.33[b]	26.00[b]	34.33[ab]
	Sum Nut 22	14.67[b]	26.67[ef]	31.67[bc]	37.33[b]	15.33[ab]	23.33[ab]	32.67[cde]	48.00[cd]
	Yenyawoso	14.00[b]	21.00[bcd]	29.33[b]	38.67[b]	14.33[ab]	23.00[ab]	37.33[e]	49.67[de]
30 × 40	Nketi Sari	15.00[b]	27.33[ef]	35.33[cd]	45.00[c]	15.33[ab]	22.00[ab]	30.00[bc]	38.00[b]
	Sum Nut 22	15.33[b]	30.00[f]	37.33[d]	46.00[c]	13.67[ab]	23.67[ab]	34.00[cde]	45.33[cd]
	Yenyawoso	15.67[b]	22.67[cde]	34.67[cd]	47.33[c]	12.67[ab]	25.33[b]	34.67[cde]	53.33[ef]
LSD (p = 0.05)		**3.39**	**5.23**	**4.09**	**3.43**	**4.31**	**4.09**	**4.41**	**4.42**

3.1.4. Number of Flowers

During the 2020 major cropping season, the number of flowers showed significant differences ($p < 0.05$) at 4 and 6 WAP. During 4 WAP, Yenyawoso at a plant spacing of 30 × 40 cm recorded the maximum number of flowers (42.67), whereas Nkatie Sari at a plant spacing of 30 cm × 15 cm recorded the minimum number of flowers (17.67). However, at 6 WAP, Yenyawoso at a plant spacing of 30 cm × 40 cm produced significantly the highest number of leaves (54), whilst Sum Nut 22 at a plant spacing of 30 cm × 15 cm produced the lowest number of flowers (24) (Table 6).

The number of flowers for the 2020 minor cropping season showed significant differences ($p < 0.05$) at 4 and 6 WAP following treatment application. During 4 WAP, Yenyawoso at a plant spacing of 30 cm × 30 cm recorded the maximum number of flowers (24.14) whereas Nkatie Sari at a plant spacing of 30 cm × 15 cm recorded the minimum number of flowers (5.63). However, at 6 WAP, Yenyawoso at a plant spacing of 30 × 30 cm produced significantly the highest number of leaves (47.18), whilst Sum Nut 22 at a plant spacing of 30 × 15 cm produced the lowest number of flowers (31.93) (Table 6).

3.2. Influence of the Different Planting Density on the Yield of the Various Varieties of Groundnut

3.2.1. Number of Pods per Plant

Plant spacing significantly influenced ($p < 0.05$) the number of pods per plant during the major season of 2020. Yenyawoso at 30 cm × 40 cm spacing recorded the highest mean number of pods (47.33), whereas the lowest was recorded from Nkatie Sari at 30 cm × 15 cm plant spacing (27). The results showed variation ($P < 0.05$) in the number of pods per plant among the treatments for the 2020 minor growing season. Yenyawoso at a spacing of 30 cm × 30 cm produced the highest mean number of pods per plant (49), followed by Yenyawoso at a plant

Table 6. Effect of plant spacing on the number of flowers of different varieties of groundnut.

Spacing (cm)	Variety	2020 Minor Season		2020 Minor Season	
		4 WAP	6 WAP	4 WAP	6 WAP
30 × 15	Nkatie Sari	17.67^{a}	24.00^{a}	5.63^{a}	32.23^{a}
	Sum Nut 22	29.33^{c}	39.33^{c}	13.70^{a}	31.93^{bc}
	Yenyawoso	36.67^{d}	40.67^{c}	12.13^{c}	45.24^{c}
30 × 30	Nkatie Sari	23.00^{b}	28.00^{b}	16.11^{b}	38.26^{c}
	Sum Nut 22	37.33^{d}	45.00^{d}	18.21^{bc}	42.88^{c}
	Yenyawoso	40.00^{de}	47.33^{d}	24.14^{b}	47.18^{bc}
30 × 40	Nkatie Sari	26.00^{bc}	30.33^{b}	18.11^{c}	39.26^{bc}
	Sum Nut 22	41.33^{e}	52.00^{e}	13.21^{bc}	42.84^{bc}
	Yenyawoso	42.67^{e}	54.00^{e}	23.76^{c}	46.19^{c}
LSD (p = 0.05)		**3.72**	**3.33**	**4.63**	**3.93**

spacing of 30 cm × 40 cm (47.67), whereas the least mean number of pods per plant was recorded from Sum Nut 22 at a spacing of 30 cm × 15 cm (17.67) (Table 7).

3.2.2. 100 Seeds Weight

Plant spacing significantly affected ($p < 0.05$) the 100 seed weight of the groundnut during the major season of 2020. Yenyawoso at 30 cm × 40 cm spacing recorded the heaviest 100 seed weight (57.33 g), whereas Nkatie Sari at 30 × 15 cm spacing recorded the least (37 g) During the 2020 minor season, there were significant differences ($p < 0.05$) among the treatments for the 100 seeds weight (g). Nonetheless, Yenyawoso at a plant spacing of 30 cm × 30 cm produced the maximum 100 seeds weight (66 g) followed by Yenyawoso at a plant spacing of 30 cm × 40 cm (62.33 g), whereas the minimum 100 seeds weight was recorded from Nkatie Sari at a plant spacing of 30 × 30 cm (25.67 g) (Table 7).

3.2.3. Pod Yield

For the major cropping season, there were significant ($p < 0.05$) differences among the spacing for the pod yield. The highest pod yield was recorded from Yenyawoso at 30 cm × 40 cm spacing (4781 kg/ha), while the lowest pod yield was recorded from Nkatie Sari at 30 cm × 15 cm (2708 kg/ha). The pod yield of the different groundnut varieties was significantly influenced ($p < 0.05$) by the plant spacing. The highest pod yield (4375.14 kg/ha) was recorded from Nkatie Sari at a plant spacing of 30 × 15 cm, Yenyawoso at a plant spacing of 30 cm × 40 cm, followed by Nkatie Sari at a plant spacing of 30 cm × 40 cm (4340.42 kg/ha), whilst Sum Nut 22 at a plant spacing of 30 cm × 40 cm and Yenyawaso at a plant spacing of 30 cm × 40 cm recorded the lowest pod yield (3507.06 kg/ha) (Table 7).

Table 7. Effect of plant spacing on the yield and yield related parameters of different varieties of groundnut during the 2020 major and 2020 minor cropping seasons.

Spacing (cm)	Variety	No of Pods per Plant		100 Seeds Weight (g)		Pod Yield (kg/ha)	
Seasons		Major	Minor	Major	Minor	Major	Minor
	Nkatie Sari	27.00^{a}	19.33^{bc}	37.00^{a}	47.67^{a}	2708^{a}	4375.14^{a}
30 × 15	Sum Nut 22	33.00^{ab}	17.67^{c}	43.00^{ab}	40.33^{ab}	3333^{ab}	3576.50^{bc}
	Yenyawoso	37.67^{bc}	26.00^{bc}	47.67^{bc}	47.67^{abc}	3804^{bc}	3507.06^{c}
	Nkatie Sari	29.67^{a}	25.00^{bc}	39.6^{7a}	25.67^{a}	2996^{a}	4027.91^{abc}
30 × 30	Sum Nut 22	39.67^{bc}	29.33^{b}	49.67^{bc}	58.67^{bc}	4006^{bc}	3958.46^{abc}
	Yenyawoso	43.00^{cd}	49.00^{a}	53.00^{cd}	66.0^{c}	4343^{cd}	4236.25^{ab}
	Nkatie Sari	33.00^{ab}	30.00^{b}	43.00^{ab}	36.67^{ab}	3333^{ab}	4340.42^{a}
30 × 40	Sum Nut 22	42.67^{cd}	29.33^{b}	52.67^{cd}	47.67^{abc}	4309^{cd}	3507.06^{c}
	Yenyawoso	47.33^{d}	47.67^{a}	57.33^{d}	62.33^{bc}	4781^{d}	4375.14^{a}
LSD (p = 0.05)		**6.64**	**4.74**	**12.23**	**22.85**	**668.6**	**362.9**

4. Discussion

4.1. Influence of Different Planting Density on the Growth of the Different Varieties of Groundnut

4.1.1. Plant Height

The plant height was influenced by the plant spacing of the different varieties of groundnut in both cropping seasons. However, the results showed that the groundnut varieties Sum Nut 22 and Yenyawoso with a planting spacing of 30 × 15 cm (control) produced the tallest plant heights in both cropping seasons of the study. The finding of this study supports the observations of [30], who noted an increase in Sparaxis tricolour height with close spacing. A larger planting density also results in taller plants while growing lilies [31] and gladioli [32]. According to [31], planting depth as well as plant density may have an impact on the height of a plant. This shows that the widely used 30 × 15 cm by the farmers in the cultivation of groundnut influences the plant height of the crop. Plants compete for light and become taller at high plant densities, which is a characteristic of crowded plants. This finding is consistent with [33]. He explained that there is little room for horizontal development and that closer planting distances stimulate vertical growth at the expense of lateral growth in order to absorb light. Also, [33] suggested that crops grown in close proximity to one another compete more fiercely for light than crops grown farther apart. The observation that the groundnut plants with closer spacing produced higher plant height than those with wider spacing is consistent with reports by [34] on Bambara groundnut and the findings of [35]. [35] again, found that peanuts grown in rows of 10 and 20 cm grew taller than those grown in rows of 30 and 50 cm.

4.1.2. Number of Leaves

The number of leaves of the different groundnut varieties was significantly influenced ($p < 0.05$) by plant spacing. The number of leaves per plant significantly increased with the increase in plant density. The highest number of leaves was recorded from Sum Nut at a plant spacing of 30 × 40 cm during the major season, whereas Yenyawoso at a spacing of 30 cm × 40 cm recorded the maximum number of leaves during the minor season. This suggests that the wider spacing results in maximum number of leaves as compared to the control (30 cm × 15 cm) which produced lower number of leaves. The higher number of leaves in the wider plant spacing could be attributed to the fact that more light tends to reach plants with a wider spacing than those with a narrow spacing. Hence, more leaves are typically present on plants receiving higher amount of light than those receiving less [36]. This is due to the fact that photosynthesis functions better when plants receive high amount of light [37]. Similar finding was reported by [38]. In contrast to widely spread crops, the closely planted groundnuts covered the ground earlier, reducing weed growth. The explanation provided by [39] and [40], who stated that crops planted at shorter planting distances reach full canopy coverage earlier than crops planted at widely spaced intervals, which is consistent with this data. This may be due to an increase in canopy area, which benefits from more horizontal growing space than crop planted in close proximity to one another.

4.1.3. Number of Branches

The results revealed that all the groundnut varieties used in the present study produced a greater number of branches in both cropping seasons with a wider plant spacing of 30 cm × 40 cm. Yenyawoso at 30 cm × 40 cm spacing produced the highest number of branches during the major season, while Yenyawoso at 30 × 15 cm spacing (control) produced the maximum number of branches during the minor season. The high number of leaves produced by Yenyawoso during both seasons under different plant spacing might be ascribed to the genetic characteristics of the variety. Nonetheless, it was observed that at a wider plant spacing, a higher number of branches was recorded from the other varieties. [41] indicated the increase in plant branches with wider spacing (low plant density). The study of [42] revealed fewer ranges of the number of branches (3.22 - 8.13) because of the low plant spacing. The findings may agree with the results of this study. However, increasing row spacing allows for the use of solar energy and light absorption. [21] discovered that the number of branches develops less frequently at close spacing than at wider spacing. This outcome may be due to a healthy plant that has less competition for nutrients and light. Similar observation was recorded in this study. The result of this study is also in line with the findings of [33].

4.1.4. Number of Flowers

The study showed that the number of flowers was influenced by the plant spacing. Yenyawoso at 30 × 40 cm plant spacing produced the maximum number of flowers during the major season as compared to the control (30 × 15 cm) plant spacing adopted by the farmers. However, for the minor season, Yenyawoso at 30 × 30 cm plant spacing produced the maximum number of flowers. The results imply that the wider the spacing between the groundnut plants, the more flowers are being produced. [30] also reported similar observations using lachenalia cultivars as the test crop. Further, the high amount of flower produced by Yenyawoso in both seasons regardless of the plant spacing might be attributed to the soil nutrient and the photosynthetic ability of the variety for more accumulation of photosynthesis which results in higher number of flowers.

4.2. Influence of Different Planting Density on the Yield of Different Varieties of Groundnut

4.2.1. Number of Pods per Plant

The increased number of pods per plant with larger plant spacing 30 × 40 cm spacing during the major season and Yenyawoso at a spacing of 30 × 40 cm and 30 × 30 cm during the minor season) recorded in this study is consistent with findings from several studies using various crops by [21]. According to their findings, fewer number of pods per plant was recorded from closer plant spacing. These outcomes might be due to competition between plants and within individual plants under conditions of large planting population.

During the two seasons, the close plant spacing reduced seed output per plant. This was mostly caused by fewer pods on each plant with closer spacing. In a similar perspective, [43] discovered that reduced plant spacing significantly reduced seed output per plant. Previous studies by [44] and [35] suggested that decreasing plant density will boost pod and seed yield. Wide plant spacing may have less intra-specific competition for growth resources than close plant spacing which produces lower plant density and more accessible growth resource, which may account for the increased number of pods per plant. Groundnut cultivation in tight rows resulted in the preservation of a full crop cover over the soil, successfully inhibiting weed germination and lowering the cost of weeding, a conclusion previously reported by [45].

It has also been demonstrated that early canopy closure by tightly spaced groundnut crops smothers weeds, hence minimizing weed/crop competition, particularly for soil nutrients and water [46]. These advantages are, especially pronounced in low input environments, which are typical of smallholder farms. According to several researchers, wider-spaced groundnut systems provide greater yields than systems with closer spacing [47] [48], which may be related to efficient use more water, nutrients, and probably most crucially, light.

4.2.2. Pod Yield of Groundnut

From the present study, Yenyawoso at 30 × 40 cm spacing and Nkatie Sari at 30 × 15 cm spacing gave the maximum pod yield (4375.14 kg/ha). The lower plant densities may have had higher grain yields due to more luxurious growth and efficient resource usage, while the lower yields at higher plant densities may be due to competition for resources, which resulted in greater pod thickness than grain yield. Genetic variations among cultivars were likely to have influenced the variations in grain production. Previous investigations have revealed similar results [49] [50].

5. Conclusion

The growth and yield of groundnut was significantly influenced by the plant spacing. Groundnut grown at a spacing of 30 × 15 cm produced the highest plant height, whereas the highest number of leaves, number of branches and number of flowers were produced from 30 × 40 cm spacing. Yenyawoso variety with a wider plant spacing performed better vegetatively, among all the varieties. The Yenyawoso at 30 × 40 produced the highest number of pods, 100 seeds weight and pod yield. Also, Yenyawoso at 30 × 40 cm spacing and Nkatie Sari at 30 × 15 cm spacing gave the maximum pod yield.

Authors' Contributions

Conceptualization was a collaborative effort led by A.I., E.A., S.A., K.G.S., D.A., and I.A.P.; The **methodology** was designed and implemented by A.I. and E.A.; **Data analysis** was conducted by A.I. and E.A.; Allocation of **resources** was managed by A.I. and E.A.; **Data curation** responsibilities were handled by A.I. and E.A.; The **writing of the original draft** was primarily carried out by E.A. and A.I.; **Review and editing** involved contributions from A.I., E.A., S.K.A., K.G.S., D.A., and I.A.P. **Visualization** efforts were collaborative, led by A.I., E.A., S.K.A., K.G.S., D.A., and I.A.P. **Supervision** of the project was jointly conducted by S.K.A. and K.G.S.

Conflicts of Interest

All authors read, approved and have no conflict of interest regarding the publication of this manuscript.

References

[1] MoFA-SRID (2014) Agriculture in Ghana: Facts and Figures. Ministry of Food and Agriculture/Statistics Research Information Directorate, Accra, 1-53.

[2] Debrah, S.K. and Waliyar, F. (1996) Groundnut Production and Utilization in Africa; Past Trends; Projections and Opportunities for Increased Production. *The 5th Regional Groundnut Workshop for West Africa*, Accra, 18-21 November 1996.

[3] Food and Agriculture Organization of the United Nations (2012) FAOSTAT Statistics Database.

[4] Attuahene-Amankwah, G., Hossain, M.A. and Asibi, M.A. (1990) Peanut Production and Improvement in Ghana. *Summary Proceedings of the First Reg. Peanut Meeting for West Africa*, Niamey, 13-16 September 1988.

[5] Okello, D.K., Biruma, M. and Deom, C.M. (2010) Overview of Groundnuts Research in Uganda: Past, Present and Future. *African Journal of Biotechnology*, **9**, 6448-6459.

[6] Okello, D.K., Akello, L.B., Tukamuhabwa, P., Odong, T.L., Ochwo-Ssemakula, M.,

Adriko, J. and Deom, C.M. (2014) Groundnut Rosette Disease Symptoms Types' Distribution and Management of the Disease in Uganda. *African Journal of Plant Science*, **8**, 153-163. https://doi.org/10.5897/AJPS2014.1164

[7] Shilman, F., Brand, Y., Brand, A., Hedvat, I. and Hovav, R. (2011) Identification and Molecular Characterization of Homeologous Δ9-Stearoyl Acyl Carrier Protein Desaturase 3 Genes from the Allotetraploid Peanut (*Arachis hypogaea*). *Plant Molecular Biology Reporter*, **29**, 232-241. https://doi.org/10.1007/s11105-010-0226-9

[8] Reddy, T.Y., Reddy, V.R. and Anbumozhi, V. (2003) Physiological Responses of Groundnut (*Arachis hypogaea* L.) to Drought Stress and Its Amelioration: A Critical Review. *Plant Growth Regulation*, **41**, 75-88. https://doi.org/10.1023/A:1027353430164

[9] Mekontchou, T., Ngueguim, M. and Fobasso, M. (2006) Stability Analyse for Yield and Yield Components of Selected Peanut Breeding Lines *Arachis hypogaea* L. in the North Province of Cameroon. *Tropicultura*, **24**, 90.

[10] Johnson, D.R. and Leuders, V.D. (1994) Effect of Plant Seed Size on Emergence and Yield of Soyabeans. *Agronomy Journal*, **66**, 117-119. https://doi.org/10.2134/agronj1974.00021962006600010035x

[11] Howlader, S.H., Bashar, H.M.K., Islam, M.S., Mamun, M.H. and Jahan, S.M.H. (2009) Effect of Plant Spacing's on the Yield and Yield Attributes of Groundnut. *International Journal of Sustainable Crop Production*, **4**, 41-44.

[12] Gómez, K. and Gómez, A. (1983) Statistical Procedures for Agricultural Research. 2nd Edition, John Wiley and Sons, Hoboken, 630 p.

[13] Nimje, P.M. (1996) Effect of Row Spacing, Mulching and Weed Control on Weed Growth and Yield of Soybean (*Glycine max*). *Indian Journal of Agronomy*, **41**, 427-432.

[14] Quin, F. (2004) Groundnut. By R. Schilling and R. Gibbons. London and Oxford: Macmillan Education Ltd (2002), 146, £7.85. ISBN 0-333-72365-1. *Experimental Agriculture*, **40**, 140. https://doi.org/10.1017/S0014479703251528

[15] Jaaffar, Z. and Gardner, F.P. (1988) Canopy Development, Yield, and Market Quality in Peanut as Affected by Genotype and Planting Pattern. *Crop Science*, **28**, 299-305. https://doi.org/10.2135/cropsci1988.0011183X002800020024x

[16] Badiane, C. (2001) Senegal's Trade in Groundnuts: Economic, Social and Environmental Implications. Senegal.

[17] Dulvenbooden, N.V., Abdoussalam, S. and Moamed, A.B. (2002) Impact of Climate Change on Agricultural Production in the Sahel-Part 2. Case Study for Groundnut and Cowpea in Niger. *Climatic Change*, **24**, 349-368.

[18] Yakubu, H., Kwari, J.D. and Tekwa, J.A. (2010) Nodulation and N_2-Fixation by Grain Legumes as Affected by Boron Fertilizers in Sudano-Sahelian Zone of North Eastern Nigeria. *American Eurasian Journal of Agriculture and Environmental Science*, **8**, 514-519.

[19] Teng, W., Zhai, Y., Du, Y., Sun, D., Zhang, Z., Qu, L., Sun, G. and Li, W. (2008) QTL Analysis of Seed Weight during the Development of Soybean (*Glycine max* L. Merr.). https://doi.org/10.1038/hdy.2008.108

[20] Panda, S.C. (2010) Crop Management and Integrated Farming. Agrobios Publisher, Jodhpur, 271 p.

[21] El Naim, A.M., Eldoma, M.A. and Abdalla, A.E. (2010) Effect of Weeding Frequencies and Plant Density on Vegetative Growth Characteristic of Groundnut (*Arachis hypogaea* L.) in North Kordofan of Sudan. *International Journal of Applied Biology*

and Pharmaceutical Technology, **1**, 1188-1193.

[22] Page, A.L. (1982) Methods of Soil Analysis Part 2, Chemical and Microbiological Properties, Edited by Albert Lee Page, RH Miller, DR Keeney. Agronomy. 9. https://doi.org/10.2134/agronmonogr9.2.2ed

[23] Oudhia, P. (2004) Phyto-Sociology Studies of Rainy Wastelands Weed with Special Reference to *Parthenium hysterophorus* L. in Raipur District India. *Asian Journal of Microbiology, Biotechnology and Environmental Sciences*, **3**, 89-92.

[24] Garko, M.S., Abdulmumuni, M., Sa'ad, A.M. and Abba, U.U. (2018) Growth and Development of Bambara Groundnut (*Vigna subterranea* L.) as Affected by Phosphorus Levels and Weed Control Method in Sudan Savanna, Nigeria. *FUDMA Journal of Agriculture and Agricultural Technology*, **4**, 24-31.

[25] Ansa, J.E.O. and Adesina, O.L. (1998) Effect of Population Density on Cowpea (*Vigna unguiculata* L.) Yield in the Tropical Rainforest of Nigeria. *Nigerian Journal of Agricultural Teacher Education*, No. 1-2, 50-54.

[26] Ghana Statistical Services (2014) Brong Ahafo Regional Analytical Report, 2010, Accra.

[27] Nelson, D.W. and Sommers, L.E. (1982) Total Carbon, Organic Carbon, and Organic Matter. *Methods of Soil Analysis: Part* 3 *Chemical Methods*, **5**, 961-1010. https://doi.org/10.2136/sssabookser5.3.c34

[28] Bremner, J.M. and Mulvaney, C.S. (1982) Nitrogen-Total. In: Page, A.L., Ed., *Methods of Soil Analysis, Chemical and Microbiological Properties*, American Society of Agronomy, Madison, Part 2, 595-624. https://doi.org/10.2134/agronmonogr9.2.2ed.c31

[29] Murphy, J. and Riley, J.P. (1962) A Modified Single Solution Method for the Determination of Phosphate in Natural Waters. *Analytica Chimica Acta*, **27**, 31-36. https://doi.org/10.1016/S0003-2670(00)88444-5

[30] Kapczyńska, A. (2013) Effect of Plant Spacing on the Growth, Flowering and Bulb Production of Four Lachenalia Cultivars. *South African Journal of Botany*, **88**, 164-169. https://doi.org/10.1016/j.sajb.2013.07.015

[31] Amjad, A. and Ahmad, I. (2015) Optimizing Plant Density, Planting Depth and Postharvest Preservatives for *Lilium longifolium*. *Journal of Ornamental Plants*, **2**, 13-20.

[32] Roychowdhury, N. (1989) Effect of Plant Spacing and Growth Regulators on Growth and Flower Yield of Gladiolus Grown under Polythene Tunnel. *International Symposium on Protected Cultivation of Ornamentals in Mild Winter Climates*, Vol. 246, 259-264. https://doi.org/10.17660/ActaHortic.1989.246.31

[33] Farnham, D.E. (2001) Row Spacing, Plant Density, and Hybrid Effects on Corn Grain Yield and Moisture. *Agronomy Journal*, **93**, 1049-1053. https://doi.org/10.2134/agronj2001.9351049x

[34] Akpalu, M.M., Sarkodie-Addo, J. and Akpalu, S.E. (2012) Effect of Spacing on Growth and Yield of Five Bambara Groundnut (*Vigna subterranea* (L) Verdc.) Landraces. *Journal of Science and Technology* (*Ghana*), **32**, 9-19. https://doi.org/10.4314/just.v32i2.2

[35] El Naim, A.M., Eldouma, M.A., Ibrahim, E.A., Moayad, M. and Zaied, B. (2011) Influence of Plant Spacing and Weeds on Growth and Yield of Peanut (*Arachis hypogaea*) in Rain-Ted of Sudan. *Advance in Life Science*, **1**, 45-48. https://doi.org/10.5923/j.als.20110102.08

[36] Milthorpe, F.L. and Moorby, J. (1980) An Introduction to Crop Physiology. Cam-

bridge University Press, Cambridge.

[37] Polnaya, F. and Patty, J.E. (2018) Kajian pertumbuhan dan produksi varietas jagung lokal dan kacang hijau dalam sistem tumpangsari. *Agrologia*, **1**, 42-50. https://doi.org/10.30598/a.v1i1.297

[38] Qodliyati, M. and Nyoto, S. (2018) Influence of Spacing and Depth of Planting to Growth and Yield of Arrowroot (*Marantha arundinacea*). *IOP Conference Series: Earth and Environmental Science*, **142**, Article ID: 012035. https://doi.org/10.1088/1755-1315/142/1/012035

[39] Brown, S.L., Culbreath, A.K., Todd, J.W., Gorbet, D.W., Baldwin, J.A. and Beasley Jr, J.P. (2005) Development of a Method of Risk Assessment to Facilitate Integrated Management of Spotted Wilt of Peanut. *Plant Disease*, **89**, 348-356. https://doi.org/10.1094/PD-89-0348

[40] Tillman, B.L., Gorbet, D.W., Culbreath, A.K. and Todd, J.W. (2006) Response of Peanut Cultivars to Seeding Density and Row Patterns. *Crop Management*, **5**, 1-7. https://doi.org/10.1094/CM-2006-0711-01-RS

[41] Kathirvelan, P. and Kalaiselvan, P. (2007) Groundnut (*Arachis hypogaea* L.) Leaf Area Estimation Using Allometric Model. *Research Journal of Agriculture and Biological Sciences*, **3**, 59-61.

[42] Singh, A.L. (1999) Mineral Nutrition of Groundnut. *Advances in Plant Physiology*, **2**, 161-200.

[43] Ahmed, E.M. and Jabereldar, A.A. (2010) Effect of Plant Density and Cultivar on Growth and Yield of Cowpea (*Vigna unguiculata* L. Walp). *Australian Journal of Basic and Applied Sciences*, **4**, 3148-3153.

[44] Awal, M.A. and Aktar, L. (2015) Effect of Row Spacing on the Growth and Yield of Peanut (*Arachis hypogaea* L.) Stands. *International Journal of Agriculture, Forestry and Fisheries*, **3**, 7-11.

[45] Lee, H.C., Berry, M.P., de Toledo, V.C., deffune, G., Haymes, R., Lopez, R.J., Morrish, C.J., Rodigues, R., Scofield, A.M., Watt, T.A. and Wu, B.Z. (1994) Nonchemical Weed Management in Major UK Arable Crops. *Aspects of Applied Biology*, **40**, 317-324.

[46] Thellen, K.D. (2006) Interaction between Row Spacing and Yield: Why It Works. *Crop Management*, **5**, 1-6. https://doi.org/10.1094/CM-2006-0227-03-RV

[47] Mickelson, J.A. and Renner, K.A. (1997) Weed Control Using Reduced Rates of Postemergence Herbicides in Narrow and Wide Row Soybean. *Journal of Production Agriculture*, **10**, 431-437. https://doi.org/10.2134/jpa1997.0431

[48] Munir, A., Munir, M., Ahmad, I. and Yousuf, M. (2011) Evaluation of Bread Wheat Genotypes for Salinity Tolerance under Saline Field Conditions. *African Journal of Biotechnology*, **10**, 4086-4092. http://www.academicjournals.org/AJB

[49] Abdullah, T., Rahmianna, A.A., Hardaningsih, S. and Rozi, F. (2007) Increasing Groundnut Yield on Dry Land Alfisols in Indonesia. *Journal of Semi-Arid Tropics Agricultural Research*, **5**, 84-96.

[50] Virender, S. and Kandhola, S.S. (2007) Productivity of Semi-Spreading and Bunch Type Varieties of Groundnut as Influenced by Sowing Dates. *Journal of SAT Agricultural Research*, **5**, 1-3.