Vol. 20(5), pp. 337-355, May 2024
DOI: 10.5897/AJAR2023.16598
Article Number: CEA872572136
ISSN: 1991-637X

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African Journal of Agricultural Research

Full Length Research Paper

Phenology and growth response of maize and groundnut to different spatial arrangement and intercropping systems

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Received 21 December, 2023; Accepted 30 April, 2024

Field trials were carried out at the research field of AAMUSTED in two cropping seasons (2021 and 2022) to determine the effect of intercropping groundnut varieties with maize using different spatial arrangements on phenology and growth. A 3 x 3 factorial experiment arranged in Randomized Complete Block Design (RCBD), plus four sole crops replicated four times, was used. The treatments were: (i) groundnut varieties (Yenyawoso, Dehye, and Oboshie) and Opeaburo maize; (ii) Spatial arrangements (SP1 = 1-row maize alternating with 1-row groundnut, SP2 = 1-row maize alternating with 2 rows of groundnut, and SP3 = 1-row maize alternating with 3 rows of groundnut) plus four sole crops. The results showed that Opeaburo-Yenyawoso x SP1 interaction and sole Yenyawoso were the earliest to flower, while for maize, Opeaburo-Yenyawoso x SP2 and SP3 interaction demonstrated the earliest days to 50% tasseling and silking across both cropping seasons. Opeaburo-Dehye x SP2 and SP3 interactions had the tallest plants and greatest dry shoot weight, whereas Opeaburo-Oboshie x SP2 interaction had the highest number of branches per plant. To maximize growth and early phenological response of maize and groundnut, it is recommended that farmers should intercrop Opeaburo with Yenyawoso or Oboshie using SP2 and SP3 spatial arrangements.

Key words: Maize, Groundnut, Phenology, Intercropping, Spatial arrangement.

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crops used in the human diet in large parts of the world, and it is also an important feed component for livestock (Kaushal et al., 2023). The total maize production in Ghana has been estimated at 2,303 – 2,759 MT in 2018 – 2019 (FAO, 2020). Groundnut is an important cash crop grown in Ghana by smallholder farmers in sole stands or mixed with other crops because of its high protein content (25 - 28%) and edible oil content (50%) (Amoako et al., 2023). The crop has high commercial and nutritional values due to its high protein, fatty acid, vitamins, oil, carbohydrates, and minerals content (Bonku and Yu, 2020).

Intercropping is one of the oldest practices that have remained a dominant form of agriculture in many parts of the world (Zustovi et al., 2024). Smallholder farmers in

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Africa have long used intercropping, which is now gaining popularity due to its potential for maximizing land usage while producing high yields with minimal inputs, such as nitrogen fertilizer (Feng et al., 2021). Intercropping also reduces pests and diseases (Zhang et al., 2019), and in agricultural systems, it can boost soil organic matter and nitrogen retention (Wang et al., 2023). According to Raza et al. (2023), intercropping of cereals and legumes has been promoted specifically for the purpose of acquiring nitrogen (N). Both cereals and legumes absorb nitrogen (N) from the soil solution; however, only the legumes fix nitrogen (N) from the air through symbiosis with nitrogen-fixing bacteria in root nodules. Due to less competition for nitrogen (N) since legumes get some of their nitrogen from the air, cereals thrive better in a mixture with a legume than in a single stand at low soil nitrogen (N) supply. According to Li et al. (2022a), nitrogen-fixing crops (NFCs) are often used as intercrops in intercropping patterns to fix N from the atmosphere and improve soil fertility, provide nutrients for plant growth, and change the level of other nutrients in the soil.

Agricultural production systems in Ghana are based on smallholder farms. However, most farmers still use traditional production technologies, low-yielding local varieties, and predominantly practice monocropping systems. Monocropping depends on excessive use of agrochemical fertilizers and pesticides, which contribute to agricultural pollution and soil erosion, reduce genetic diversity in crops, and can lead to food insecurity and crop failure due to pests, diseases, or weather conditions.

In the Guinea and Sudan Savannah agroecological zones of Ghana, some farmers practice intercropping cowpea or groundnuts with sorghum, millet, or maize, while in the humid zones (forest and forest savannah transition zones), intercropping maize with cowpea or groundnuts is practiced by a few farmers. The maize-groundnut intercrops practiced by farmers in such agroecologies of Ghana have been characterized by low crop yields and overall productivity. This is because farmers still use low-yielding crop varieties and do not consider the row arrangements in the intercropping system.

Intercropping can provide higher yields with fewer inputs, such as nitrogen fertilizer, and has the potential to maximize land use. Therefore, it has been utilized by some smallholder farmers in Ghana and Africa (Li et al., 2020). New varieties of groundnuts have been released by the CSIR-Crops Research Institute of Ghana, which have had limited testing in intercropping systems compared to sole cropping. Additionally, examining the varieties under different row arrangements might increase the overall performance and productivity of the intercrop systems. Olayinka (2017) indicated that growth characters such as the number of leaves and leaf area were improved in 3-rows of groundnut alternating with 1-row maize (3G: 1M) and 3-rows of groundnut alternating with 2-rows of maize (3G: 2M) spatial arrangement compared to 3-rows of groundnut alternating with 3-rows of maize (3G: 3M) and their respective sole cropping. Much research has been done on intercropping, but limited attention has been given to spatial arrangement, especially in maize-groundnut intercropping systems in Ghana. A maize and groundnut intercropping system with a good spatial arrangement will provide a variety of intercropping alternatives that will address issues with insect pest infestation and soil fertility, leading to proper crop growth. The objective of the study was to evaluate the effect of different spatial arrangements and varietal combinations of maize and groundnut intercrops on phenology and growth.

MATERIALS AND METHODS

Experimental site and location

Two field experiments were carried out at different locations from August to December 2021 in the minor rainy season and from March to July 2022 in the major rainy season. The field research was conducted at the Research Field of the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED), Mampong Campus. Asante Mampong is located in the Forest-Savannah transitional zone of Ghana (Geodatos, 2020). The mean annual rainfall of Asante Mampong is approximately 1270 mm with a bimodal rainfall pattern. The major rains begin around early April and end in July, while the minor rains start in September and end in November. There is a short dry period in August, but the main dry season begins in December and ends in March. The area experiences a mean temperature of about 27°C per annum with a temperature range normally from 22°C to 30°C (GSS, 2014). The soil at the experimental site is derived from the Voltaian sandstone and belongs to the Bediese Series of the Savannah Ochrosol class. It is classified as a Chromic Luvisol (Asiamah, 1987). It is deep red, sandy loam, and free from stones. It is well-drained and friable and also has good water-holding capacity, texture, and structure. It has a pH of about 6.5.

Experimental design and treatments

The experimental design used was a 3 x 3 factorial experiment arranged in a Randomized Complete Block Design (RCBD) and replicated four times. Sole crops of maize and groundnut varieties were added.

The Treatments were:

1. Varietal combination of maize and groundnut: (i) Opeaburo + Yenyawoso, (ii) Opeaburo + Dehye, and (iii) Opeaburo + Oboshie. The sole crops were: sole Yenyawoso, sole Dehye, sole Oboshie, and sole Opeaburo.
2. Spatial arrangements: (i) 1-row maize alternating with 1-row groundnut (SP1), (ii) 1-row maize alternating with 2 rows groundnut (SP2), and (iii) 1-row maize alternating with 3 rows groundnut (SP3).

Field layout and planting materials

Each plot size consisted of 4 sets of the intercrop spatial arrangement, with a row length of 5 m. Therefore, the plot sizes for the intercrops were as follows: SP1 = 4 m wide x 5 m long, SP2 = 6 m wide x 5 m long, and SP3 = 8 m wide x 5 m long. The within-row spacing for the intercrops was 40 cm for maize and 20 cm for groundnuts. The sole crops also consisted of 4 rows each per plot and a length of 5 m per row. The sole maize was planted at 80 cm x 40 cm, and the groundnut varieties at 50 x 20 cm. Both maize and groundnuts had 2 plants per hill for both intercrops and sole crops.

The Opeaburo maize variety and Yenyawoso, Dehye, and Oboshie groundnut varieties used for the study were obtained from the Crops Research Institute of the Council for Scientific and Industrial Research (CSIR-CRI), developed and released by the same Institute. The Opeaburo maize variety is a white dent with a maturity period between 110 - 115 days. This variety was selected for the study because it is drought and disease-resistant, with a high-yielding potential of 7.5 t/ha.

The Yenyawoso groundnut variety is early maturing with a maturity period of 85 - 90 days, Dehye is an early maturing variety with a maturity period between 85 – 90 days, and Oboshie is a late-maturing variety with a maturity period between 105 – 110 days. These three varieties of groundnuts were also selected for the study because they are high-yielding varieties with the following yield potentials: Yenyawoso (2.7 t/ha), Dehye (2.9 t/ha), and Oboshie (2.6 t/ha). They are also drought-resistant varieties that grow vigorously under normal weather conditions.

Land preparation and planting

The land was prepared in August 2021 and March 2022 for the first and second experiments respectively by ploughing, harrowing, and later leveling. The land was demarcated into four blocks (replications). Both maize and groundnut seeds were planted directly on the same day using three seeds per hole. Maize seeds were planted on flat land, while groundnut seeds were planted on ridges. The within-row spacing for the intercrops was 40 cm for maize and 20 cm for the groundnuts, and the between-row spacing for the intercrop was 50 cm. The sole maize was planted at 80 x 40 cm, and the groundnut varieties at 50 x 20 cm. The maize and groundnut were thinned to two seedlings per hill two weeks after emergence for the intercrops and sole crops.

Measurement for one-row maize and one-row groundnut (SP1) experimental plot had 4 rows of maize and 12 plants per row given 24 plants per row and 96 plants per plot and for the groundnut, there were 4 rows and 24 plants per row given a total of with 48 plants per row (192) plants per plot. For one-row maize and two rows of groundnut (SP2) experimental plot had 4 rows of maize and 12 plants per row given 24 plants per row and 96 plants per plot and for the groundnut, there were 8 rows and 24 plants per row given a total of 48 plants per row (384 plants). Plot of one-row maize and three rows of groundnuts (SP3) experimental plot had 4 rows of maize and 12 plants per row given 24 plants per row and 96 plants per plot and there were 12 rows and 24 plants per row given a total of 48 plants per row and (576) plants per plot. Sole maize experimental plot had 6 rows and 24 plants per row (144) plants per plot whereas for sole groundnut experimental plot, there were 6 rows and 48 plants per row given a total of 288 plants per plot.

Agronomic practices

Weed control

Three separate weedings were done with the aid of a hoe and a cutlass. The first weeding was done two weeks after seedling emergence. The second and third weeding were done 30 and 60 days after planting, respectively.

Pest and disease control

Frequent visit to the experimental field was done to observe the incidence of pests such as stem borers, corn leaf aphid rodents, and fall armyworm on maize and diseases such as rust, early leaf spot, late leaf spot, and rosette on groundnut. Emaster (*Emamectin benzoate*) insecticide was applied at a rate of 10 - 20 ml per 15L knapsack sprayer to control Fall Armyworm infestation two weeks after seedling emergence and at every one week interval. Incidence of diseases on groundnut was very minimal so no control measures were taken against it.

Data collection

Maize data collected

Days to 50% tasseling for both sole and intercrop maize were estimated by counting from the two central harvestable rows from the day of sowing seeds to when 50% or half of the plants had tasseled. The days to 50% silking for both sole and intercrop were determined by counting from the two central harvestable rows from the day of sowing to when 50% or half of the plants had silked. A meter stick was used to determine the height of the maize plant from the plant's base to its flag leaf. Plant height was measured from five randomly selected and tagged plants in the two central rows for sole crops and intercrops, 3 weeks after planting and every two-week interval, and their mean values were estimated.

The dry shoot and root weight of maize plants for both sole and intercrop were determined 3 weeks after planting and every two-week interval. Two plants were cut from each plot of sole maize and intercrop and were separated into shoot and root. They were then chopped into smaller pieces, and the fresh shoot and root weight were determined using the Westinghouse electronic weighing scale. A 200 g of fresh root and shoot was fetched from the bulk and placed into an envelope and was oven-dried in the laboratory at 85°C until the constant weight was attained, and their means estimated.

Groundnut data collected

Days to 50% flowering of groundnut were assessed by counting from the two central harvestable rows from the day of sowing to when 50% or half of the plants had flowered. This was done for both sole and intercrop groundnut. The plant height was determined from the base of the plant to the flag leaf using the meter rule. This was done for both sole and intercrop of groundnut from the five randomly selected and tagged plants in the two central rows, three weeks after planting and every two weeks interval, and their mean values were estimated.

The number of branches per plant for both sole and intercrop from the five randomly selected and tagged plants in the two central rows were determined 3 weeks after planting and every two weeks interval. This was done by counting the total number of branches from each tagged plant and estimating the mean.

The dry shoot and root weight of groundnut for both sole and intercrop were determined 3 weeks after planting and every two weeks interval. Two plants were cut from each plot of sole groundnut and intercrop and were separated into shoot and root. They were then chopped into smaller pieces, and the fresh shoot and root weight were determined using the Westinghouse electronic weighing scale. A 200 g of fresh root and shoot was fetched from the bulk and placed into an envelope and was oven-dried in the laboratory at 85°C until the constant weight was attained, and their means estimated.

Statistical analysis

Using GenStat Release 18.1 statistical package, analysis of variance (ANOVA) was used to analyse the data that were

Table 1. Climatic data for 2021 Minor cropping season for Experiment 1.

Month	Total rainfall (mm)	Relative humidity (%)	Mean temperature (°C)	
			Max	Min
August, 2021	1695	77	29.7	22.7
September	225.1	77	30.3	23.2
October	208.7	72	32.1	22.3
November	73.4	68	33.1	23.4
December	0.0	58	34.3	23.7
Total	676.7			

Source: Ghana Meteorological Agency – Mampong Ashanti (2021).

Table 2. Climatic data for 2022 Major cropping season for Experiment 2.

Month	Total rainfall (mm)	Relative humidity (%)	Mean temperature (°c)	
			Max	Min
March, 2022	109.2	67	34	23.9
April	79.6	66	33.1	23.5
May	147.8	71	32.7	23.8
June	149.0	74	31	23.3
July	203.6	74	30	22.7
Total	694.6			

Source: Ghana Meteorological Agency – Mampong Ashanti (2021).

collected. Tukey's Honestly Significant Difference (HSD) was used to separate treatment means at a 5% level of probability.

RESULTS

Climatic conditions at the experimental site

The total rainfall during the experiment for the 2021 minor raining season was 676.7 mm. The highest relative humidity (77%) was recorded in August and September and the least was recorded in December 2021 (58%). The mean maximum and minimum temperatures during the 2021 minor raining season were 31.9 ^{O}C and 23.06 ^{O}C, respectively (Table 1). The total rainfall during the 2022 major raining season was 694.6 mm. The highest relative humidity (74%) was recorded in June and July, while the least was recorded in April 2022 (66%) during the major raining season. The mean maximum and minimum temperatures during the 2022 major raining season were 26.76 ^{O}C and 23.44 ^{O}C, respectively (Table 2).

Influence of variety and spatial arrangement on phenology of groundnut and maize

Phenology of groundnut

Days to 50% flowering: Table 3 presents the results of days to 50% flowering of groundnut for the 2021 minor and 2022 major cropping seasons. Yenyawoso groundnut flowered a few days earlier (27 – 28 days) than Dehye groundnut (30 – 31 days) and Oboshie groundnut (32 – 34 days) in the intercrops during both seasons. For the 2021 period, the Opeaburo maize + Yenyawoso groundnut x SP1 interaction and sole Yenyawoso groundnut had the earliest days to 50% flowering, while for the 2022 major season, Opeaburo maize x Yenyawoso groundnut x SP1, SP2, and SP3 interactions exhibited the earliest and same days to 50% flowering of groundnut. On the other hand, plots with Opeaburo maize + Oboshie groundnut x SP2 and Opeaburo maize + Oboshie groundnut x SP3 interactions, as well as Sole Oboshie groundnut, were late to flower for the 2021 minor and 2022 major cropping seasons. Days to 50% flowering were similar for both seasons. However, spatial arrangement and varietal combination x spatial arrangements interaction effects on days to 50% flowering were not significant (P > 0.05) for both seasons (Table 3).

Phenology of maize

Days to 50% tasseling: The results for the days to 50% tasseling for the maize variety Opeaburo in intercrop and sole crop are shown in Table 4. There was a significant difference between the treatment means in both cropping seasons (P ≤ 0.05). The days to 50% tasseling ranged from 52 – 54 days for both seasons. Opeaburo maize +

Table 3. Days to 50 % flowering of groundnut as influenced by variety and spatial arrangement for 2021 minor and 2022 major cropping seasons.

Treatment		Days to 50% flowering	
Varietal combination (VC)	**Spatial arrangement (SP)**	**2021**	**2022**
	SP1	27	28
Opeaburo + Yenyawoso	SP2	28	28
	SP3	28	28
	SP1	30	30
Opeaburo + Dehye	SP2	30	30
	SP3	31	30
	SP1	34	32
Opeaburo + Oboshie	SP2	33	32
	SP3	33	33
Sole Yenyawoso	-	27	28
Sole Dehye	-	30	30
Sole Oboshie	-	33	33
CV (%)		**2.4**	**2.7**
Variety =		HSD=0.49**	*p=<.001*
Season =		HSD=0.51**	*p=0.038*
Spatial arrangement =		NS	
Season x variety =		HSD=0.72**	*p=0.008*
Season x spatial arrangement =		NS	
Variety x spatial arrangement =		NS	

SP1= 1-row maize alternating with 1-row groundnut, SP2= 1-row maize alternating with 2 rows of groundnut, SP3= 1-row maize alternating with 3 rows of groundnut, NS = non-significance, HSD= Honestly significant difference, CV (%) = Coefficient of variation.

Yenyawoso groundnut x SP2 interaction recorded the earliest days to 50% tasseling for the 2021 cropping season, while Opeaburo maize + Oboshie groundnut x SP2 interaction obtained the earliest days to 50% tasseling for the 2022 major cropping season. For the 2021 minor cropping season, plots with Opeaburo maize + Dehye groundnut x SP2, Opeaburo maize + Oboshie groundnut x SP1, and Opeaburo maize + Oboshie groundnut x SP2 interactions were late to tassel, while for the 2022 major cropping period, Opeaburo maize + Dehye groundnut x SP1 interaction was late to tassel. The days to 50% tasseling were not significantly different among the varietal combinations, spatial arrangements, nor the varietal combination x spatial arrangement interactions for both seasons. Generally, tasseling did not differ between the two seasons either (Table 4).

Days to 50% silking: The results for the days to 50% silking for the maize variety Opeaburo in intercrop and sole crop are shown in Table 4. The days to 50% silking ranged from 57 – 60 days for both seasons. Opeaburo maize + Yenyawoso groundnut x SP2 interaction recorded the earliest days to 50% silking for the 2021 cropping period. The days to 50% silking was not significantly different among the varietal combinations, spatial arrangements nor the varietal combination x spatial arrangement interactions for both seasons. Generally, silking did not differ between the two cropping seasons either (Table 4).

Influence of variety and spatial arrangement on vegetative growth of groundnut

Plant height

Figures 1 and 2 show the results of plant height for groundnut varieties and their intercrops from 21 DAP to 77 DAP for the 2021 minor and 2022 major cropping seasons. The plant height increased throughout the entire period from 21 DAP to 77 DAP for both seasons. Generally, Dehye groundnut and its intercrop showed the highest increase in plant height throughout the growing period, followed by Yenyawoso groundnut and its intercrop, whereas Oboshie groundnut and its intercrop had the lowest trends in plant height among the groundnut varieties (Figures 1 and 2). Figures 3 and 4

Table 4. Days to 50% tasseling and days to 50% silking of maize as influenced by variety and spatial arrangement for 2021 minor and 2022 major cropping seasons.

Treatment		Days to 50% tasseling		Days to 50% silking	
Varietal combination (VC)	**Spatial arrangement (SP)**	**2021**	**2022**	**2021**	**2022**
Opeaburo + Yenyawoso	SP1	52.75	53.50	58.25	58.75
	SP2	52.25	53.25	57.25	59.50
	SP3	52.75	52.75	57.50	58.75
Opeaburo + Dehye	SP1	53.00	54.25	58.25	59.25
	SP2	53.50	53.25	58.75	59.50
	SP3	53.25	53.25	58.25	58.75
Opeaburo + Oboshie	SP1	53.50	53.50	59.00	59.50
	SP2	53.50	52.50	59.50	58.50
	SP3	53.25	53.50	58.50	59.25
Sole Opeaburo	-	53.50	53.0	59.00	58.75
CV (%)		1.1	1.5	1.7	1.2
Variety =		NS		NS	
Season =		NS		HSD=0.42**	*p=0.004*
Spatial arrangement =		NS		NS	
Season x variety =		NS		HSD=0.86**	
Season x spatial arrangement =		NS		NS	*p=0.046*
Variety x spatial arrangement =		NS		NS	

SP1= 1-row maize alternating with 1-row groundnut, SP2= 1-row maize alternating with 2 rows of groundnut, SP3= 1-row maize alternating with 3 rows of groundnut, NS = non-significance, HSD= honestly significant difference, CV (%) = Coefficient of variation.

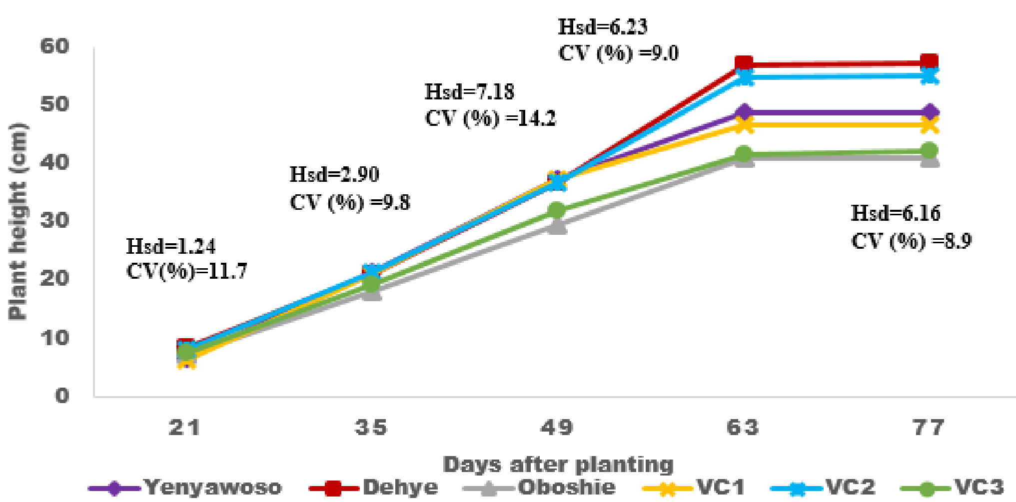

Figure 1. Plant height of groundnut as influenced by variety for 2021 minor cropping season. VCI: varietal combination 1 (Opeaburo + Yenyawoso); VC2: varietal combination 2 (Opeaburo + Dehye); and VC3: varietal combination 3 (Opeaburo + Oboshie).

show the results of spatial arrangement for plant height of groundnut varieties for both 2021 minor and 2022 major cropping periods. Generally, no significant difference was observed among the spatial arrangements. However, the spatial arrangements showed an increase in plant height from 21 – 77 DAP, with SP2 standing out in terms of plant height among the groundnut varieties and their intercrops for the spatial arrangement.

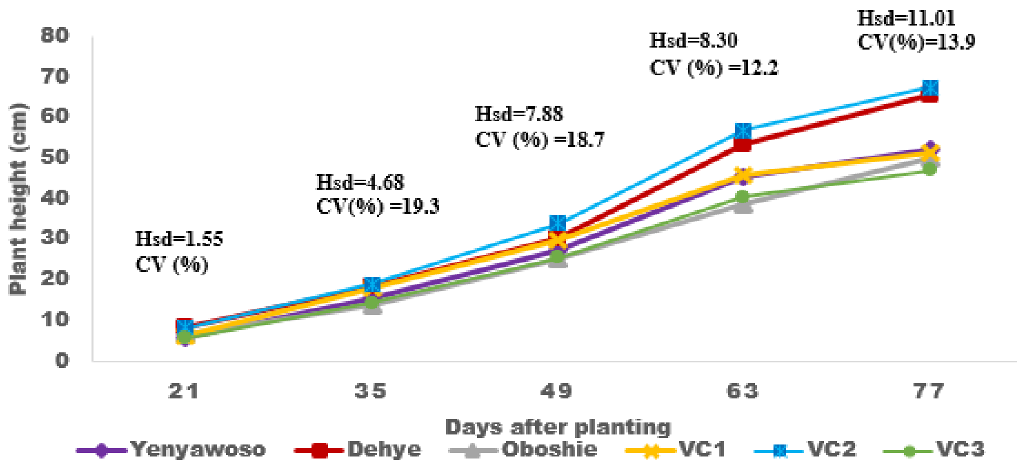

Figure 2. Plant height of groundnut as influenced by variety for 2022 major cropping season. VCI: varietal combination 1 (Opeaburo + Yenyawoso); VC2: varietal combination 2 (Opeaburo + Dehye); and VC3: varietal combination 3 (Opeaburo + Oboshie).

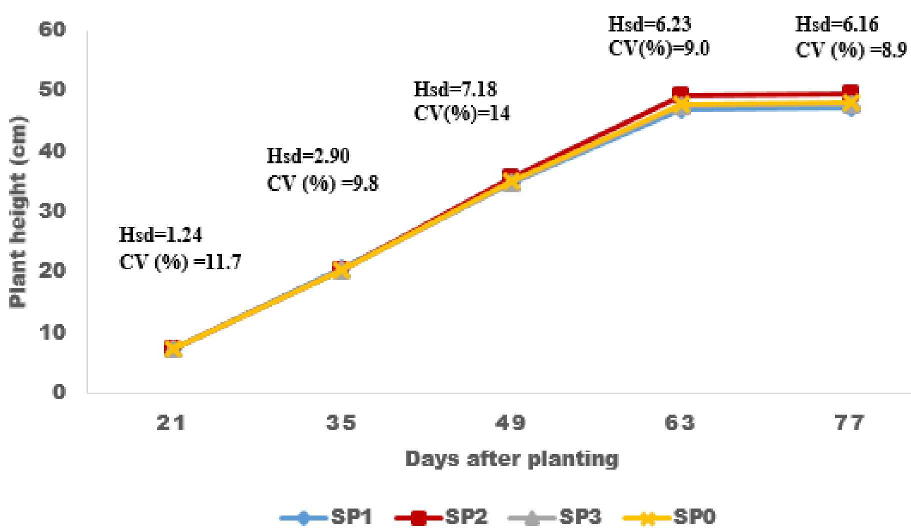

Figure 3. Plant height of groundnut as influenced by spatial arrangement for 2021 minor cropping season.

Number of branches per plant

Figures 5 and 6 indicate the results of the number of branches per plant among groundnut varieties and their intercrops for both seasons. The number of branches per plant of groundnut increased from 21 DAP to 63 DAP for both cropping seasons until 77 DAP, where it remained constant. Generally, Oboshie groundnut variety and its intercrop had the highest increase in the number of branches per plant followed by Yenyawoso groundnut and Dehye groundnut throughout the growing period in both seasons. Figures 7 and 8 show the results of spatial arrangement for the number of branches per plant of groundnut varieties for both seasons. Generally, the spatial arrangements showed an increase in the number of branches per plant of groundnut from 21 – 63 DAP until 77 DAP, where it remained constant. SP2 had the greatest number of branches per plant in the 2021 minor season, whereas in the 2022 major season, SP3 had the greatest number of branches per plant among the groundnut varieties and their intercrops for the spatial arrangement.

Dry shoot weight (DSW)

Figures 9 and 10 present the results of dry shoot weight among groundnut varieties and their intercrops.

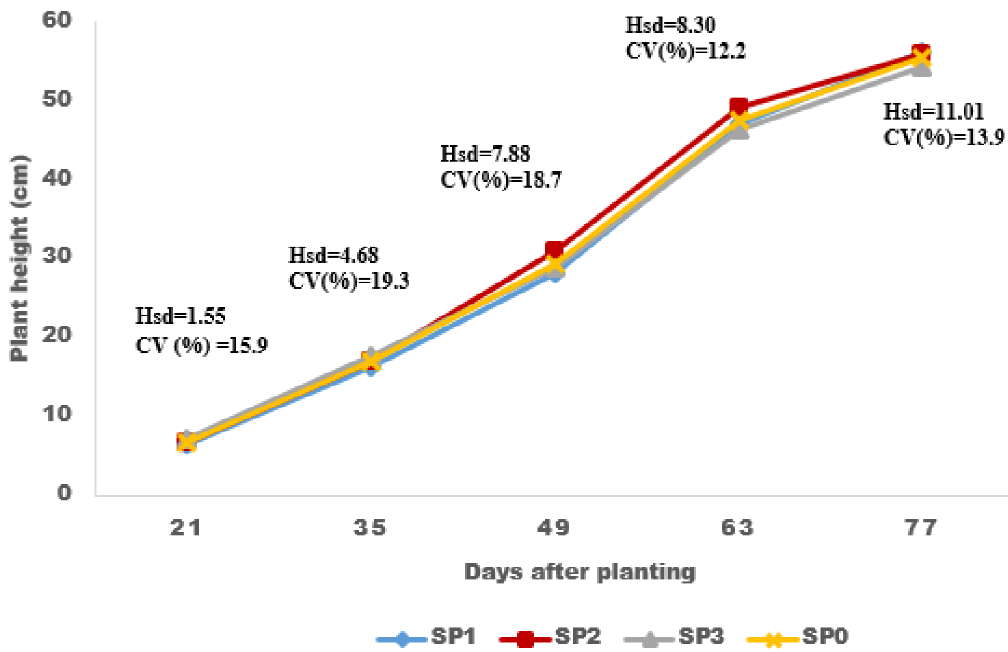

Figure 4. Plant height of groundnut as influenced by spatial arrangement for 2022 major cropping season.

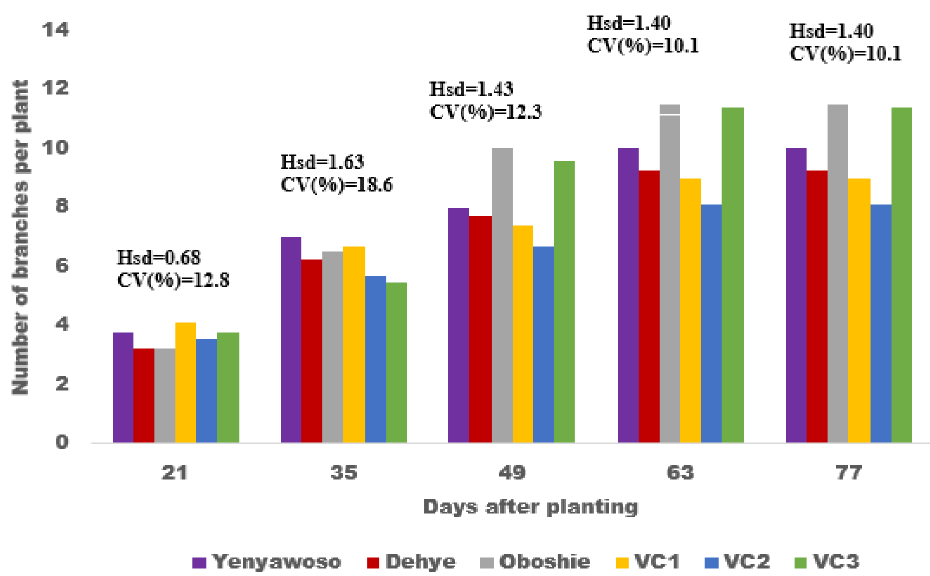

Figure 5. Number of branches per plant of groundnut as influenced by variety for 2021 minor cropping season. VCI: varietal combination 1 (Opeaburo + Yenyawoso); VC2: varietal combination 2 (Opeaburo + Dehye); and VC3: varietal combination 3 (Opeaburo + Oboshie).

Generally, there was an increase in dry shoot weight among the groundnut varieties and their intercrops from 21 – 49 DAP until 63 DAP, where there was a decline for both seasons. Dehye groundnut and its intercrop generally had the greatest dry shoot weight, followed by Oboshie groundnut, with Yenyawoso groundnut recording the least for both the 2021 minor and 2022 major seasons (Figures 9 and 10). Results of dry shoot weight of spatial arrangements among groundnut varieties and their intercrops are shown in Figures 11 and 12. Dry shoot

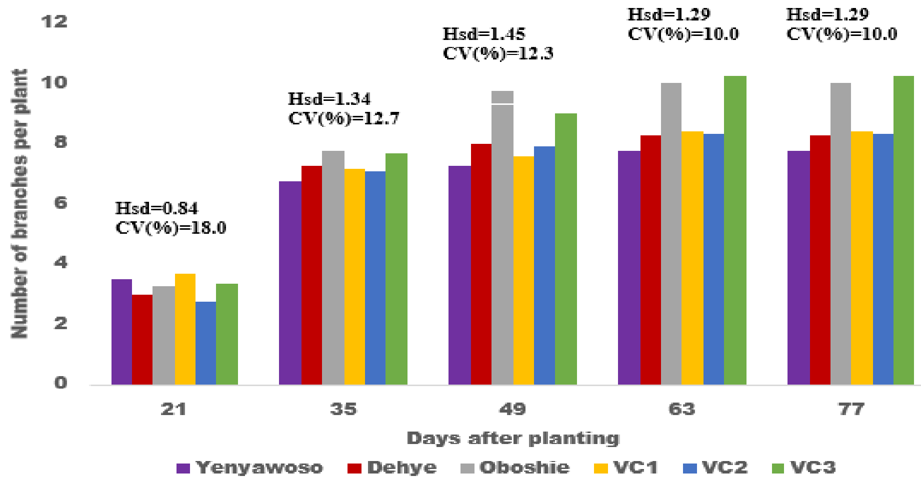

Figure 6. Number of branches per plant of groundnut as influenced by variety for 2022 major cropping season. VCI: varietal combination 1 (Opeaburo + Yenyawoso); VC2: varietal combination 2 (Opeaburo + Dehye); and VC3: varietal combination 3 (Opeaburo + Oboshie).

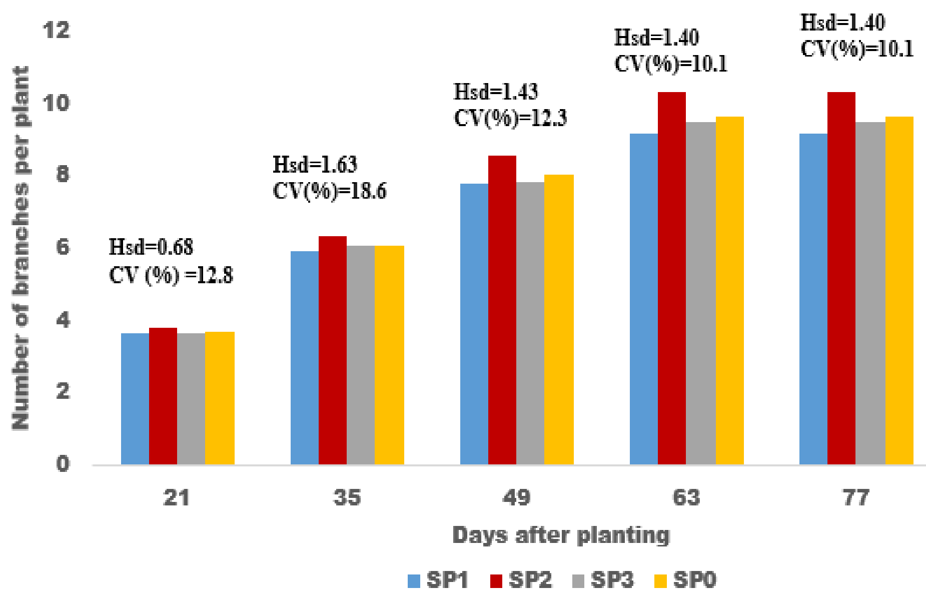

Figure 7. Number of branches per plant of groundnut as influenced by spartial arrangement for 2021 minor cropping season.

weight showed an increasing trend from 21 DAP to 49 DAP until 63 DAP where it declined. Generally, SP2 showed the highest increase in dry shoot weight among the spatial arrangements (Figures 11 and 12).

Influence of variety and spatial arrangement on vegetative growth of maize

Plant height

Results of plant height of maize and its intercrop are shown in Figures 13 and 14 for both the 2021 minor and 2022 major cropping seasons. Plant height increased from 21 DAP – 63 DAP for both seasons until 77 DAP where it remained constant. For the 2021 minor season, plant height was higher in varietal combination 1 (VC1), whereas in the 2022 major season, plant height was higher in sole Opeaburo. Plant height was lower in varietal combination 2 (VC2) (Figures 13 and 14). Figures 15 and 16 show the results of spatial arrangements for the plant height of maize and its intercrop. There was an increasing trend of maize plant height among the spatial arrangements from 21 DAP – 77 DAP for both seasons.

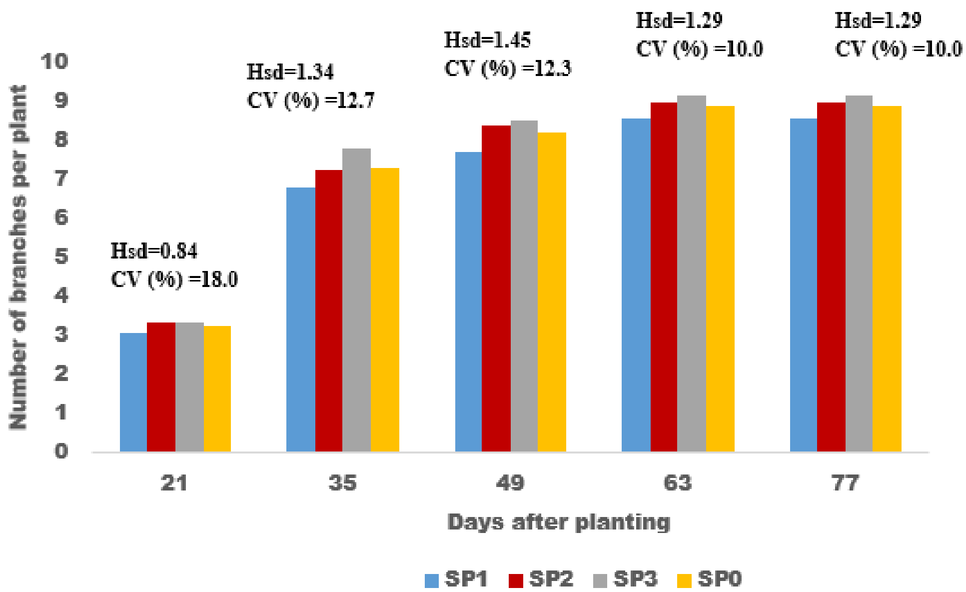

Figure 8. Number of branches per plant of groundnut as influenced by spartial arrangement for 2022 major cropping season.

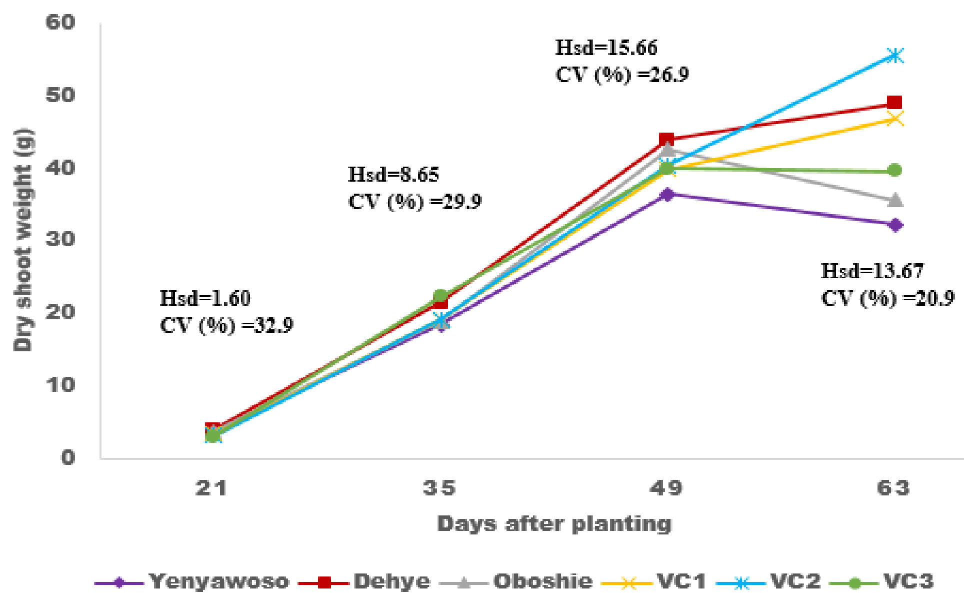

Figure 9. Dry shoot weight of groundnut as influenced by variety for 2021 minor cropping season. VCI: varietal combination 1 (Opeaburo + Yenyawoso); VC2: varietal combination 2 (Opeaburo + Dehye); and VC3: varietal combination 3 (Opeaburo + Oboshie).

Spatial arrangements 1 (SP1) and the sole plots (SP0) had the highest increase in plant height for both seasons.

Dry shoot weight (DSW)

Figures 17 and 18 present the results of the dry shoot weight of maize for the 2021 minor and 2022 major cropping seasons. Generally, there was an increasing trend from 21 – 63 DAP throughout the growing season for both seasons. Varietal combination 3 (VC3) generally had the greatest dry shoot weight for both the 2021 minor and 2022 major cropping seasons, whereas varietal combination 1 (VC1) had the least for both seasons.

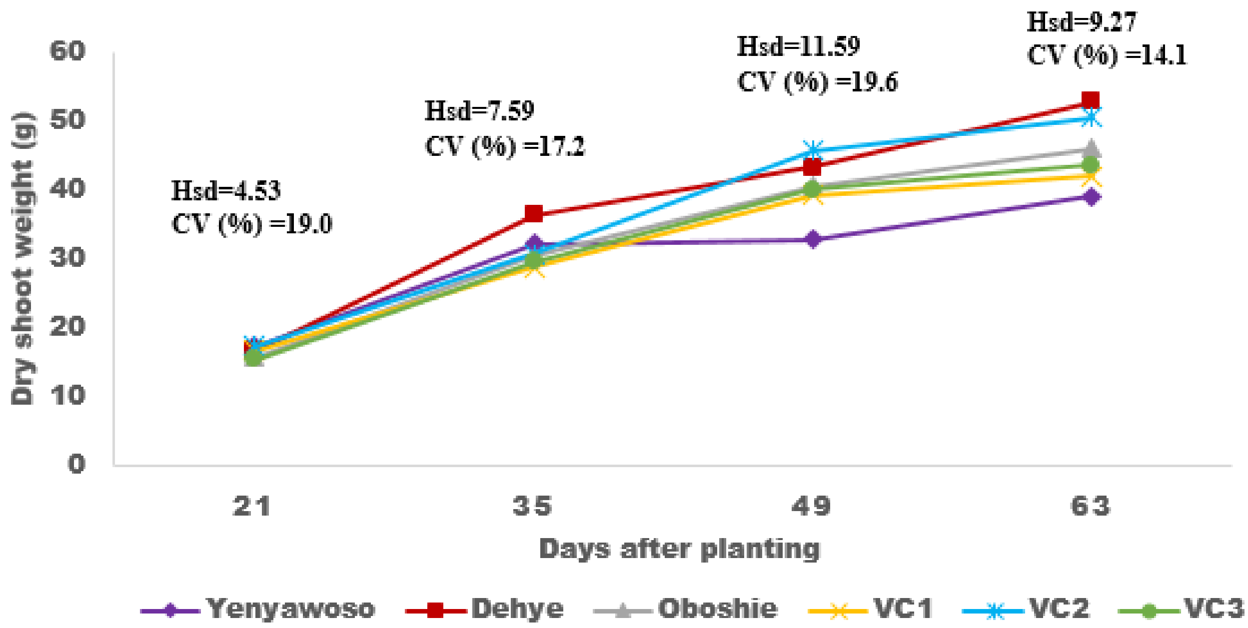

Figure 10. Dry shoot weight of groundnut as influenced by variety for 2022 major cropping season. VCI: varietal combination 1 (Opeaburo + Yenyawoso); VC2: varietal combination 2 (Opeaburo + Dehye); and VC3: varietal combination 3 (Opeaburo + Oboshie).

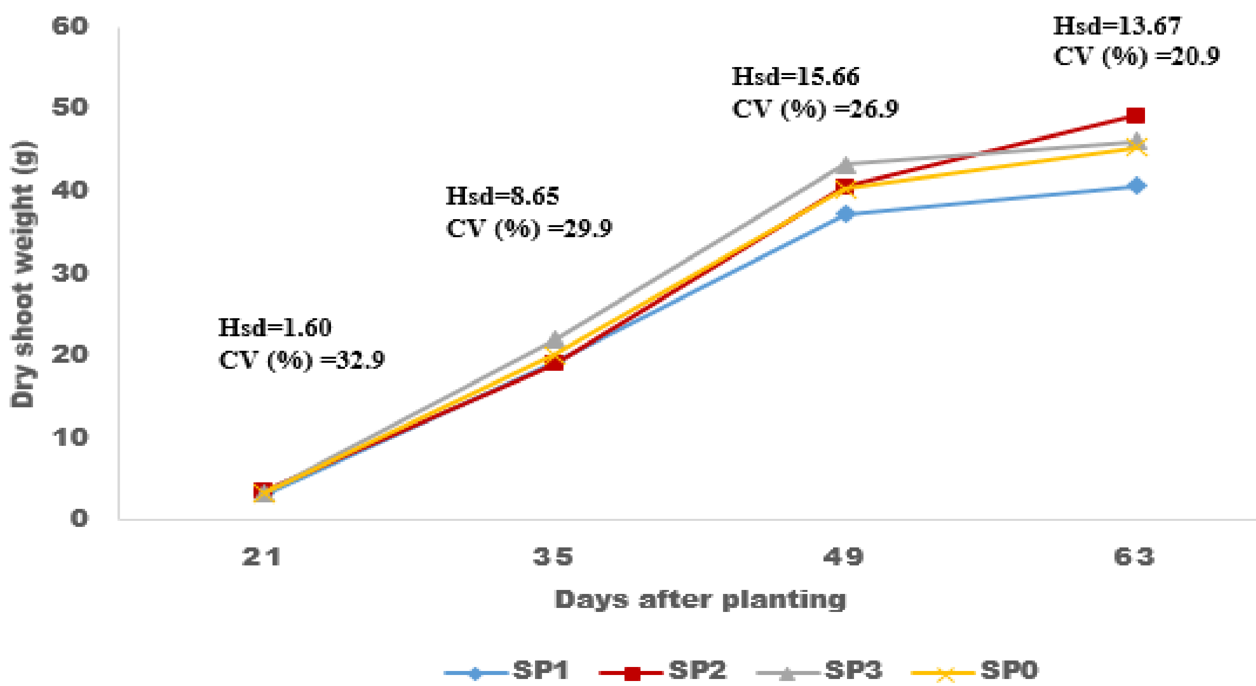

Figure 11. Dry shoot weight of groundnut as influenced by variety for 2021 minor cropping season.

Results of spatial arrangements for dry shoot weight of maize are shown in Figures 19 and 20. Generally, there was an increasing trend from 21 – 63 DAP throughout the growing season for both seasons. Spatial arrangement 3 (SP3) generally had the highest dry shoot weight for both the 2021 minor and 2022 major cropping seasons.

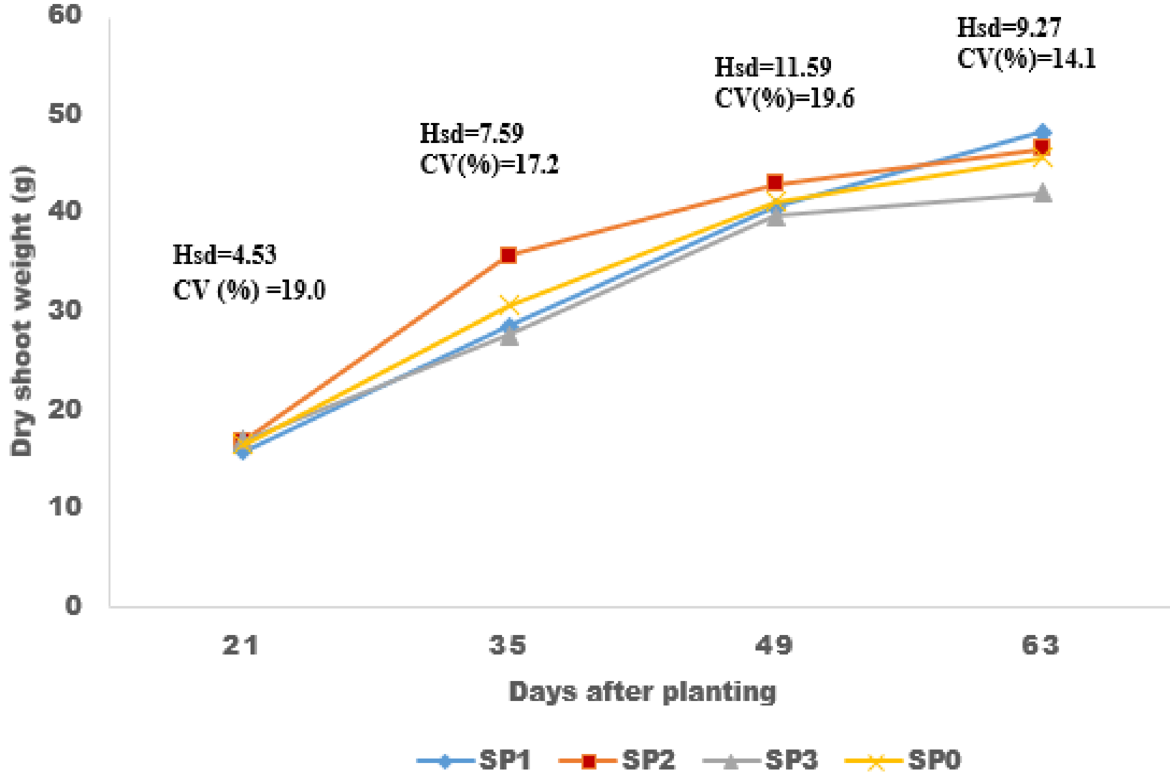

Figure 12. Dry shoot weight of groundnut as influenced by variety for 2022 major cropping season.

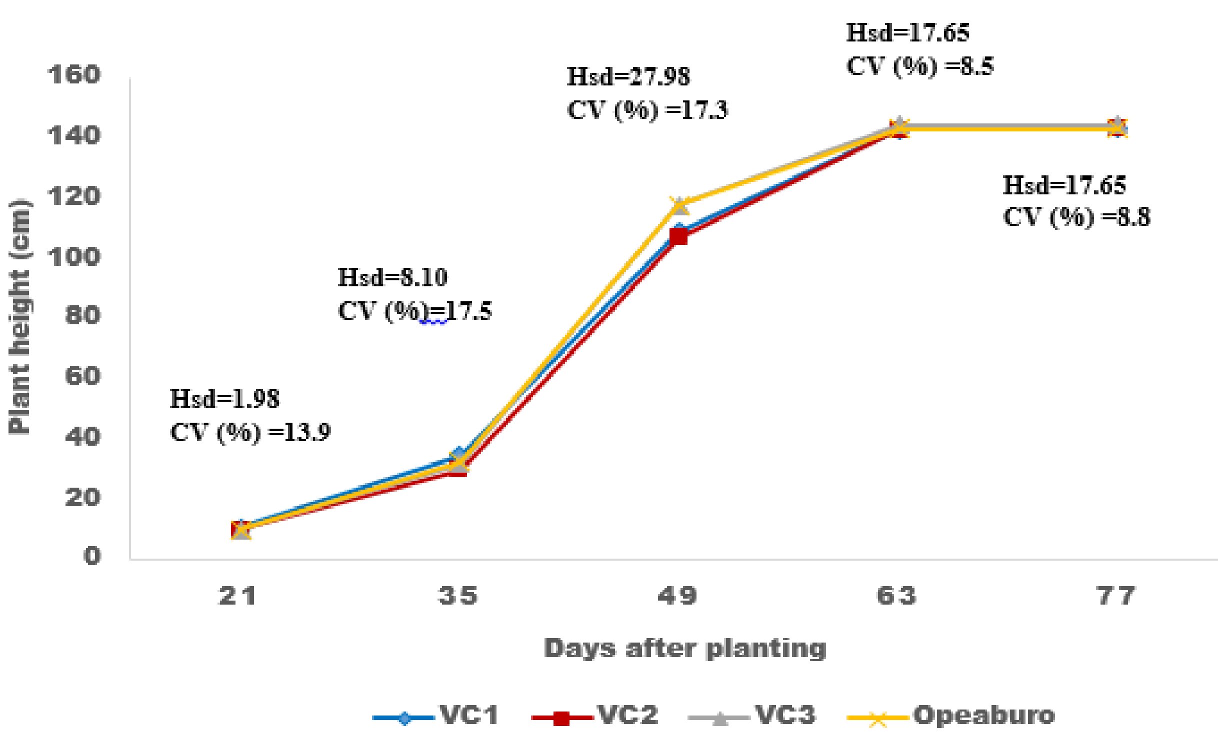

Figure 13. Plant height of maize as influenced by variety for 2021 minor cropping season. VCI: varietal combination 1 (Opeaburo + Yenyawoso); VC2: varietal combination 2 (Opeaburo + Dehye); and VC3: varietal combination 3 (Opeaburo + Oboshie).

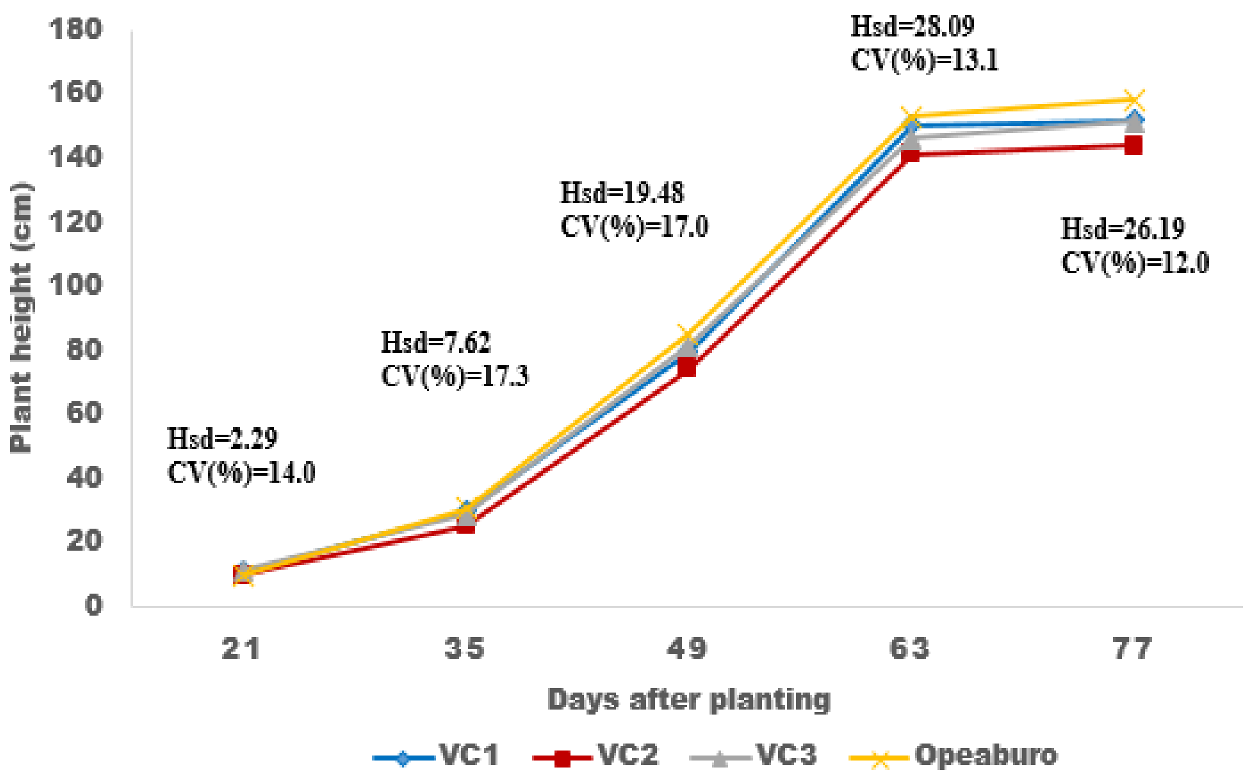

Figure 14. Plant height of maize as influenced by variety for 2022 major cropping season. VCI: varietal combination 1 (Opeaburo + Yenyawoso); VC2: varietal combination 2 (Opeaburo + Dehye); and VC3: varietal combination 3 (Opeaburo + Oboshie).

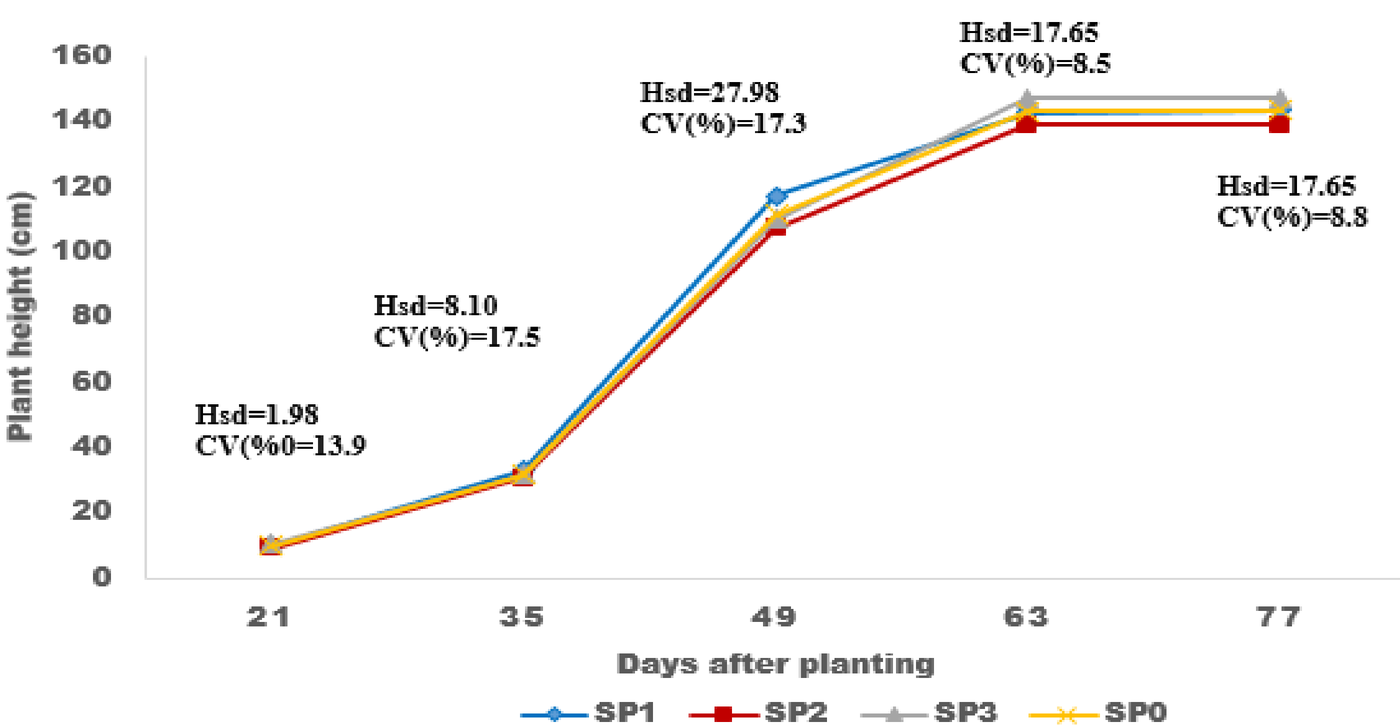

Figure 15. Plant height of maize as influenced by spartial arrangement for 2021 minor cropping season.

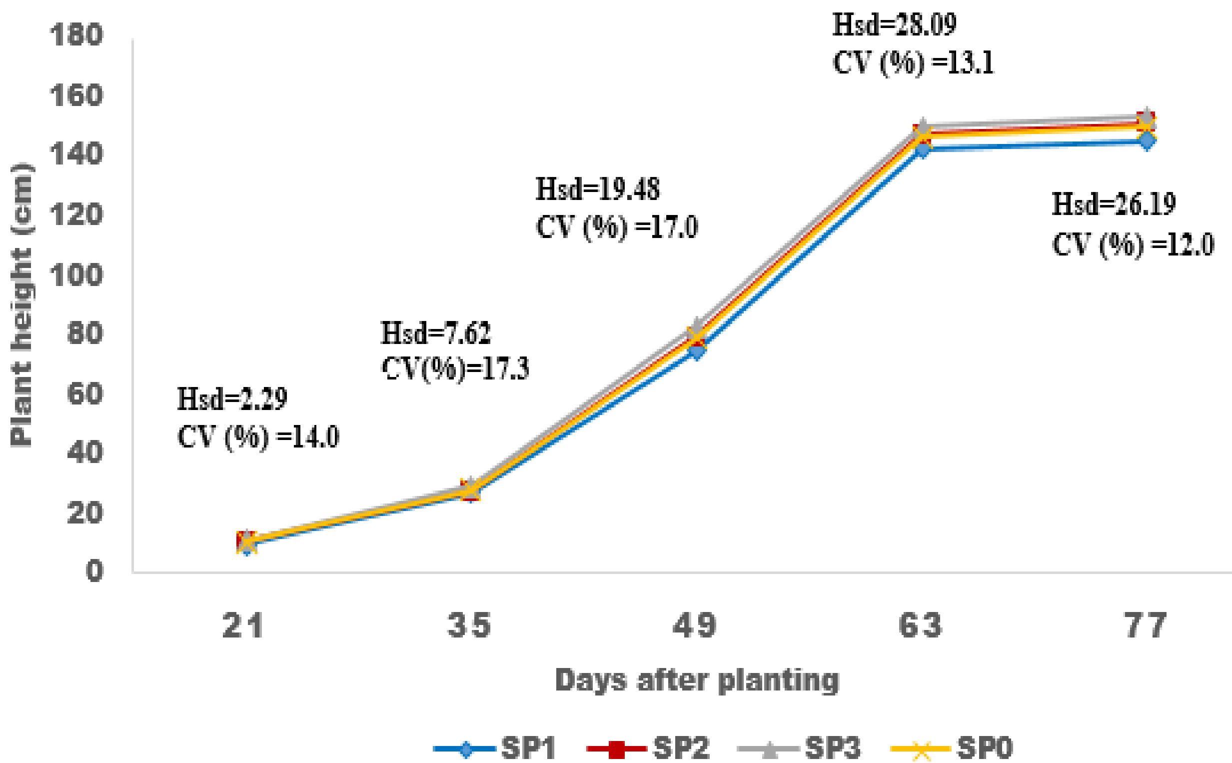

Figure 16. Plant height of maize as influenced by spartial arrangement for 2022 major cropping season.

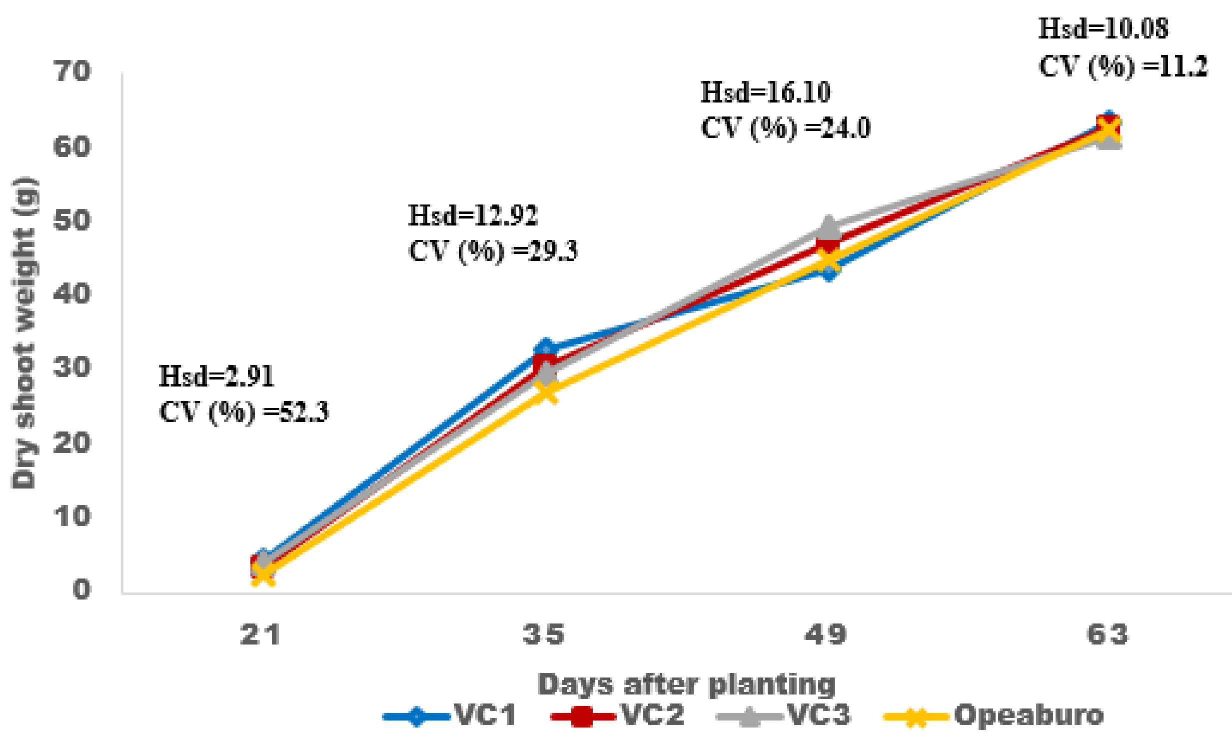

Figure 17. Dry shoot weight of maize as influenced by variety for 2021 minor cropping season. VCI: varietal combination 1 (Opeaburo + Yenyawoso); VC2: varietal combination 2 (Opeaburo + Dehye); and VC3: varietal combination 3 (Opeaburo + Oboshie).

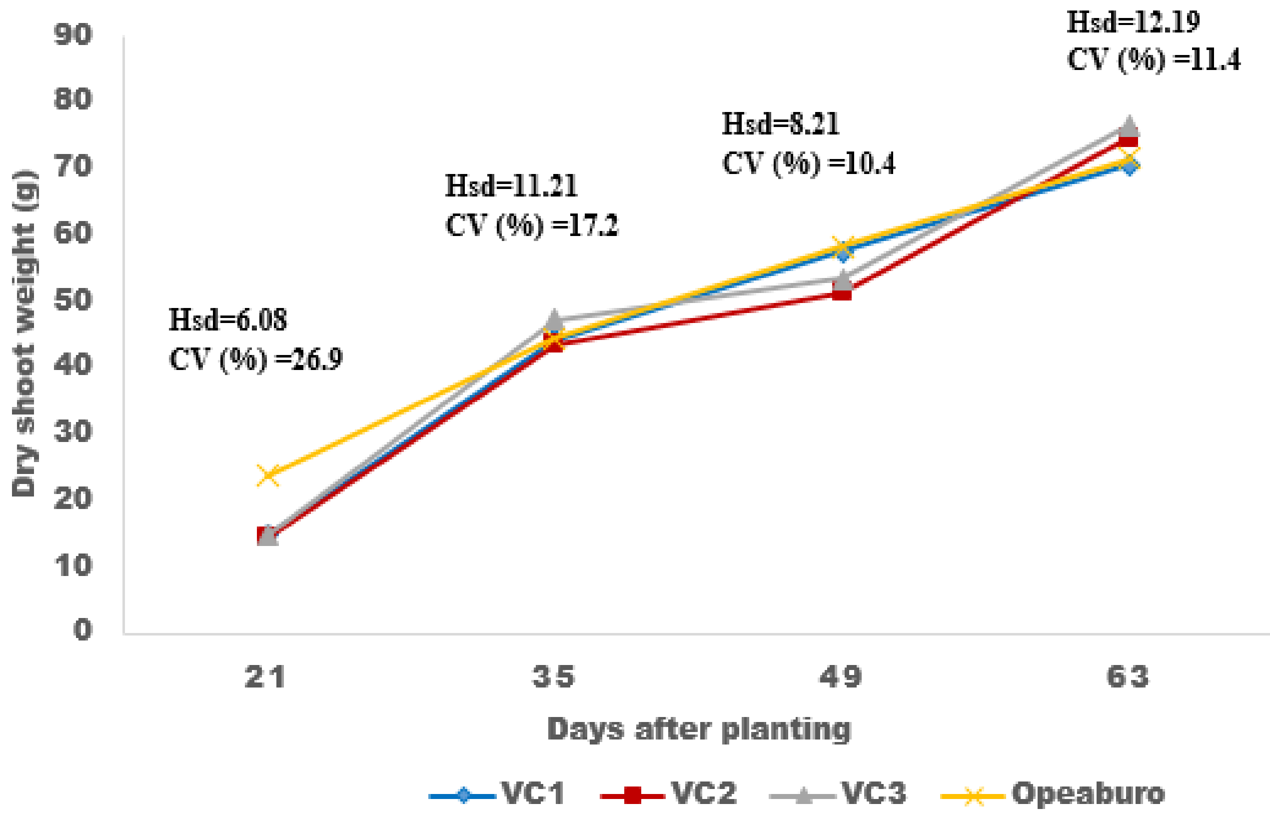

Figure 18. Dry shoot weight of maize as influenced by variety for 2022 major cropping season. VCI: varietal combination 1 (Opeaburo + Yenyawoso); VC2: varietal combination 2 (Opeaburo + Dehye); and VC3: varietal combination 3 (Opeaburo + Oboshie).

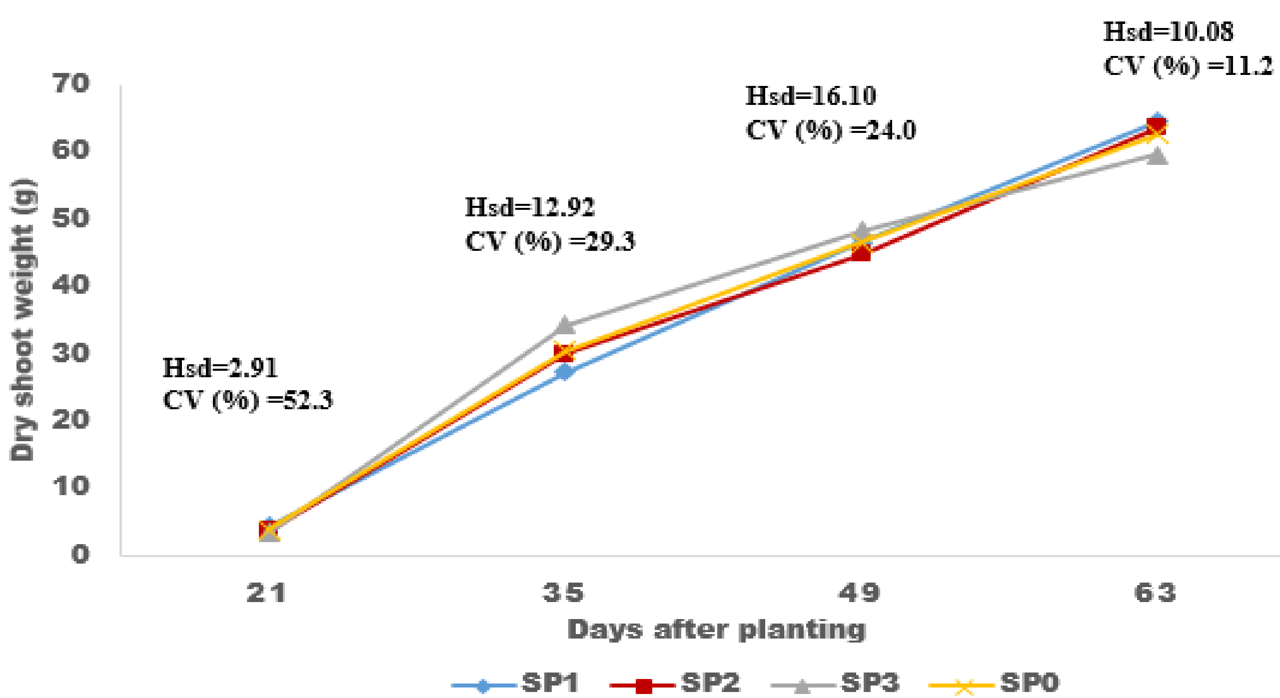

Figure 19. Dry shoot weight of maize as influenced by spartial arrangement for 2021 minor cropping season.

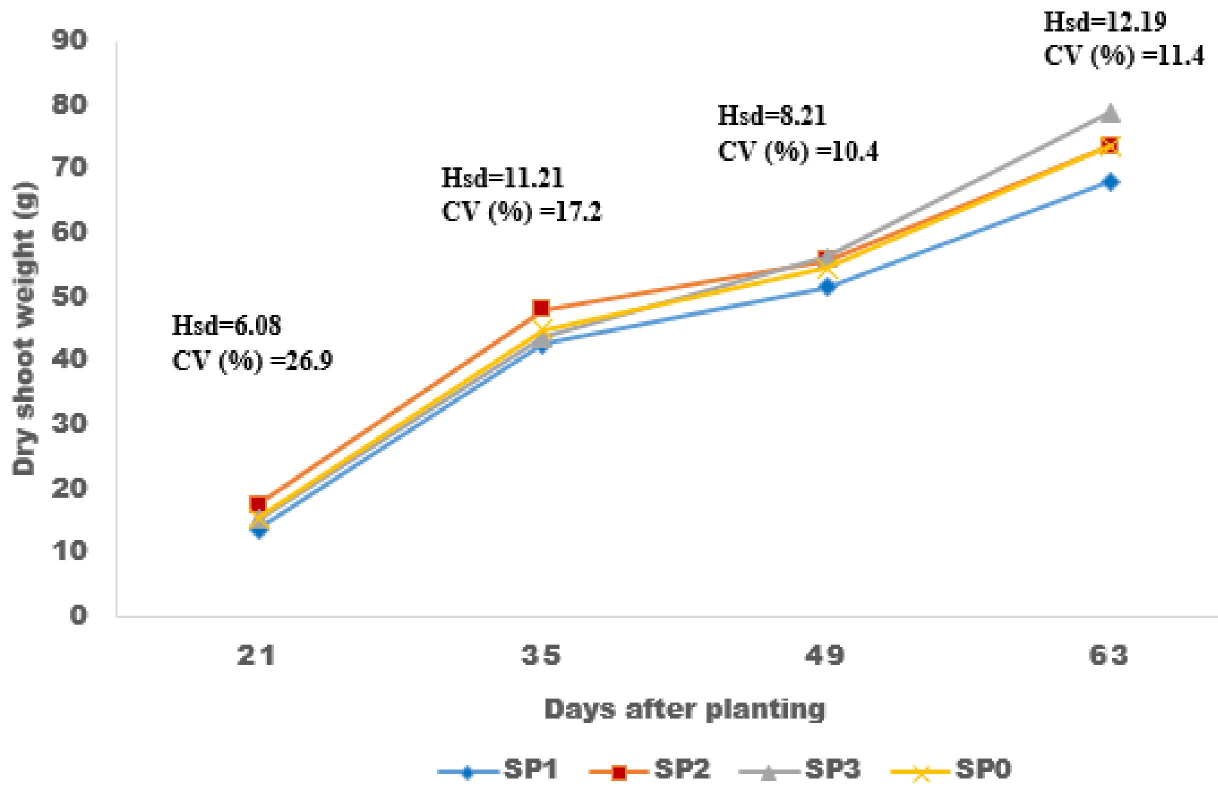

Figure 20. Dry shoot weight of maize as influenced by spartial arrangement for 2022 major cropping season.

DISCUSSION

Influence of variety and spatial arrangement on phenology of groundnut and maize

The results indicate that Yenyawoso groundnut consistently emerged the earliest in terms of days to 50% flowering compared to Dehye and Oboshie groundnut varieties. This difference may be attributed to genetic variations among the varieties. This finding is supported by Li et al. (2022b), who noted that genetic differences can influence the growth and development of groundnut varieties. Additionally, Owusu–Akyaw et al. (2019) suggested that Yenyawoso groundnut may possess genetic traits that enhance its adaptation to growing conditions and tolerance to environmental factors, giving it a competitive edge over other groundnut varieties. The observed increased growth rates in SP2 and SP3 spatial arrangements could be due to reduced interspecific competition and the moderate soil coverage provided by maize plants, resulting in lower soil temperatures. This observation is consistent with previous studies suggesting that intercropping helps maintain favorable soil micro-climates (Khan et al., 2022). Moreover, variations in crop canopies have been reported to lead to more efficient light utilization in spatial arrangements compared to single-crop cultivation (Maitra et al., 2019). The shading effects caused by taller maize plants were found to delay the flowering and maturity of Oboshie groundnut variety.

The significant impact on the days to 50% tasseling of maize during the 2021 minor cropping season, as opposed to the 2022 major cropping season, could be attributed to variations in weather patterns that might have affected plant growth and development differently in the two seasons. Differences in temperature, rainfall, and humidity between the two cropping seasons can influence plant growth and development. Prolonged exposure of crop plants to high temperatures can disrupt cellular processes, reduce photosynthetic efficiency, and even lead to cellular damage. The earliest days to 50% tasseling recorded by Opeaburo maize + Yenyawoso groundnut x SP2 interaction in the 2021 cropping season, and by Opeaburo maize + Oboshie groundnut x SP2 interaction in the 2022 major cropping season, could be attributed to genetic variations in the groundnut varieties affecting maize growth. Fang et al. (2023) suggested that peanut cultivars exhibit variations in growth habits. The significant differences between treatment means for both the 2021 minor and 2022 major cropping seasons of maize suggest that interactions between groundnut varieties and spatial arrangements may have resulted in variations in nutrient availability, light penetration, or other factors affecting plant growth and development. The higher days to 50% tasseling of maize recorded by SP2 and SP3 could be attributed to these rows of groundnuts possibly providing higher nitrogen fixation, thereby promoting early tasseling of maize. Similarly, the earliest days to 50% silking by Opeaburo maize + Yenyawoso groundnut x SP2 interaction in the 2021 period and by Opeaburo maize + Oboshie groundnut x SP2 in the 2022 season might be influenced by temperature and genetic factors. These findings align with previous research on the effects of genetics and environmental conditions on days to 50% silking of maize (Silva et al., 2022). The two rows of groundnut possibly providing higher nitrogen fixation could have promoted early silking.

Influence of variety and spatial arrangement on vegetative growth of groundnut and maize

The differences in plant height among groundnut varieties during the 2021 minor cropping season could be attributed to genetic variation. These variations in plant height corroborate the findings of Zhang et al. (2024), who reported differences among groundnut cultivars in terms of plant height. The notably higher plant heights observed with Opeaburo maize + Dehye groundnut x SP2 and SP3 interactions could be influenced by their genetic makeup and favourable climatic conditions (such as rainfall and temperature) during the cropping season. Gao et al. (2022) also noted that intercropping groundnut with maize tends to increase the plant height of groundnut, especially in the early growth stages. Similarly, Zhang et al. (2023) suggested that intercropping groundnut and maize could enhance the plant height of groundnut compared to sole cropping.

Despite maize providing shade to the groundnut, which might hinder proper leaf formation, the shading effect was beneficial for the intercropped groundnut, resulting in taller growth compared to groundnut plants grown alone or in SP1. The intercropped groundnut plants exhibited greater height than the sole groundnut plants, possibly due to competition for sunlight with maize. As maize plants were taller and cast shadows on the groundnut, the intercropped groundnut adapted by growing in a way to emerge from the shadows and receive more light, resulting in slightly increased height compared to sole groundnut plants. The shading caused by maize likely encouraged elongation of groundnut internodes as a strategy to intercept more sunlight. These findings are consistent with previous research conducted by Han et al. (2022), which highlighted the positive impact of shading on legume crop growth and height, ultimately affecting their yield.

Regarding maize, the taller plant height observed with Opeaburo maize + Yenyawoso groundnut x SP2 and SP3 interactions could be attributed to variations in spatial arrangement. The study revealed that certain spatial arrangements led to taller plant height at specific growth stages, while others resulted in lower plant height. This suggests that the spatial arrangement of crops can significantly influence plant growth and development, as noted by Chen et al. (2022). The higher plant height observed in SP2 and SP3 arrangements might be due to plants allocating resources to grow taller to intercept more sunlight for photosynthesis, serving as a survival mechanism.

The non-significant difference in the number of branches of groundnut varieties at 21 and 35 DAP in both the 2021 minor and 2022 major cropping seasons may be attributed to the early growth stage of the plants, where differences in varieties might not yet be evident, resulting in non-significant treatment effects on the number of branches. However, as the plants continued to grow, significant differences emerged between treatment means of groundnut varieties from 49 to 77 DAP, indicating that the impact of variety on the number of branches per plant became more apparent as the plants matured. This significant difference between treatments in the number of branches per plant from 49 to 77 DAP could be attributed to differences in genetic traits among the varieties.

Yenyawoso groundnut consistently exhibited the greatest number of branches among the varieties at its early growth stage (21 DAP), suggesting that it may have an early advantage in branching. Conversely, Oboshie groundnut consistently displayed the highest number of branches per plant in the 2021 minor cropping season compared to the other groundnut varieties from 49 to 77 DAP in both cropping seasons, indicating its superior ability to branch and produce more pods later compared to the other varieties. This variation in branching patterns among groundnut varieties could be attributed to their genetic differences, as reported by Onat et al. (2017).

The presence of intercropped maize likely increased interspecific competition among the groundnut plants, leading to limited access to essential resources such as water, nutrients, light, and space. This competition may have resulted in fewer branches being produced by the intercropped groundnut plants compared to the sole groundnut plants. Additionally, the mutual shading effect from the maize in the intercropped system may have inhibited the photosynthesis process of groundnut, reducing the assimilates available for branching. As a result, the sole groundnut plants, free from mutual shading, likely experienced enhanced photosynthesis and produced more branches due to reduced competition. These findings are consistent with similar outcomes observed in studies conducted by Bugilla et al. (2023) and during the minor cropping season in this study.

The significant differences observed in the treatment means of maize's dry shoot weight in both cropping seasons suggest that the combination of groundnut and maize can indeed impact the dry shoot weight of maize. Setiawan et al. (2023) have noted that different combinations of varieties and spatial arrangements can yield varying effects on the dry shoot weight of maize at different stages of growth.

Conclusion

The study revealed that intercropping Opeaburo maize with Yenyawoso groundnut variety in a 1-row maize alternating with 1-row groundnut arrangement, as well as sole Yenyawoso groundnut, promoted earlier days to 50% flowering of groundnut compared to their intercrop and sole crop counterparts and spatial arrangements. Similarly, for maize, the interaction of Opeaburo maize with Yenyawoso groundnut in a 1-row maize alternating with 2 rows of groundnut and 1-row maize alternating with 3 rows of groundnut arrangements exhibited the earliest days to 50% tasseling and silking across both cropping seasons compared to their intercrop and sole crop counterparts and spatial arrangements. Additionally, Opeaburo maize combined with Oboshie groundnut in a 1-row maize alternating with 2 rows of groundnut arrangement increased the number of branches per plant.

Furthermore, Opeaburo maize intercropped with Yenyawoso groundnut in a 1-row maize alternating with 3 rows of groundnut interaction displayed the maximum plant height in both cropping seasons. Regarding dry shoot weight, Opeaburo maize combined with Oboshie groundnut in a 1-row maize alternating with 3 rows of groundnut interaction exhibited the greatest dry shoot weight across seasons.

These findings suggest that the varietal intercrop system can offer maize and groundnut farmers benefits such as early crop growth, development, and maturity whereas for spatial arrangement, intercropping maize with groundnut using SP2 and SP3 will promote early flowering, tasseling, silking, and early crop growth. Therefore, farmers should consider intercropping maize with groundnut while also paying attention to spatial arrangement, as it can significantly impact crop growth and development.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The authors extend their sincere gratitude to the management of AAMUSTED, Mampong campus, for generously providing the land for conducting the field research. Additionally, the authors express their appreciation to the CSIR-Crops Research Institute in Kumasi, Ghana, for supplying the maize and groundnut seeds used in the study.

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