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Effect of Intercropping Different Varieties of Groundnut with Maize and Spatial Arrangement on Yield and Yield Components of the Crops

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Abstract Three groundnut and one maize improved varieties were studied for their yield and yield components by intercropping them using different spatial arrangement. Intercropping legumes with maize in different spatial arrangements improve the quality and natural soil fertility, and reduce fertilizer use and boost crop yield. Crops were planted at the research field of AAMUSTED using a 3 x 3 factorial experiment laid in Randomized Complete Block Design (RCBD) plus four sole crops with four replications during the minor rainy season of 2021 and the major rainy season of 2022. The aim was to determine the yield and yield components of different varieties of groundnut with maize intercropping system as affected by different spatial arrangement. Factors studied were; (i) groundnut varieties (*Yenyawoso, Dehye, and Oboshie*), Opeaburo maize variety and (ii) spatial arrangements; (SP1 = 1-row maize alternating with 1-row groundnut, SP2 = 1-row maize alternating with 2 rows groundnut, and SP3 = 1-row maize alternating with 3 rows groundnut) plus four sole crops. The combined analysis showed that Opeaburo + Oboshie x SP2 and SP3 interactions had the higher number of pods per plant, 100-seed weight, and grain yield of groundnut, while for maize the same treatments produced the highest cob diameter, cob length, 100-seed weight, shelling percentage and grain yield across both cropping seasons. Opeaburo + Yenyawoso x SP1 interaction produced highest number of seeds per pod across both seasons. For shelling percentage of groundnut, Opeaburo + Yenyawoso x SP2 recorded the highest for 2021 minor season whereas Opeaburo + Dehye x SP3 had the greatest for the 2022 major cropping season. For Land Equivalent Ratio (LER), Opeaburo + Oboshie x SP2 and SP3 interaction had the greatest. For best yield and heavy grains of maize and groundnut, it is recommended that farmers should intercrop Opeaburo with Oboshie by alternating with 2-rows and/or 3-rows.

Keywords Intercropping, Varieties, Crop Interactions, Opeaburo, Grain Yield

1. Introduction

Maize (*Zea mays* L.) is regarded as the third most important cereal in the world after wheat and rice in the area cultivated and total production [1]. Since the introduction of maize in Ghana in the 16th century, it is the most widely produced and consumed cereal crop [2]. Maize grains contain 72% starch, 10% protein, 4.8% oil, 8.5% fiber, 3.0% sugar, and 1.7% ash which makes them have a great nutritional value [3]. Groundnut (*Arachis hypogaea* L.) on the other hand is one of the world's most popular legume crops grown in the tropical and sub-tropical regions

[4]. In Ghana, groundnut serves as a significant cash crop, food security crop, highly nutritious and engaging approximately 90% of smallholder farming households in its cultivation [5].

Intercropping encompasses arrangement of crop plants particularly cereals and legumes on the same land either in row, strip, mixed, alley or relay depending on farmers choice. The primary goal of intercropping cereals with legumes is to optimize the yield of crops from a piece of land by efficiently utilizing resources, a feat not achievable through sole cropping [6]. Additionally, intercropping such crops will increase profit, reduce chemical applications to control pest and help improve weed management. Intercropping is recognized for its potential to yield higher outputs with reduced inputs, such as nitrogen fertilizer, and as a strategy to optimize land utilization. This approach has been widely adopted by smallholder farmers in Ghana and across Africa [7].

Despite the numerous benefits of the crops, their production remains insufficient, and with low yield to meet the demand of Ghanaians. This inadequacy is attributed to use of unimproved varieties, unpredicted rains, depletion of nutrients in agricultural land caused by continuous cropping, a consequence of the expanding population. As a result, there is competition for land, exerting pressure on the available space for crop cultivation leading to decline in soil nutrients. Most smallholder farmers involved in maize and groundnut production are in the Guinea and Sudan Savannah agroecological zones of Ghana. Majority of these farmers practice intercropping involving cowpea or groundnuts with sorghum, millet, or maize. The maize-groundnut intercropping system in Ghana, is faced with challenges characterized by low crop yields and overall productivity [8]. This predicament is often attributed to the utilization of low-yielding groundnut varieties and suboptimal row arrangements by farmers. The release of new groundnut varieties by the CSIR-Crops Research Institute, Ghana has undergone limited testing within intercropping systems compared to sole cropping. Assessing these varieties under various row arrangements holds the potential to enhance the overall performance and productivity of the intercrops. According to [9], a 2:2 intercrop configuration produced the highest grain yield of maize and Roselle leaf yield (1685.4 kg and 16981.3 kg/ha, respectively) and also, the two rows of roselle and two rows of maize generated the highest yield. While extensive research has been conducted on intercropping, there has been limited focus on spatial arrangements, particularly, maize-groundnut intercropped in Ghana [10]. It is evident that well-designed spatial arrangements for intercropping maize and groundnut can offer diverse alternatives to address challenges related to soil fertility and in turn, have potential to enhance yields and overall profitability. The main objective of the study was to evaluate the yield and yield components of different varieties of groundnut with maize intercropping system as influenced by spatial arrangements.

2. Materials and Methods

2.1. Experimental Site and Location

Three groundnut and one maize improved varieties released by CSIR-CRI were planted at the research field of Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED) using a 3 x 3 factorial experiment laid in Randomized Complete Block Design (RCBD) plus four sole crops with four replications. The field experiment was conducted during the minor cropping season of 2021 and the major cropping season of 2022. Mampong-Ashanti is situated in the forest-savannah transitional agroecological zone of Ghana [11]. Asante Mampong receives an average annual rainfall of approximately 1270 mm, characterized by a bimodal rainfall pattern with major rainy season from early April to July, and the minor rainy season from September to November. August witnesses a brief dry period, but the main dry season extends from December to March. The experimental area has an average annual temperature of around 27 ℃, with temperatures typically ranging from 22 ℃ to 30 ℃ [12]. The major and minor rainy seasons are associated with the growing of maize by farmers particularly in the forest and forest-savannah transitional agroecological zones of Ghana as the major and minor maize cropping seasons respectively. The soil at the experimental site is derived from Voltaian sandstone and falls under the Bediese Series of the Savannah Ochrosol class. According to the [13] classification system, it is categorized as Chromic Luvisol. The soil is characterized by its deep red colour, sandy loam composition, with absence of stones. It exhibits excellent drainage, friability, and possesses favourable water-holding capacity, texture, and structure with a pH of 6.5.

2.2. Experimental Design and Treatments

A 3 x 3 factorial experiment laid in a Randomized Complete Block Design (RCBD) was used as the experimental design with nine treatments plus four sole crops and four replications.

The Factors studied 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).

2.3. Field Layout and Planting Materials

Each plot size measured 5 m long with variations in plot length depending on number of rows in each intercrop as arranged spatially. The plot sizes for the intercrops were; 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 intra row spacing for the intercrops was 40 cm for the maize and 20 cm for the groundnut. The sole crops had 4 rows each per plot, and each row measured 5 m long. The planting spacing for the sole maize was 80 cm x 40 cm, and groundnut was 50 cm x 20 cm. The maize and groundnuts had 2 plants per stand for the intercrops and sole crops.

The maize and groundnut varieties (*Opeaburo*) and (*Yenyawoso, Dehye, and Oboshie*) respectively used for the study were sourced from the CSIR- Crops Research Institute of Ghana, where they were developed. The Opeaburo maize variety is characterized by its white dent and has a maturity period ranging between 110 and 115 days. This maize variety was chosen for the study due to the fact that it is able to tolerate drought and not easily infected by diseases. Notably, it is a high-yielding maize variety with yield capacity of 7.5 t/ha [14].

Both groundnut varieties, *Yenyawoso* and *Dehye* are 85 – 90 days early- maturing varieties. However, the variety *Oboshie* matures late (105 – 110 days). These three varieties of groundnuts were chosen for the study due to their high yielding potential as follows; *Yenyawoso* (2.7 t/ha), *Dehye* (2.9 t/ha), and *Oboshie* (2.6 t/ha). Additionally, they are known for their ability to tolerate drought and exhibit robust vegetative growth when the weather conditions are favourable [14].

2.4. Land Preparation and Planting

The land preparation for the minor cropping season experiment was done in August 2021, and that for the major cropping season experiment in March 2022. The land was ploughed, harrowed, and subsequently levelled. The land was demarcated according to field size of 67.8 m x 24 m (1,627.2 m^2) and later divided into four blocks (replications). Planting of both maize and groundnut seeds was done simultaneously, with three seeds placed in each hole. Maize seeds were sown on flat land, while groundnut seeds were planted on ridges. For the intercrops, the intra row spacing was 40 cm for maize and 20 cm for groundnuts, with inter row spacing of 50 cm. In the case of sole crops, sole maize was planted with a spacing of 80 cm x 40 cm, while groundnut varieties were planted at 50 cm x 20 cm. Two weeks after emergence, both maize and groundnut plants in both intercrop and sole crop were thinned to two seedlings per stand.

The experimental plot for the 1-row maize and 1-row groundnut (SP1) spatial arrangement consisted of four (4) rows of maize, with twelve (12) plants per row, resulting in a total of twenty-four (24) plants per row and ninety-six (96) plants per plot. For groundnut in the same plot, there were four (4) rows with twenty-four (24) plants per row, and with 2 plants per stand totaling forty-eight (48) plants per row and one hundred ninety-two (192) plants per plot.

In the experimental plot for 1-row maize and 2 rows of groundnut (SP2), there were four (4) rows of maize, each with twelve (12) plants per row, resulting in twenty-four (24) plants per row and ninety-six (96) plants per plot. For the groundnut, there were eight (8) rows with twenty-four (24) plants per row, totaling forty-eight (48) plants per row and three hundred and eighty-four (384) plants per plot. In the experimental plot for 1-row maize and 3 rows of groundnuts (SP3), there were four (4) rows of maize, each with twelve (12) plants per row, leading to twenty-four (24) plants per row and ninety-six (96) plants per plot. Additionally, there were twelve (12) rows of groundnuts, each with twenty-four (24) plants per row, resulting in forty-eight (48) plants per row and (576) plants per plot. For the sole maize experimental plot, there were six (6) rows with twenty-four (24) plants per row, totaling (144) plants per plot. In the sole groundnut experimental plot, there were six (6) rows with forty-eight (48) plants per row, resulting in a total of 288 plants per plot.

2.5. Agronomic Practices

2.5.1. Weed Control

Weed control was done three (3) times using a hoe and a cutlass. The initial weeding took place two weeks after the emergence of seedlings, followed by the second weeding at 30 days after planting, and the third weeding at 60 days after planting.

2.5.2. Pest and Disease Control

Regular field visits were conducted to monitor the occurrence of pests, including stem borers, corn leaf aphids, rodents, and fall armyworms that may affect maize, as well as diseases such as rust, early leaf spot, late leaf spot, and rosette that may infect groundnuts. To address fall armyworm infestation on maize, Emaster (*Emamectin benzoate*) insecticide was applied at a rate of 10 - 20 ml per 15L knapsack sprayer. This treatment was initiated two weeks after seedling emergence and repeated at weekly intervals. The effect of diseases on maize and groundnuts were minimal, and as a result, no specific control measures were done.

2.6. Data Collected

2.6.1. Maize Data Collected

The maize yield and yield traits data collected were; cob diameter, cob length, hundred seed weight, shelling percentage, grain yield. The diameter and length of five cobs that were randomly selected at harvest from the two central harvestable rows were measured. The one hundred seed weight of maize was measured by randomly selecting one hundred seeds from each plot after shelling and their weight taken using the Westinghouse electronic weighing scale and their means recorded.

All cobs from the two central rows per plot for sole and intercrop maize after harvest were weighed using a saltersuspended weighter (model number 235). Cobs were shelled and the grains were weighed using an electronic weighing scale. The cob weight and the grain weight were used to compute the shelling percentage as follows;

$$\text{Shelling } \% = \frac{Maize\ grain\ weight}{Weight\ of\ cobs}\ x\ 100\% \ [15]$$

The grain yield from the harvestable area per plot of both sole and intercrop maize was estimated in tonnes per hectare using the formular as described below by [16]

$$\text{Grain yield (kg) per hectare} = \frac{10000m^2\ x\ Q\ grain\ (kg)}{Harvest\ area\ (m^2)}$$

2.6.2. Groundnuts Data Collected

The groundnut yield and yield traits data collected were; number of pods per plant, number of seeds per pod, one hundred seed weight, shelling percentage and grain yield (t/ha).

The total number of pods per plant for both sole and intercrop groundnuts were counted from the five plants randomly selected and tagged from the two central rows and the mean was recorded. The number of groundnut seeds per pod from ten (10) randomly selected pods from the two central rows of both sole and intercrop groundnut were counted and their mean recorded. The 100-seed weight of groundnut was measured by randomly selecting one hundred seeds from each plot after shelling and their weight taken using the Westinghouse electronic weighing scale and their means recorded. All pods from the two central rows per plot for sole and intercrop groundnut were weighed using the Westinghouse electronic weighing scale. Pods were shelled and the grains were weighed using an electronic weighing scale. The pod weight and the grain weight were used to compute the shelling percentage as follows;

$$\text{Shelling } \% = \frac{Groundnut\ grain\ weight}{Weight\ of\ pods}\ x\ 100\% \ [15]$$

The grain yield from the harvestable area per plot of both sole and intercrop groundnut was estimated in tonnes per hectare using the formular as described below by [16]

$$\text{Thus, grain yield (kg) per hectare} = \frac{10000m^2\ x\ Q\ grain\ (kg)}{Harvest\ area\ (m^2)} \ [16]$$

2.7. Statistical Analysis

Analysis of variance (ANOVA) was used to analyse the data using GenStat Release 18.1 statistical package. Tukey's Honestly Significant Difference (HSD) was used to separate treatment means at a probability level of 5%.

3. Results

3.1. Climatic Conditions at the Experimental Site

The climatic conditions experienced during 2021 minor rainy season experiment shows that, the total rainfall amounted to 676.7 mm. The peak relative humidity of 77% was observed in August and September, with the lowest recorded in December 2021 at 58%. The mean maximum and minimum temperatures for the same season were 31.9 ℃ and 23.06 ℃, respectively. For the 2022 major rainy season experiment, the total rainfall registered was 694.6 mm. The highest relative humidity of 74% occurred in June and July, while the lowest was recorded in April 2022 at 66%. The mean maximum and minimum temperatures during the 2022 major rainy season were 26.76 ℃ and 23.44 ℃, respectively.

3.2. Yield and Yield Components of Groundnut

3.2.1. Number of Pods Per Plant

The number of pods per plant ranged from 8 – 12 pods/plant for the 2021 minor cropping season and 14 – 19 pods/plant for the 2022 major cropping season (Table 1). There was no significant effects of varietal combination, spatial arrangement nor varietal combination x spatial arrangement interaction in number of pods/plant. However, the 2022 major season had significantly ($P \leq 0.05$) greater number of pods/plant of about 58 – 75% more than the 2021 minor season. Sole Dehye recorded a significantly ($P \leq 0.05$) higher number of pods per plant (14.25) than the other spatial arrangements for the 2021 minor cropping season, while the lowest number of pods per plant (8.75) was observed in Opeaburo + Oboshie x SP1 interaction (Table 1). In 2022 major cropping season Opeaburo + Oboshie x SP2 interaction had higher number of pods per plant (18.50) with the least by Opeaburo + Oboshie x SP3 interaction (Table 1).

3.2.2. Number of Seeds Per Pod

There was a significant ($P \leq 0.05$) interactive difference between the treatment means in both cropping seasons (Table 1). The number of seeds per pod ranged from 2 – 3 for the groundnut varieties. Opeaburo + Yenyawoso x SP2 interaction had a higher mean number of seeds per pod (2.75 and 2.50) compared to the other spatial arrangements and their sole crops in both cropping seasons. Season, season x variety, and season x spatial arrangement did not differ significantly in number of seeds per pod (Table 1).

Table 1. Number of pods per plant and number of seeds per pod of groundnut as influenced by variety and spatial arrangement for 2021 minor and 2022 major cropping seasons

Treatment		Number of pods per plant		Number of seeds per pod	
Varietal combination (VC)	**Spatial arrangement (SP)**	**2021**	**2022**	**2021**	**2022**
Opeaburo + Yenyawoso	SP1	9.00	16.50	2.00	2.00
	SP2	9.50	16.25	2.75	2.50
	SP3	12.00	17.50	2.00	2.00
Opeaburo + Dehye	SP1	9.75	17.25	2.00	2.00
	SP2	11.00	15.75	2.00	2.00
	SP3	10.00	15.75	2.00	2.00
Opeaburo + Oboshie	SP1	8.75	15.00	2.00	2.00
	SP2	9.00	18.50	2.00	2.00
	SP3	9.00	14.00	2.25	2.00
Sole Yenyawoso	-	12.00	17.25	2.00	2.00
Sole Dehye	-	14.25	16.50	2.00	2.00
Sole Oboshie	-	13.00	17.75	2.00	2.00
CV (%)		**17.6**	**23.8**	**9.6**	**8.2**
	Variety =	*NS*		*HSD=0.11***	*P= 0.002*
	Season =	*HSD=1.19***	*p=<.001*	*NS*	
	Spatial arrangement =	*NS*		*HSD=0.11***	*p=0.008*
	Season x variety =	*NS*		*NS*	
	Season x spatial arrangement =	*NS*		*NS*	
	Variety x spatial arrangement =	*NS*		*HSD=0.18***	*P = <.001*

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.

3.2.3. 100 – Seed Weight

Interactively, a significant ($P \leq 0.05$) difference occurred between the treatments means of 100-seed weight in both cropping seasons (Table 2). The 100-seed weight ranged from 34.5 – 39 g for Yenyawoso, 33.8 – 44.5 g for Dehye and 54.3 – 72 g for Oboshie. In 2021 minor cropping season, Opeaburo + Oboshie x SP3 interaction had the highest mean 100-seed weight (66.50 g) compared to other spatial arrangements and sole crops, while Opeaburo + Oboshie x SP2 interaction had the highest mean 100-seed weight (72.00 g) from other spatial arrangements and their sole crops in 2022 major cropping season (Table 2). For 2021 minor cropping season, Opeaburo + Dehye x SP1 interaction had significantly lowest mean 100-seed weight (33.75g) from other spatial arrangements, while for 2022 major cropping season, Opeaburo + Yenyawoso x SP1 interaction had the lowest mean 100-seed weight (37.25 g) from other spatial arrangements and sole crops. There were no significant effects of spatial arrangement or varietal combination x spatial arrangement interactions.

3.2.4. Grain Yield

There was a significant ($P \leq 0.05$) in the combined effect of grain yield for both cropping seasons (Table 2). Sole Dehye had a significantly ($P \leq 0.05$) higher grain yield (1.28 t ha^{-1}) in 2021 minor cropping season, while Opeaburo + Oboshie x SP3 interaction had a statistically higher grain yield (2.03 t ha^{-1}) in 2022 major cropping season compared to other spatial arrangements and their sole plots. Opeaburo + Oboshie x SP1 interaction had the lowest grain yield (0.93 t ha^{-1}) in 2021 minor cropping season and Opeaburo + Dehye x SP3 interaction had a significant ($P \leq 0.05$) lower grain yield (1.43 t ha^{-1}) in 2022 major cropping season than the 2021 cropping season (Table 2). There was a significant ($p \leq 0.05$) difference between seasons, variety x season, and variety x spatial arrangement. The 2022 major cropping season recorded a significant ($P \leq 0.05$) higher grain yield (t ha^{-1}) from the 2021 minor cropping season (Table 2).

Table 2. 100-seed weight and grain yield of groundnut as influenced by variety and spatial arrangement for 2021 minor and 2022 major cropping seasons

Treatment		100 - Seed weight (g)		Grain yield (t ha^{-1})	
Varietal combination (VC)	**Spatial arrangement (SP)**	**2021**	**2022**	**2021**	**2022**
Opeaburo + Yenyawoso	SP1	36.00	37.25	0.98	1.53
	SP2	34.50	38.75	1.03	1.60
	SP3	36.00	39.00	1.10	1.53
Opeaburo + Dehye	SP1	33.75	44.50	0.95	1.70
	SP2	37.00	43.25	0.98	1.58
	SP3	38.75	43.25	1.10	1.43
Opeaburo + Oboshie	SP1	54.25	70.50	0.93	1.63
	SP2	55.50	72.00	0.95	2.03
	SP3	66.50	67.00	1.00	1.85
Sole Yenyawoso	-	35.00	38.50	1.20	1.53
Sole Dehye	-	38.50	40.00	1.28	1.63
Sole Oboshie	-	66.25	68.00	1.18	1.63
CV (%)		**19.1**	**9.9**	**8.1**	**11.2**
	Variety =	*HSD=4.45***	*p=<.001*	*HSD=0.09***	*p=0.035*
	Season =	*HSD=2.80***	*p=<.001*	*HSD=0.07***	*p=<.001*
	Spatial arrangement =	*NS*		*NS*	
	Season x variety =	*NS*		*HSD=0.18***	*p=<.001*
	Season x spatial arrangement =	*NS*		*HSD=0.14***	*p=0.002*
	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.

3.2.5. Shelling Percentage

The results on shelling percentage of groundnut for 2021 minor and 2022 major cropping seasons are shown in Table 3. There was a significant (P≤0.05) difference between treatments in shelling percentage for both cropping seasons. Opeaburo + Yenyawoso x SP2 interaction had a significantly (P≤0.05) higher shelling percentage (76.61%) in 2021 minor cropping season, while Opeaburo + Dehye x SP3 interaction had a statistically higher shelling percentage (86.11%) in 2022 major cropping season than the other spatial arrangements and their sole plots. However, Sole Oboshie had significantly (P≤0.05) lowest shelling percentages (61.26% and 60.00%) for both 2021 minor and 2022 major cropping seasons, respectively. The season x variety interaction was significant in shelling percentage. There were no significant effects of spatial arrangement or varietal combination x spatial arrangement interactions in shelling percentages (Table 3).

Table 3. Shelling percentage of groundnut as influenced by variety and spatial arrangement for 2021 minor and 2022 major cropping seasons

Treatment		**Shelling percentage (%)**	
Varietal combination (VC)	**Spatial arrangement (SP)**	**2021**	**2022**
Opeaburo + Yenyawoso	SP1	74.93	65.20
	SP2	76.61	71.94
	SP3	66.35	71.54
Opeaburo + Dehye	SP1	68.39	71.15
	SP2	65.95	83.86
	SP3	66.38	86.11
Opeaburo + Oboshie	SP1	65.44	63.82
	SP2	64.82	58.41
	SP3	62.35	58.38
Sole Yenyawoso	-	64.45	64.86
Sole Dehye	-	67.96	71.90
Sole Oboshie	-	61.26	60.00
CV (%)		**9.8**	**15.0**
	Variety =	*HSD=5.43***	*p=<.001*
	Season =	*NS*	
	Spatial arrangement =	*NS*	
	Season x variety =	*HSD=10.01***	*p=0.014*
	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.

3.3. Yield and Yield Components of Maize

3.3.1. Cob Diameter

Table 4 illustrates results of cob diameter of maize for 2021 minor and 2022 major cropping seasons. There was a significant (P≤0.05) difference between the treatment means for both cropping seasons. The cob diameter ranged from 4.22 to 4.93 cm for both seasons. For 2021 minor cropping season, the interaction of Opeaburo + Oboshie and SP3 had a significantly (P≤0.05) higher mean cob diameter (4.67 cm), while the interactions of Opeaburo + Yenyawoso and SP2, as well as Opeaburo + Oboshie and SP1, and sole Opeaburo had the same and lowest mean cob diameter (4.27 cm). In 2022 major cropping season, the interaction of Opeaburo + Dehye and SP3 produced higher mean cob diameter (4.93 cm), while the interaction of Opeaburo + Dehye and SP1 had the lowest mean cob diameter (4.22 cm). There was a significant (P≤0.05) difference between the treatment means for 2021 minor and 2022 major cropping season in cob diameter. The cob diameter was not significantly affected by varietal combination, spatial arrangement, nor varietal combination x spatial arrangement interaction (Table 4).

3.3.2. Cob Length

The results on cob length of maize are shown in Table 4. Generally, the cob length ranged from 14.99 – 16.50 cm for both cropping seasons. For 2021 minor cropping period, the interaction of Opeaburo + Oboshie and SP3 had a significantly (P≤0.05) higher mean cob length (16.41 cm), while sole Opeaburo had the highest mean cob length (17.08 cm) for 2022 major cropping season. For 2021 minor cropping season, the interaction of Opeaburo + Yenyawoso and SP1 and sole Opeaburo had the lowest mean cob length (4.99 cm) while for 2022 major cropping season, the interaction of Opeaburo + Dehye and SP1 had the lowest mean cob length (13.17 cm). There was no significant (P>0.05) difference between the treatment means of season and season x variety interaction for both cropping seasons (Table 4). However, season x spatial arrangement recorded a statistical difference.

Table 4. Cob diameter and cob length of maize as influenced by variety and spatial arrangement for 2021 minor and 2022 major cropping seasons

Treatment		**Cob diameter (cm)**		**Cob length (cm)**	
Varietal combination (VC)	**Spatial arrangement (SP)**	**2021**	**2022**	**2021**	**2022**
Opeaburo + Yenyawoso	SP1	4.34	4.59	14.99	14.51
	SP2	4.39	4.62	15.67	15.69
	SP3	4.27	4.81	15.67	16.50
Opeaburo + Dehye	SP1	4.42	4.22	15.54	13.17
	SP2	4.39	4.47	15.47	15.45
	SP3	4.34	4.93	15.36	15.96
Opeaburo + Oboshie	SP1	4.27	4.56	15.29	14.71
	SP2	4.44	4.83	15.97	16.38
	SP3	4.67	4.67	16.41	15.94
Sole Opeaburo	-	4.27	4.90	14.99	17.08
CV (%)		**4.7**	**6.2**	**5.4**	**12.7**
	Variety =	*NS*		*NS*	
	Season =	*HSD=0.12***	*p=<.001*	*NS*	
	Spatial arrangement =	*HSD=0.15***	*p=0.031*	*HSD=1.50***	*p=0.011*
	Season x variety =	*NS*		*NS*	
	Season x spatial arrangement =	*NS*		*HSD=1.39***	*p=0.042*
	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.

3.3.3. 100 - Seed Weight

Table 5 shows results of 100-seed weight of maize for 2021 minor and 2022 major season. There were no significant (P>0.05) differences among varietal combination nor varietal combination x spatial arrangement interaction effects on 100-seed weight. With seasons, the 2022 major season produced slightly higher 100-seed weight (22.5 – 30.75g) than the 2021 minor season (19.75 – 26.50g). Opeaburo + Oboshie x SP3 interaction had a higher mean 100-seed weight (26.50g) compared to other spatial arrangements and their sole crops for 2021 minor season (Table 5). Similarly, for 2022 major cropping season, Opeaburo + Oboshie x SP2 interaction had the highest mean 100-seed weight (30.75g) compared to other spatial arrangements and their sole crops. The lowest mean 100-seed weight for 2021 minor season was recorded by Opeaburo + Yenyawoso x SP3 interaction (19.75g), while Opeaburo + Dehye x SP1 interaction had the lowest mean 100-seed weight (22.50g) for 2022 major cropping season (Table 5).

3.3.4. Grain Yield

The results on maize grain yield are indicated in Table 5. The grain yield of maize intercropped with three varieties of groundnut ranged from 2.70 – 3.93 and 2.88 – 6.03 t ha^{-1} for 2021 minor and 2022 major cropping seasons respectively. The grain yield of intercropped Opeaburo was not significantly affected by varietal combinations. However, on the average between seasons, the 2022 major season had approximately 30 – 58% higher maize grain yield than the 2021 minor cropping season which was significantly different (Table 5). The interaction of Opeaburo + Oboshie and SP3 had significantly (P≤0.05) higher grain yield (3.93 t ha^{-1}) of maize compared to Opeaburo + Yenyawoso x SP3 interaction with the lowest grain yield (2.70 t ha^{-1}) recorded in 2021 minor cropping season. In 2022 major cropping season, Opeaburo + Oboshie x SP2 interaction had significantly (p≤0.05) higher grain yield (6.03 t ha^{-1}) of maize compared to the lowest grain yield (2.88 t ha^{-1}) recorded by Opeaburo + Dehye x SP1 interaction (Table 5).

Table 5. 100-seed weight and grain yield of maize as influenced by variety and spatial arrangement for 2021 minor and 2022 major cropping seasons

Treatment		100 - Seed weight (g)		Grain yield (t ha^{-1})	
Varietal combination (VC)	**Spatial arrangement (SP)**	**2021**	**2022**	**2021**	**2022**
Opeaburo + Yenyawoso	SP1	20.75	27.50	3.68	4.38
	SP2	24.50	26.75	2.80	3.53
	SP3	19.75	27.75	2.70	5.83
Opeaburo + Dehye	SP1	21.00	22.50	2.90	2.88
	SP2	22.00	28.25	2.88	4.48
	SP3	23.25	28.50	3.20	5.20
Opeaburo + Oboshie	SP1	20.00	26.75	3.05	3.90
	SP2	25.25	30.75	3.05	6.03
	SP3	26.50	25.75	3.93	4.95
Sole Opeaburo	-	21.00	28.50	2.93	5.40
CV (%)		**11.5**	**16.1**	**24.0**	**27.8**
	Variety =	*NS*		*NS*	
	Season =	*HSD=317.00***	*p=<.001*	*HSD=0.49***	*p=<.001*
	Spatial arrangement =	*HSD=2.12*	*p=0.033*	*HSD=0.64***	*p=0.019*
	Season x variety =	*NS*		*NS*	
	Season x spatial arrangement =	*NS*		*NS*	
	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.

3.3.5. Shelling Percentage

Results of shelling percentage (%) of maize for 2021 minor and 2022 major seasons are shown in Table 6. Shelling percentage (%) ranged from 60 – 77% and 63 – 75% for the 2021 minor and 2022 major seasons, respectively. Shelling percentage (%) was not significant among the varietal combinations, spatial arrangement nor varietal combination x spatial arrangement interactions (Table 6). Similarly, there was no significant difference between the two cropping seasons in shelling percentage (%). although in the 2021 minor cropping season, Opeaburo + Oboshie x SP2 interaction had higher shelling percentage (76.88%), while Opeaburo + Yenyawoso x SP1 interaction had the highest shelling percentage (74.80%) in 2022 major cropping season (Table 6).

Table 6. Shelling percentage of maize as influenced by variety and spatial arrangement for 2021 minor and 2022 major cropping seasons

Treatment		Shelling percentage (%)	
Varietal combination (VC)	**Spatial arrangement (SP)**	**2021**	**2022**
Opeaburo + Yenyawoso	SP1	73.99	74.80
	SP2	66.98	70.06
	SP3	66.87	70.19
Opeaburo + Dehye	SP1	72.01	69.39
	SP2	60.44	63.31
	SP3	73.99	69.13
Opeaburo + Oboshie	SP1	74.73	67.13
	SP2	76.88	72.90
	SP3	76.82	74.04
Sole Opeaburo	-	65.64	69.21
CV (%)		**11.2**	**13.2**
	Variety =		*NS*
	Season =		*NS*
	Spatial arrangement =		*NS*
	Season x variety =		*NS*
	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.

3.3.6. Land Equivalent Ratio (LER)

Table 7 shows results of Land equivalent ratio (LER) for maize and groundnut intercrop. The land equivalent ratio was calculated for maize and groundnut intercropping. In the 2021 minor cropping season, Opeaburo + Oboshie x SP3 interaction recorded the highest land equivalent ratio of 1.29 (129 %) whereas Opeaburo + Yenyawoso x SP1 interaction gave a lesser land equivalent ratio of 0.82 (82 %). In the 2022 major cropping season, Opeaburo + Oboshie x SP2 interaction recorded the highest land equivalent ratio of 1.41 (141 %) while Opeaburo + Yenyawoso x SP1 and Opeaburo + Dehye x SP1 interactions gave a lesser land equivalent ratio of 0.82 (82 %) and 0.59 (59 %), respectively (Table 7). LER was not significant among the varietal combinations, spatial arrangement nor varietal combination x spatial arrangement interactions. Similarly, there was no significant difference between the two seasons for LER (Table 7).

Table 7. Land equivalent ratio (LER) of maize and groundnut as influenced by variety and spatial arrangement for 2021 minor and 2022 major cropping season

Treatment		**LER**	
Varietal combination (VC)	**Spatial arrangement (SP)**	**2021**	**2022**
Opeaburo + Yenyawoso	SP1	1.82	1.88
	SP2	1.84	1.75
	SP3	2.04	2.12
Opeaburo + Dehye	SP1	1.87	1.59
	SP2	1.88	1.81
	SP3	2.09	1.83
Opeaburo + Oboshie	SP1	2.01	1.76
	SP2	1.98	2.41
	SP3	2.29	2.14
Tukey's HSD (P ≤ 0.05)		**0.25**	**0.36**
	Variety =		*NS*
	Season =		*NS*
	Spatial arrangement =		*NS*
	Season x variety =		*NS*
	Season x spatial arrangement =		*NS*
	Variety x spatial arrangement =		*NS*
	Season x 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.

4. Discussion

4.1. Influence of Variety and Spatial Arrangement on Yield and Yield Components of Groundnut and Maize

The non-significant difference between groundnut varieties, spatial arrangement and their interactions in number of pods per plant in both 2021 minor and 2022 major cropping seasons could be that the treatment effects were similar [17]. The significant difference between cropping seasons in number of pods per plant could be attributable to variations in climatic conditions such as rainfall and temperature experienced across seasons, as well as well distributed rainfall, especially during the pod formation stage in the major cropping season. Climatic conditions such as rainfall and temperature significantly had influence on groundnut production [18].

The variation in number of seeds per pod in the groundnut varieties might be due to genetic variation. [19] reported that different groundnut varieties may have distinct genetic traits that influence seed development. The spatial arrangement 2 (SP2) might have also offered specific advantages, such as optimal spacing, light penetration, or airflow, which positively impacted the reproductive processes of Opeaburo and Yenyawoso groundnut varieties intercropped by creating microenvironments that favour seed development [20].

The variations among groundnut varieties in 100-seed weight in both 2021 minor and 2022 major cropping seasons might be due to genotypic and climatic differences. [21] reported that genotype is one of the major factors that influence seed weight in groundnuts, and the varieties can differ significantly in their seed size and weight. The significantly higher mean 100-seed weight produced by Opeaburo + Oboshie x SP2 and SP3 interactions compared to other treatments in both cropping seasons suggests that these varieties might be genetically predisposed to producing larger seeds. [22] in their study reported that the seeds of Oboshie are genetically big and had the highest 100-seed weight.

For maize, Opeaburo + Oboshie x SP3 and SP2 interactions produced significantly higher 100-seed weight compared to other spatial arrangements and their sole crops in 2021 minor and 2022 major cropping seasons. This could be because maize and different groundnut varieties (Opeaburo and Oboshie) might have varying genetic traits that influence seed development and weight. These genetic differences can result in variations in seed size and weight. The combination of Opeaburo maize and Oboshie groundnut in SP3 and SP2 interactions might have created a more favourable nutrient availability that enhanced seed development. Adequate nutrient availability, including nitrogen from groundnut, can contribute to larger seed size. Meanwhile, the lowest mean 100-seed weight recorded by Opeaburo + Yenyawoso x SP3 interaction in 2021 minor cropping season and Opeaburo + Dehye x SP1 interaction in 2022 major cropping season could be due to the selected plant combinations which might have led to higher competition for essential plant growth resources such as nutrients, water, and light. Increased competition can result in reduced resource availability for individual seeds, leading to smaller seed sizes [23].

Shelling percentage is the percentage of the weight of the seeds in the pods after they have been shelled, relative to the total weight of the pods. Opeaburo + Yenyawoso x SP2 interaction in 2021 minor cropping season had the highest shelling percentage. This indicates that the spatial arrangement combination may be optimal for achieving a high shelling percentage in the groundnut varieties used. Sole Oboshie had significantly lower shelling percentages from Opeaburo + Yenyawoso x SP1 and SP2 interactions in the minor cropping seasons which suggests that the groundnut variety may not be the best choice for achieving a high shelling percentage.

For maize, in both 2021 minor and 2022 major cropping seasons, high shelling percentage values were observed across all treatments. This indicates that the maize kernels were effectively separated from the cobs, resulting in good overall results. In the 2021 minor cropping season, the Opeaburo + Oboshie x SP2 interaction resulted in a significantly higher shelling percentage (76.88%) than other spatial arrangements and their sole plots. Similarly, in the 2022 major cropping season, the Opeaburo + Yenyawoso x SP1 interaction had higher shelling percentage (74.80%) compared to other spatial arrangements and their sole plots although non-significant. These interactions indicate that certain combinations of maize varieties and spatial arrangements led to more favourable shelling percentages. The treatment combination of Opeaburo + Dehye x SP2 had the lowest shelling percentage in both cropping seasons. This could be due to poor compatibility between the maize varieties and the intercrop groundnut and their response to weather conditions such as rainfall and temperature for the development and maturation of maize cobs.

The significant difference between treatments in cob diameter and cob length observed in the combined effect of maize and groundnut treatment across both cropping seasons could be due to the interaction between the two crops. According to [24], intercropping maize with legumes such as groundnut can improve maize cob diameter and cob length due to improved soil fertility and nutrient availability.

The highest grain yield produced by sole Dehye, Oboshie groundnut varieties and Opeaburo + Oboshie x SP2 interaction in the 2022 major cropping season could be due to variations in genotype and spatial arrangement as well as favourable and well distributed rainfall experienced during the 2022 growing period. The highest groundnut grain yield obtained in this current study is somewhat close to National attainable yield of 2.5 t ha^{-1} in Ghana [25]. According to [26], seasonal changes to rainfall could lead to changes in soil water content, which is likely to affect plant growth and yield. [27] found that different spatial arrangements had a significant impact on groundnut grain yield. This finding is consistent with the study by [28], who reported that the interaction between variety and spatial arrangement significantly influenced groundnut yield. The higher rainfall experienced in 2022 than in 2021 cropping seasons might have enhanced plants to produce more pods. The lower pod yield observed in Opeaburo + Yenyawoso x SP1 interaction in 2021 minor cropping season and Opeaburo + Dehye x SP3 interaction in the 2022 major cropping season suggest that these combinations may be less well adapted to the climatic conditions (rainfall, temperature, and relative humidity) during the experimental period.

For maize, Opeaburo + Oboshie x SP3 and SP2 interactions recorded the highest grain yield (3.93 t ha^{-1} and 6.03 t ha^{-1}), in the minor and major cropping seasons respectively and was significant. The significant boost in yield in the intercropped plants may be attributed to the beneficial effects of groundnut in the spatial arrangement. The current study shows that the average maize grain yield obtained is comparable to National achievable yield of approximately 6.0 t ha^{-1} in Ghana [29]. [30], opined that groundnut has been known to involve in symbiotic biological nitrogen fixation, which allows it to take up a portion of its nitrogen requirements from the atmosphere, thereby reducing the strain on soil nitrogen reserves. In this study, the intercropping of groundnut with maize proved advantageous for the maize plants, as they benefited from the nitrogen-fixing ability of groundnut roots and the transfer of nitrogen-fixation products to the maize. Conversely, Opeaburo + Yenyawoso x SP3 and Opeaburo + Dehye x SP1 interactions consistently had the lowest grain yield, suggesting potential incompatibilities in its genetic traits related to yield potential. This is in line with [31]. Generally, the major cropping season trial outperformed the minor cropping season trial in terms of grain yield, which probably might be due to well distributed rainfall pattern, appropriate temperature, suitable soil-water relationships, and efficient dry matter partitioning in maize during the major cropping season of 2022.

Land equivalent ratio (LER) is the total land area required under sole cropping to give yields obtained in the intercropping [32]. In the 2021 minor cropping season, Opeaburo + Oboshie x SP3 interaction recorded the highest land equivalent ratio of 1.29 (129 %) whereas Opeaburo + Dehye x SP1 interaction gave a lesser land equivalent ratio of 0.82 (82 %). In the 2022 major cropping season, Opeaburo + Oboshie x SP2 interaction recorded the highest land equivalent ratio of 1.41 (141 %) while Opeaburo + Yenyawoso x SP1 and Opeaburo + Dehye x SP1 interactions gave a lesser land equivalent ratio of 0.82 (82 %) and 0.59 (59 %), respectively for both seasons. The intercrops had a yield advantage over the sole crops. The lower LER by Opeaburo + Dehye x SP1 interaction might have exhibited competitive growth behaviours for resources like water, sunlight, and nutrients. This agrees with [33]. The advantage of intercrops with LER (1.29 and 1.41) over the sole crops (0.82 and 0.59) might be that different crops have varying root depths and nutrient requirements. When intercropped, they can utilize resources (water, nutrients, sunlight) more efficiently. Legumes in an intercrop may fix nitrogen, benefiting neighbouring non-legume crops. According to [34], when the land equality ratio (LER) equals 1, it indicates that the yield of intercrop and sole crops is the same. LER values greater than 1 suggest the usefulness of intercrop cultivation, while LER values less than 1 indicate the unprofitability of intercrop cultivation. In this current study, the land equality ratio (LER) was greater than 1 therefore in line with this statement. An LER of 1.29 and 1.41 respectively indicates that if planted in pure stands, the yield produced in the total intercrop would have required 29 % and 41 % more land, while an LER of 0. 57 indicates that the yield produced in the total intercrop was only 57 % of that of the same amount of land as pure stands planted.

5. Conclusions

The study revealed that for best yield and heavy grains of maize and groundnut, farmers are advised to intercrop Opeaburo with Oboshie by alternating with 2-rows and/or 3-rows for optimized grain yield rather than growing them as sole crops.

Further studies could consider the relative times of planting the component crops since it can influence competition and the use of resources.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript.

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