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Performance of Maize (*Zea mays* L.) and Land Equivalent Ratio under Maize-Groundnut (*Arachis hypogea* L.) Intercropping System

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Abstract

Soil fertility continues to decline in Ghana due to unsustainable human activities like bush burning, quarrying, improper farming practices, among others. To resolve this challenge, crop farmers resort to continuous use of mineral fertilizers in Ghana, which contaminates the environment and makes crop farming less sustainable and productive. One of the strategies to improve soil fertility and productivity for sustainable crop yields is intercropping. Studies were, therefore, undertaken at Miminaso in the Ejura-Sekyedumase municipality of Ashanti Region of Ghana during the 2020 cropping seasons to determine the effects of spatial row arrangement and time of planting maize and groundnut intercrops on productivity of maize and land equivalent ratio (LER). One row of maize and one row of groundnut (1M1G), one row of maize and two rows of groundnut (1M2G), two rows of maize and one row of groundnut (2M1G), two rows of maize and two rows of groundnut (2M2G), sole maize (M) and sole groundnut (G) were factorially arranged with concurrent planting of intercrops (0 WAP), planting groundnut one week after planting maize (1 WAP) and planting groundnut two weeks after planting maize (2 WAP) in a Randomized Complete Block Design with three replicates. There were significant treatment interaction ($P < 0.05$) effects for shelling percentage for maize in both seasons of the trial. In the major season of 2020, the highest shelling percentage of 79.30% was associated with 0 WAP × M, while in the minor season of 2020, the highest shelling percentage of 75.02% was recorded by 0 WAP × 2M1G. The treatment interaction effects for maize grain yield were significant only in the minor season of 2020 with the highest maize grain yield of 6341 kg/ha being produced by the sole maize treatment, followed by 1 WAP × 2M2G (6152 kg/ha). The highest LER of 3.05 was associated with 1 WAP × 2M2G in the minor season of 2020. Planting groundnuts within the first week of planting maize (1 WAP) increased maize seed yield and LER in two rows of maize and two rows of groundnut (2M2G) row arrangements.

Keywords

Intercropping, Maize, Groundnut, Yield

1. Introduction

Agriculture is associated with myriads of encounters to guarantee food security, improve resource use efficiency, and alleviate the effects of climate change, which cannot single-handedly be resolved [1]. However, an attempt to boost grain production could increase the use of farm inputs like fossil fuel, irrigation water, mineral fertilizers [2], which could significantly increase emission of greenhouse gases (GHGs) and degrade soil and freshwater resources as reported by Chen *et al.* [1]. Under such unfavourable conditions, sustainable and climate-resilient means of agriculture could be adopted to maintain crop production, promote availability of limited resources, and reduce GHGs emission in agricultural systems [3].

The maize crop (*Zea mays* L.) does well in different agro-ecologies in both tropical and temperate regions. In Ghana, maize is a significant cereal crop grown in all five agro-ecological zones, including Guinea, Sudan, and Costal savannas [4].

Smallholder farmers frequently utilize intercropping, which is the technique of growing two or more plants simultaneously on the same piece of land throughout the growing season. The component crops for certain straightforward combinations occasionally can be either lines, cultivars, or varieties, or a crop of trees or ornamental plants [5]. The majority of the plants used in this intercropping method are legumes [6]. Always, a primary crop is present, along with one or more crops that are secondary or tertiary in significance [7]. The component crops do not always need to be planted at the same time. Depending on when the other crop is expected to mature on the land, one crop may be planted before it or even after it [8]. Intercropping can be done with a variety of crop combinations such as cereal-cereal, cereal-legume, cereal-vegetables, cereal-tree crops, legumes-vegetables, etc., or more complex combinations such as cereal-legume-vegetable-tree crop, etc. [9].

Mixed row, relay and strip row intercropping are the main intercropping systems [10]. Another technique for intercropping involves planting two or more crops in different rows or alternate rows on the same plot of land [11]. Through the complementary use of growth nutrients, both crops benefit from the relationship in legume-cereal cropping systems [12]. Alhassan and Egbe [13] reported that the primary benefit of intercropping is to enhance yield per unit area. Intercrops ensure that growth resources like sunshine, accessible water, and nutrients are used effectively [14] [15]. Gamboa *et al.* [16] and Zhang *et al.* [17] found that intercropping ensures complete ground cover, improves soil aggregation and stability and soil chemical properties and reduces soil erosion. Studies by Zou *et al.* [18] showed that rotational maize-groundnut strip intercropping could improve soil properties such as organic matter and reduce emission of carbon.

The most popular and commonly used measure for comparing the productivity of intercrops to sole crops is the land equivalent ratio [19]. Land equivalent ratio is the overall yield ratio from an intercrop to the total yield obtained from the same plant species in the sole crop. It is the total amount of intercrop yield expressed as a percentage of the yield of the same species' single crop [20].

Reports by FAO [21] and Mallano *et al.* [22] showed that tilling agricultural lands constantly without rotations and fallows could erode farmlands, which could reduce soil fertility and crop yield. Most areas are associated with low crop yield and increasing production through opening of new farmlands has restricted potentials. Most Ghanaian farmers are resource poor and can hardly raise sufficient revenue to meet domestic needs and purchase expensive mineral fertilizers. Studies by Chukwu [23] have shown that number of acreages for agricultural purposes has reduced following an increase in human population, rising urbanization, deforestation, and soil erosion.

Despite the numerous benefits of intercropping, some farmers in Ghana have little knowledge on the effects of time of introducing legumes in cereal-legume intercropping systems and the effects of spatial row arrangement as a type of intercropping on the performance of the intercrops. It is against this background that studies were undertaken in Ejura in the Ashanti Region of Ghana to determine the effects of spatial row arrangement and time of planting intercrops on productivity of maize under maize-groundnut intercropping system. Specifically, the objectives of the study were to determine the effects of spatial row arrangement for maize-groundnut intercropping on maximum growth and yield of maize; effects of time of introducing groundnut in maize-groundnut intercropping on growth and yield of maize and interaction effects of spatial row arrangement for maize-groundnut intercrops and time of introducing groundnut in maize-groundnut intercropping on grain yield of maize and land equivalent ratio.

2. Materials and Methods

2.1. Experimental Site

The field experiment was conducted at Miminaso in the transitional agroecology (latitude 07˚24'N and longitude 01˚21'W) in Ejura – Sekyedumase municipality of Ashanti Region of Ghana during the 2020 cropping season [24].

There are two rainy seasons in the area, namely major rainy season (late March-mid-July) and minor rainy season (September-late November). The agro-ecology is characterized by short dry spells in August. The mean minimum and maximum temperatures are about 20.5˚C and 37.9˚C, respectively. Mean relative humidity is 63%. The soil is moderately drained sandy loam, less to coarse-textured, with fairly low moisture holding capacity [24].

2.2. Experimental Design and Treatments

The experiment was a 5 × 3 factorial, in which five levels of row arrangement of maize and groundnut intercrops and three levels of time of sowing the groundnut intercrop were evaluated in a randomized complete block design (RCBD). The treatments were replicated thrice. Thus, there were fifteen (15) treatment combinations in each block and forty-five (45) plots per the experimental field.

The first factor was row arrangement of intercrops and the levels were as follows:

- One row of maize and one row of groundnut (1M1G)
- One row of maize and two rows of groundnut (1M2G)
- Two rows of maize and one row of groundnut (2M1G)
- Two rows of maize and two rows of groundnut (2M2G)
- Sole maize (M)
- Sole groundnut (G)

Time of introducing groundnut into the intercropping system was the second factor and comprised:

- Simultaneous planting of intercrops (0 WAP)
- Planting groundnut one week after planting maize (1 WAP)
- Planting groundnut two weeks after planting maize (2 WAP)

The treatment combinations were 0 WAP × 1M1G, 0 WAP × 1M2G, 0 WAP × 2M1G, 0 WAP × 2M2G, 0 WAP × M, 1 WAP × 1M1G, 1 WAP × 1M2G, 1 WAP × 2M1G, 1 WAP × 2M2G, 1 WAP × M, 2 WAP × 1M1G, 2 WAP × 1M2G, 2 WAP × 2M1G, 2 WAP × 2M2G and 2 WAP × M.

2.3. Soil Sampling and Analysis

Prior to planting, soil samples were collected with an auger at a depth of 0 - 30 cm. The samples were collected from separate areas on each plot and then composited, which was dried continuously in the air for five days after which the composite soil sample was sieved to remove big particles, debris, and stones. The initial soil analysis was conducted using normal procedures defined by Motsara and Roy [25] at the soil science laboratory of the Department of Crop and Soil Sciences at the Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. **Table 1** shows the physical and chemical properties of the soil at the experimental site. Climatic data at the experimental site are shown in **Figure 1**.

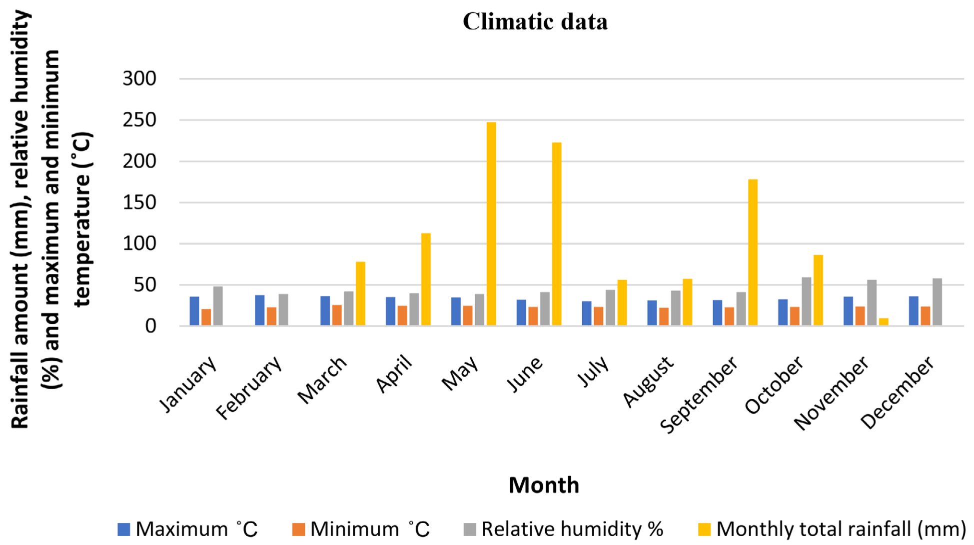

Figure 1. Temperature, relative humidity and rainfall data at the experimental site in 2020. Source: Ejura Meteorological Station [27].

Table 1. Initial physical and chemical properties of soil at the experimental site.

Parameter	level
pH (1:2.5 H_2O)	5.5
Organic C (%)	0.87
Total N (%)	0.06
OM (%)	1.5
Ca^{2+} (ppm)	349
Mg^{2+} (ppm)	68
Exchangeable K^+ ppm	<40
Boron (ppm)	<0.5
Available P (ppm)	0 - 10
Manganese (ppm)	118
Zinc (ppm)	1.1
CEC me/100g	3.9
Iron (ppm) Soil texture: Sandy loam	106

Source: KNUST soil science laboratory [26].

2.4. Agronomic Operations

The vegetation was cleared, and the land was ploughed to a depth of about 30 cm with a tractor-mounted plough and harrowed to break down large clods of soils to a fine tilth during the 2020 major and minor cropping seasons. Fourteen (14) days after ploughing, weeds were controlled with a systemic herbicide called sunphosate (glyphosate) at a rate of 15 ml per litre of water using a hand-operated knapsack sprayer. The experimental field was lined and further divided into 45 plots. Every plot measured 4 m × 4 m with 1 m and 1.5 m between plots and blocks, respectively.

Seed maize (Lake 601 variety) was obtained from the RMG Seed Company, while the groundnut seeds (Chinese variety) were procured from CSIR-Crops Research Institute (CSRI) of Ghana. The Lake 601 is a white hybrid maize variety with a flint grain type. This tropical hybrid is well adapted across many of Africa's environments from hot, humid lowlands to dry mid altitudes and high potential wet highlands. LAKE 601 does better than other hybrids in acidic soils and also shows exceptionally good nitrogen-use efficiency as well as *Striga* tolerance, making this hybrid a top performer in emerging farmer sectors. It has a high yield potential of 9 t/ha and resistance to Nicosulfuron herbicides. Days to 50% flowering is 72 days and days to harvesting is 140 days [28]. The Chinese Shitaochi groundnut variety is a widely grown local Spanish type of groundnut with a maturity period of 95 to 100 days and is susceptible to the rosette virus disease [29].

The maize and groundnut seeds were planted at a spacing of 75 cm × 25 cm and 40 cm × 20 cm, respectively after a germination of 95% was accepted for seeds of both test crops. Maize was sown on 21st April, 2020 and 14th August, 2020 in the major and minor rainy seasons, respectively. Maize was sown on the same day for all the plots, but groundnut was planted as per the treatment imposed. Thus, the first level of planting the groundnut intercrop involved establishing both maize and groundnut at the same time, the second level included planting groundnut one (1) week after planting maize and the third (3) level involved planting groundnut two (2) weeks after planting maize. The spatial arrangements of the intercrop components (M:G) were 1:1, 1:2, 2:1, 2:2 and either sole maize or sole groundnut.

Application of pre-emergence herbicides was done a day after planting with sunphosate at a rate of 200 ml/15 litres of water. Weed control was done manually by hoeing. Two weedings were done at 2nd and 5th week after planting the maize.

First fertilizer application (basal) to the maize plants was carried out two weeks after planting, while the second application (top dressing) was done two weeks after the first fertilizer application. NPK 15-15-15 fertilizer was used for the basal application at the rate of 100 kg/ha, while the top dressing was carried out using ammonium sulphate at the rate of 50 kg/ha. Fertilizers were side-banded.

Best farmer, an insecticide, was applied to control fall armyworm (*Spodoptera frugiperda*) on maize plants two to three weeks after planting at the rate of 40 ml/15 litres of water and was repeated a week later using a knapsack sprayer.

Harvesting of maize was done on 13th July, 2020 and 16th November, 2020 in the major and minor rainy seasons, respectively.

2.5. Data Collection

Data on vegetative parameters of maize in the central row of each plot were collected two weeks after planting at an interval of two weeks until 6 weeks after planting. Data on days to tasseling were taken when 50% of the maize plants produced tassels and silks, respectively, while yield data were taken at harvest.

2.5.1. Plant Height

The mean plant height was computed from the six selected plants.

2.5.2. Number of Leaves Per Plant

The mean number of leaves was computed from the six selected plants.

2.5.3. Leaf Area

Leaf area and leaf area index were calculated using the formula published by Montgeomery [30] as follows:

$$\text{Leaf area} = k\left(l \times w\right)$$

where,

L = leaf length.

w = leaf width.

k = factor (in cereals = 0.75).

2.5.4. Leaf Area Index

The leaf area index was determined by dividing the total leaf area by the total amount of land it covered.

$$\text{LAI} = k(l \times w)/A$$

where A = Total land area occupied by leaves.

2.5.5. Number of Days to 50% Tasselling

Number of days from the planting date to the day when half of the plants have started producing tassels and shedding pollens were recorded.

2.5.6. Number of Days to 50% Silking

Number of days from the day of planting to the day when 50% of the plants have produced silks were recorded.

2.5.7. Number of Cobs Per Plant

The average number of ears of the six selected plants per plot was determined.

2.5.8. Cob Weight

The average cob weight of the six selected plants per plot was determined.

2.5.9. 100-Seed Weight

One hundred seeds were counted from each plot and the weight was taken.

2.5.10. Grain Yield

Data on grain yield were recorded in each plot after oven-drying the grains for 3 days at a temperature of 60˚C and converted into kg·ha^{-1}

$$\text{Thus, grain yield in kg/ha} = \frac{\text{Yield/plot}}{\text{Plot size}} \times 10000 .$$

2.5.11. Shelling Percentage

This is the proportion of seed weight to cob weight expressed as a percentage.

2.5.12. Land Equivalent Ratio (LER)

LER = La + Lb = Ya/Sa + Yb/Sb [31].

where,

- La and Lb are the LERs of the intercrops a and b;
- Ya and Yb are the yields of the individual crops in the intercrop;
- Sa and Sb are their sole yields.

2.6. Data Analysis

Data collected for the entire variables measured were subjected to Analysis of Variance (ANOVA) using the GenStat statistical package (Numerical Algorithms Group, Oxford, England) [32]. The least significant difference (LSD) was used to separate treatment means at a 5% level of probability.

3. Results

3.1. Vegetative Growth

3.1.1. Plant Height

Plant height of maize is presented in Table 2 and Table 3. Row arrangement had no significant ($P > 0.05$) effects on plant height in the major rainy season of 2020, but time of planting the intercropped groundnut did affect it at 6 weeks after planting maize. Plants from 2 WAP plots were the tallest and were similar to plants from 0 WAP plots, but differed significantly ($P < 0.05$) from plants from the 1 WAP plots. 1 WAP treatment resulted in the shortest plants and was similar to 0 WAP treatment.

There were significant ($P < 0.05$) treatment interaction effects for plant height in the major season of 2020. At 2 weeks after planting maize, 1 WAP × 1M2G treatment combination recorded the highest plant height of 5.45 cm, while 1 WAP × 2M2G recorded the lowest plant height of 4.30 cm. At 4 weeks after planting maize, 0 WAP × 2M1G recorded the highest plant height of 31.20 cm, while 1 WAP × 2M1G recorded the lowest plant height of 17.00 cm. At 6 weeks after planting maize, 2 WAP × 2M1G recorded the highest plant height of 97.10 cm, while 1 WAP × 2M2G recorded the lowest plant height of 67.70 cm.

Row arrangement had significant ($P < 0.05$) effects on maize plant height in the minor rainy season of 2020 at 6 weeks after planting maize. 1M1G treatment produced the tallest maize plants, whereas the 2M2G treatment produced the shortest plants. These two treatments differed significantly ($P < 0.05$) from each other. All other treatment differences were not significant ($P > 0.05$). The time of

Table 2. Effects of maize-groundnut intercropping on maize plant height in the major season of 2020.

Treatment:	Plant height (cm) Weeks After Planting		
	2	4	6
Row arrangement (R)			
1M1G	4.70a	25.56a	84.3a
1M2G	4.78a	24.12a	84.2a
2M1G	4.72a	24.61a	87.3a
2M2G	4.56a	21.28a	79.6a
Sole maize (M)	4.95a	22.57a	85.3a
LSD (5%)	NS	NS	NS
Time of planting groundnuts (T)			
0 WAP	4.52a	25.03a	86.4ab
1 WAP	4.95a	21.37a	76.6a
2 WAP	4.76a	24.48a	89.4b
LSD (5%)	NS	NS	11.19
Interactions (R × T)			
0 WAP × 1M1G	4.96ab	24.08ab	83.5ab
0 WAP × 1M2G	4.42ab	27.47b	88.9ab
0 WAP × 2M1G	4.49ab	31.20b	87.9ab
0 WAP × 2M2G	4.37ab	25.28ab	86.4ab
0 WAP × M	4.37ab	17.12a	85.4ab
1 WAP × 1M1G	4.77ab	25.76b	78.9ab
1 WAP × 1M2G	5.45b	20.64a	78.5ab
1 WAP × 2M1G	5.09ab	17.00a	76.8ab
1 WAP × 2M2G	4.30a	20.11ab	67.7a
1 WAP × M	5.14ab	23.37ab	81.0ab
2 WAP × 1M1G	4.37ab	26.84b	90.4ab
2 WAP × 1M2G	4.47ab	24.24ab	85.3ab
2 WAP × 2M1G	4.59ab	25.63ab	97.1b
2 WAP × 2M2G	5.00ab	18.45ab	84.8ab
2 WAP × M	5.36b	27.22b	89.6ab
LSD (5%)	1.01	8.63	25.02
CV (%)	12.7	21.8	17.8

Within column means with different letters differed significantly ($P < 0.05$). LSD-Least Significant Difference; CV-Coefficient of Variation; NS-Not Significant.

Table 3. Effects of maize-groundnut intercropping on maize plant height in the minor season of 2020.

Treatment	Plant height (cm) Weeks After Planting		
	2	4	6
Row arrangement (R)			
1M1G	10.15a	26.4a	99.3b
1M2G	9.90a	23.8a	90.5ab
2M1G	11.17a	23.7a	89.7ab
2M2G	10.67a	23.7a	87.2ab
Sole maize (M)	9.66a	34.9a	93.8a
LSD (5%)	NS	NS	10.91
Time of planting groundnuts (T)			
0 WAP	11.06b	24.3a	92.9a
1 WAP	10.72b	24.6a	94.3a
2 WAP	9.15a	30.7a	89.2a
LSD (5%)	1.31	NS	NS
Interactions (R × T)			
0 WAP × 1M1G	11.08b	27.6a	108.4b
0 WAP × 1M2G	10.70b	22.9a	89.1ab
0 WAP × 2M1G	10.71b	23.80a	92.9ab
0 WAP × 2M2G	11.25b	23.10a	81.7ab
0 WAP × M	11.55b	24.00a	92.3ab
1 WAP × 1M1G	10.59b	24.90a	90.1ab
1 WAP × 1M2G	10.65b	24.2a	91.2ab
1 WAP × 2M1G	12.36b	25.40a	99.9b
1 WAP × 2M2G	10.09ab	25.0a	87.8ab
1 WAP × M	9.91a	23.3a	102.3b
2 WAP × 1M1G	8.78a	26.7a	99.5b
2 WAP × 1M2G	8.34a	24.2a	91.1ab
2 WAP × 2M1G	10.44a	22.1a	76.3a
2 WAP × 2M2G	10.67b	23.1a	92.2ab
2 WAP × M	7.54a	57.3b	86.9ab
LSD (5%)	2.93	26.05	18.90
CV (%)	17.0	58.8	12.3

Within column means with different letters differed significantly ($P < 0.05$). LSD-Least Significant Difference; CV-Coefficient of Variation; NS-Not Significant.

planting the intercropped groundnut did affect plant height significantly (P < 0.05) at 2 weeks after planting maize. Plants from 0 WAP plots were the tallest, while 2 WAP treatment resulted in the shortest plants. Other treatment differences were not significant (P > 0.05).

There were significant (P < 0.05) treatment interaction effects for plant height in the minor season of 2020. At 2 weeks after planting maize, 1 WAP × 2M1G treatment combination recorded the highest plant height of 12.36 cm, while 2 WAP × 2M1G recorded the lowest plant height of 8.34 cm. At 4 weeks after planting maize, 2 WAP × M recorded the highest plant height of 57.30 cm, while 2 WAP × 2M1G recorded the lowest plant height of 22.1 cm. At 6 weeks after planting maize, 0 WAP × 1M1G recorded the highest plant height of 108.4 cm, while 2 WAP × 2M1G recorded the lowest plant height of 76.3 cm.

3.1.2. Number of Leaves Per Plant

In the major rainy season of 2020, number of leaves per plant was affected significantly (P < 0.05) at the first sampling period by row arrangement (Table 4). The sole maize treatment (M) recorded the highest number of leaves per plant, while the least number of leaves per plant was recorded by the 2M2G treatment. All the intercropped treatments were similar in number of leaves per plant. The sole maize treatment was similar to the intercropped treatments, except the 2M2G treatment.

Time of planting groundnut significantly (P < 0.05) affected number of leaves per plant at second and third sampling periods. Planting groundnuts 2 weeks after planting maize (2 WAP treatment) recorded the highest number of leaves per plant, while the least value was found in the 1 WAP treatment. The 2 WAP treatment differed significantly (P < 0.05) from the 1 WAP treatment, but was similar to the 0 WAP treatment. The 0 WAP treatment and 1 WAP treatment were similar in number of leaves per plant. At the third sampling period, the 0 WAP treatment recorded the highest number of leaves per plant, while the 1 WAP treatment gave the lowest value. The 1 WAP treatment varied significantly (P < 0.05) from either the 0 WAP treatment or 2 WAP treatment. The 0 WAP treatment and 2 WAP treatment were similar in the parameter measured.

There were significant (P < 0.05) treatment interaction effects for number of leaves per plant at all the sampling periods, but a clear pattern was established at 6 weeks after planting maize (last sampling period). At the last sampling period, 0 WAP × 2M1G and 2 WAP × 1M1G treatment combinations resulted in the highest number of leaves per plant (14.33), while the least value of 12.33 was registered by the 1 WAP × 1M2G treatment combination (Table 5).

In the minor rainy season of 2020, row arrangement of intercrops affected number of leaves per plant at the second sampling period (Table 5). At this sampling period, the 1M1G treatment recorded the highest number of leaves per plant and differed significantly (P < 0.05) from the sole maize, which gave the lowest value. All other treatment means were similar.

Table 4. Effects of maize-groundnut intercropping on number of leaves per maize plant in the major season of 2020.

Treatment	Number of leaves per plant Weeks After Planting		
	2	4	6
Row arrangement (R)			
1M1G	5.89ab	9.33a	13.89a
1M2G	5.78ab	9.11a	13.44a
2M1G	5.89ab	9.22a	13.89a
2M2G	5.56a	9.22a	13.33a
Sole maize (M)	6.00b	9.56a	13.89a
LSD (5%)	0.34	NS	NS
Time of planting groundnuts (T)			
0 WAP	5.80a	9.33ab	14.00b
1 WAP	5.80a	9.00a	13.13a
2 WAP	5.87a	9.53b	13.93b
LSD (5%)	NS	0.45	0.68
Interactions (R × T)			
0 WAP × 1M1G	5.67ab	9.33ab	13.67ab
0 WAP × 1M2G	6.00b	9.67ab	14.00b
0 WAP × 2M1G	5.67ab	8.67a	14.33b
0 WAP × 2M2G	5.67ab	9.67ab	14.00b
0 WAP × M	6.00b	9.33ab	14.00b
1 WAP × 1M1G	6.00b	9.00ab	13.67ab
1 WAP × 1M2G	5.67ab	8.67a	12.33a
1 WAP × 2M1G	6.00b	9.00ab	13.33ab
1 WAP × 2M2G	5.33a	9.00ab	13.00ab
1 WAP × M	6.00b	9.33ab	13.33ab
2 WAP × 1M1G	6.00b	9.67ab	14.33b
2 WAP × 1M2G	5.67ab	9.00ab	14.00b
2 WAP × 2M1G	6.00b	10.00b	14.00b
2 WAP × 2M2G	5.67ab	9.00a	13.00ab
2 WAP × M	6.00b	10.00b	14.33b
LSD (5%)	0.60	1.00	1.52
CV (%)	6.10	6.40	6.60

Within column means with different letters differed significantly ($P < 0.05$). LSD-Least Significant Difference; CV-Coefficient of Variation; NS-Not Significant.

Table 5. Effects of maize-groundnut intercropping on number of leaves per maize plant in the minor season of 2020.

Treatment	Number of leaves per plant Weeks After Planting		
	2	4	6
Row arrangement (R)			
1M1G	5.89a	9.56b	12.89a
1M2G	5.81a	9.33ab	12.89a
2M1G	5.89a	9.44ab	12.44a
2M2G	5.89a	9.44ab	12.78a
Sole maize (M)	5.78a	9.00a	12.89a
LSD (5%)	NS	0.51	NS
Time of planting groundnuts (T)			
0 WAP	5.82ab	9.40a	12.87b
1 WAP	5.93b	9.40a	13.07b
2 WAP	5.80a	9.27a	12.40a
LSD (5%)	0.12	NS	0.43
Interactions (R × T)			
0 WAP × 1M1G	5.67ab	9.67b	13.00b
0 WAP × 1M2G	5.44ab	9.33ab	12.33ab
0 WAP × 2M1G	6.00b	9.33ab	13.00b
0 WAP × 2M2G	6.00b	9.33ab	13.00b
0 WAP × M	6.00b	9.33ab	13.00b
1 WAP × 1M1G	6.00b	9.33ab	13.00b
1 WAP × 1M2G	6.00b	9.33ab	13.33b
1 WAP × 2M1G	6.00b	10.00b	13.00b
1 WAP × 2M2G	5.67ab	9.33ab	12.67b
1 WAP × M	6.00b	9.00ab	13.33b
2 WAP × 1M1G	6.00b	9.67b	12.67b
2 WAP × 1M2G	6.00b	9.33ab	13.00b
2 WAP × 2M1G	5.67ab	9.00ab	11.33a
2 WAP × 2M2G	6.00b	9.67b	12.67b
2 WAP × M	5.33a	8.67a	12.33ab
LSD (5%)	0.56	0.89	0.96
CV (%)	5.70	5.70	4.50

Within column means with different letters differed significantly ($P < 0.05$). LSD-Least Significant Difference; CV-Coefficient of Variation; NS-Not Significant.

At the first and third sampling periods where time of planting the groundnut intercrops significantly (P < 0.05) affected number of leaves per plant, the 1 WAP treatment produced maize plants with the highest number of leaves, while the 2 WAP treatment produced plants with the lowest value. At the first sampling period, the 2 WAP treatment differed significantly (P < 0.05) from the 1 WAP treatment, but was similar to the 0 WAP treatment. The 0 WAP treatment and the 1 WAP treatment were similar in number of leaves per plant.

At the third sampling period, the 1 WAP treatment and the 2 WAP treatment were similar, but either of them varied significantly (P < 0.05) from the 0 WAP treatment.

There were significant (P < 0.05) treatment interaction effects for number of leaves per plant at all the sampling periods, but a clear pattern was established at 4 and 6 weeks after planting maize (**Table 5**). At the second sampling period, 1 WAP × 2M1G treatment combination produced maize plants with the highest number of leaves (0), while the sole maize (2 WAP × M) produced the least number of leaves (8.67). At the third sampling period, the highest number of leaves per plant (10.00) was found in the 1 WAP × 1M2G and 1 WAP × M treatment combinations, whereas the least number of leaves per plant (11.33) was noticed in 2 WAP × 2M1G treatment combination.

3.1.3. Leaf Area

Leaf area of maize was significant (P < 0.05) with treatment application throughout the study (**Table 6**).

In the major rainy season of 2020, the 1M2G treatment recorded the largest leaf area of maize, while the 2M2G treatment resulted in the smallest leaf area. The 2M2G and 1M2G treatments differed significantly (P < 0.0). From each other in leaf area of maize, All other treatment differences were similar (**Table 6**).

For time of planting groundnut, the largest leaf area of maize was recorded by the 2 WAP treatment, while the smallest leaf area of maize was noticed in the 1 WAP treatment. The 0 WAP and 2 WAP treatments were similar, but either of them varied significantly from the 1 WAP treatment.

There were significant (P < 0.05) treatment interaction effects for leaf area of maize. The largest leaf area of maize (389.8 cm^2) was recorded by 0 WAP × 1M2G, while the smallest value of 252.7 cm^2 was noticed in 1 WAP × 2M2G (**Table 6**).

In the minor season of 2020, significant (P < 0.05) differences existed between 1M1G and 1M2G treatments, which had the highest and lowest values of leaf area of maize, respectively. All other treatment differences were not significant (P > 0.05). For time of planting groundnut, 1 WAP treatment gave the largest leaf area, while the 2 WAP treatment gave the lowest leaf area, and these two treatments differed significantly (P < 0.05) from each other. 1 WAP and 2 WAP treatments were similar in leaf area of maize (**Table 6**).

There were significant (P < 0.05) treatment interaction effects for leaf area of maize. The largest leaf area of maize (493.4 cm^2) was recorded by 0 WAP × 1M1G, while the smallest value of 327.2 cm^2 was noticed in 0 WAP × 1M2G (Table 6).

Table 6. Effects of maize-groundnut intercropping on leaf area of maize in the major and minor seasons of 2020.

Treatment	Leaf area (cm^2)	
	2020 major season	**2020 minor season**
Row arrangement (R)		
1M1G	328.7ab	430.3b
1M2G	343.0b	358.0a
2M1G	331.6ab	415.4ab
2M2G	287.1a	407.3ab
Sole maize (M)	328.7ab	386.4ab
LSD (5%)	48.31	59.64
Time of planting groundnuts (T)		
0 WAP	337.2a	399.1ab
1 WAP	391.3b	423.3b
2 WAP	342.9a	376.0a
LSD (5%)	37.42	46.20
Interactions (R × T)		
0 WAP × 1M1G	294.0a	493.4b
0 WAP × 1M2G	389.8b	327.2a
0 WAP × 2M1G	364.6b	432.8ab
0 WAP × 2M2G	310.4ab	368.5a
0 WAP × M	327.3ab	373.6a
1 WAP × 1M1G	338.5b	414.3ab
1 WAP × 1M2G	281.6ab	396.6ab
1 WAP × 2M1G	279.4ab	446.4b
1 WAP × 2M2G	252.7a	459.4b
1 WAP × M	304.3ab	400.0ab
2 WAP × 1M1G	353.6b	383.4ab
2 WAP × 1M2G	357.5ab	350.2ab
2 WAP × 2M1G	350.7b	366.9ab
2 WAP × 2M2G	298.2ab	393.9ab
2 WAP × M	354.5b	385.6ab
LSD (5%)	83.67	103.30
CV (%)	15.40	15.50

Within column means with different letters differed significantly ($P < 0.05$). LSD-Least Significant Difference; CV-Coefficient of Variation; NS-Not Significant.

3.2. Phenology of Maize

In both seasons of 2020, row arrangement of intercrops had no significant ($P > 0.05$) effects on days to 50% tasselling and silking. Again, time of introducing groundnut into the intercropping system had no significant ($P > 0.05$) effects on days to 50% tasselling and silking in the major season of 2020, but in the minor season of 2020 these parameters were significantly ($P < 0.05$) affected by this treatment (**Table 7**). The 0 WAP and 1 WAP treatments were similar in terms of days to flowering, but either of them differed significantly ($P < 0.05$) from the 2 WAP treatment. The 0 WAP treatment recorded the shortest days to tasselling and silking of 58.06 days and 61.20 days, respectively, while 2 WAP recorded longest days to tasselling and silking of 58.67 days and 62.67 days, respectively.

There were significant treatment interaction effects ($P < 0.05$) for days to 50% tasselling and silking throughout the study. In the major season of 2020, 2 WAP × 1M2G recorded the longest days to tasselling (59.33 days), while the shortest days to tasselling of 58 days was observed in a combination of either 0 WAP or 1 WAP with all the row arrangements, except 2M2G and 1M1M. In the minor season of 2020, 2 WAP × 2M1G recorded the longest days to tasselling (59 days), while the shortest days to tasselling of 58 days was observed in a combination of either 0 WAP or 1 WAP with all the row arrangements, except 1M2G and 1M1M.

In the major season of 2020, 2 WAP × 1M2G recorded the longest days to silking (63.67 days), while the shortest days to silking of 61 days was observed in 0 WAP × 1M2G, 0 WAP × M, 1 WAP × M, 2 WAP × 1M1G and 2 WAP × M (**Table 7**). In the minor season of 2020, 2 WAP × 2M1G and 2 WAP × 2M2G recorded the longest days to silking (63 days), while the shortest days to silking of 61 days was observed 0 WAP × 2M2G and 1 WAP × 2M2G (**Table 7**).

3.3. Yield and Yield Components and Land Equivalent Ratio

3.3.1. Number of Cobs Per Plant and Cob Weight

Number of cobs per plant was not significant ($P > 0.05$) with treatment application throughout the study (**Table 8**).

In the major rainy season of 2020, row arrangement of intercrops and time of introducing groundnut into the intercropping system had no significant ($P > 0.05$) effects on cob weight, but their interaction effects were significant. The heaviest cobs (0.26 kg) were produced by 0 WAP × 2M1G, while the lightest cobs (0.12 kg) were noticed in 1 WAP × 1M2G (**Table 8**).

In the minor rainy season of 2020, cob weight was significant with treatment application. The 1M2G treatment recorded the heaviest cob weight and was similar to the other intercropped treatments, but differed significantly from the sole maize treatment. The sole maize plants had the least cob weight. All other treatment differences were similar. 0 WAP and 1 WAP were similar in cob weight, but either of them was significantly higher than 2 WAP (**Table 8**).

Table 7. Effects of maize-groundnut intercropping on days to 50% tasselling and silking of maize in the major and minor seasons of 2020.

Treatment	Days to 50% tasselling		Days to 50% silking	
	2020 major season	2020 minor season	2020 major season	2020 minor season
Row arrangement (R)				
1M1G	58.67a	58.33a	62.00a	62.11a
1M2G	58.44a	58.33a	62.44a	61.67a
2M1G	58.22a	58.33a	62.33a	61.89a
2M2G	58.67a	58.22a	62.78a	61.67a
Sole maize (M)	58.11a	58.22a	61.67a	61.67a
LSD (5%)	NS	NS	NS	NS
Time of planting groundnuts (T)				
0 WAP	58.33a	58.06a	62.00a	61.20a
1 WAP	58.33a	58.13a	62.27a	61.53a
2 WAP	58.60a	58.67b	62.47a	62.67b
LSD (5%)	NS	0.15	NS	0.59
Interactions (R × T)				
0 WAP × 1M1G	59.00ab	58.00a	62.33ab	61.67a
0 WAP × 1M2G	58.00a	58.33ab	61.67a	61.33ab
0 WAP × 2M1G	58.00a	58.00a	62.00ab	61.33ab
0 WAP × 2M2G	58.67ab	58.00a	62.33ab	61.00a
0 WAP × M	58.00a	58.00a	61.67a	60.67a
1 WAP × 1M1G	58.67ab	58.33ab	62.00ab	62.00b
1 WAP × 1M2G	58.00a	58.00a	62.00ab	61.33ab
1 WAP × 2M1G	58.00a	58.00a	62.33ab	61.33ab
1 WAP × 2M2G	59.00ab	58.00a	63.33ab	61.00ab
1 WAP × M	58.00a	58.33ab	61.67a	62.00ab
2 WAP × 1M1G	58.33ab	58.67ab	61.67a	62.67bc
2 WAP × 1M2G	59.33b	58.67ab	63.67b	62.33b
2 WAP × 2M1G	58.67ab	59.00b	62.67ab	63.00c
2 WAP × 2M2G	58.33ab	58.67ab	62.67ab	63.00c
2 WAP × M	58.33ab	58.33ab	61.67a	62.33b
LSD (5%)	1.27	0.67	1.97	1.31
CV (%)	1.30	0.70	1.90	1.30

Within column means with different letters differed significantly ($P < 0.05$). LSD-Least Significant Difference; CV-Coefficient of Variation; NS-Not Significant.

Table 8. Effects of maize-groundnut intercropping on number of cobs per plant and cob weight in the major and minor seasons of 2020.

Treatment	No. of cobs per plant		Cob weight (kg)	
	2020 major season	2020 minor season	2020 major season	2020 minor Season
Row arrangement (R)				
1M1G	1.04a	1.04a	0.20a	0.12ab
1M2G	1.02a	1.02a	0.16a	0.13b
2M1G	1.00a	1.00a	0.23a	0.11ab
2M2G	1.00a	1.00a	0.18a	0.11ab
Sole maize (M)	1.02a	1.02a	0.23a	0.10a
LSD (5%)	NS	NS	NS	0.02
Time of planting groundnuts (T)				
0 WAP	1.03a	1.03a	0.22a	0.12b
1 WAP	1.03a	1.03a	0.18a	0.12b
2 WAP	1.00a	1.00a	0.20a	0.10a
LSD (5%)	NS	NS	NS	0.01
Interactions (R × T)				
0 WAP × 1M1G	1.07a	1.07a	0.19ab	0.12bcd
0 WAP × 1M2G	1.07a	1.07a	0.18ab	0.14d
0 WAP × 2M1G	1.00a	1.00a	0.26b	0.11abcd
0 WAP × 2M2G	1.00a	1.00a	0.22ab	0.12bcd
0 WAP × M	1.00a	1.00a	0.25b	0.11abcd
1 WAP × 1M1G	1.07a	1.07a	0.19ab	0.12bcd
1 WAP × 1M2G	1.00a	1.00a	0.12a	0.13cd
1 WAP × 2M1G	1.00a	1.00a	0.21ab	0.11abcd
1 WAP × 2M2G	1.00a	1.00a	0.17ab	0.13cd
1 WAP × M	1.07a	1.07a	0.20ab	0.11abcd
2 WAP × 1M1G	1.00a	1.00a	0.23ab	0.12bcd
2 WAP × 1M2G	1.00a	1.00a	0.18ab	0.10abc
2 WAP × 2M1G	1.00a	1.00a	0.22ab	0.10abc
2 WAP × 2M2G	1.00a	1.00a	0.16ab	0.09ab
2 WAP × M	1.00a	1.00a	0.23ab	0.08a
LSD (5%)	NS	NS	0.12	0.03
CV (%)	5.7	5.7	35.3	14.5

Within column means with different letters differed significantly ($P < 0.05$). LSD-Least Significant Difference; CV-Coefficient of Variation; NS-Not Significant.

The interaction effects between row arrangement of intercrops and time of introducing groundnut into the intercropping system were significant (P < 0.0). The heaviest cobs (0.14 kg) were produced by 0 WAP × 1M2G, while the lightest cobs (0.08 kg) were noticed in 2 WAP × M.

3.3.2. Grain Yield and Hundred-Seed Weight

Grain yield and hundred-seed weight of maize are presented in **Table 9**. Hundred-seed weight was not significant (P > 0.05) with treatment application throughout the study. In the major season of 2020, grain yield of maize did not vary with treatment application, but it significantly varied with treatment application in the minor season of 2020. The highest grain yield was recorded by sole maize, which did not differ from the intercropped maize, except 1M1G treatment that gave the lowest maize grain yield and differed significantly from the other intercropped row arrangements. 0 WAP and 1 WAP were similar in grain yield, but either of them differed significantly from 2 WAP. The 1 WAP treatment gave the highest grain yield, whereas the 2 WAP treatment gave the lowest grain yield.

Treatment interaction effects for maize grain yield were significant in the minor season of 2020 with 1 WAP × M treatment combination recording the highest maize grain yield of 6341 kg/ha, while the lowest grain yield of 3500 kg/ha was recorded by 2 WAP × 1M2G treatment combination (**Table 9**). The best interaction effects between row arrangements of intercrops and time of introducing groundnut into the intercropping system were noticed in 1 WAP × 2M2G, which recorded maize grain yield of 6152 kg/ha and this was followed by 0 WAP × 1M1G with maize grain yield of 5819 kg/ha (**Table 9**).

3.3.3. Shelling Percentage and Land Equivalent Ratio

In both seasons of the trial, row arrangement of intercrops and time of introducing groundnut into the intercropping system had no significant (P > 0.05) effects on shelling percentage of maize, but their interaction effects were significant (**Table 10**). In the major season of 2020, the highest shelling percentage of 79.30% was associated with 0 WAP × M, followed by 0 WAP × 2M2G (76.70%), while the least shelling percentage of 63.20% was recorded by 2 WAP × 1M2G. In the minor season of 2020, the highest shelling percentage of 75.02% was recorded by 0 WAP × 2M1G, followed by 1 WAP × 2M2G (74.20%), while the least shelling percentage of 66.30% was recorded by 2 WAP × 1M2G.

In the major rainy season of 2020, row arrangement of intercrops and time of introducing groundnut into the intercropping system had no significant (P > 0.05) effects on land equivalent ratio (LER), but their interaction effects were significant. The highest LER of 2.93 was associated with 2 WAP × 2M1G, whereas the least LER of 0.97 was noticed in 1 WAP × 1M2G (**Table 10**).

In the minor season of 2020, row arrangement of intercrops did not affect LER, but time of introducing groundnut into the intercropping system did affect it significantly (P < 0.05). The 1 WAP treatment significantly recorded the highest

Table 9. Effects of maize-groundnut intercropping on hundred-seed weight and grain yield of maize in the major and minor seasons of 2020.

Treatment	100-seed weight (kg)		Grain yield (kg/ha)	
	2020 major season	2020 minor season	2020 major season	2020 minor season
Row arrangement (R)				
1M1G	0.03a	0.03a	4564a	1505a
1M2G	0.04a	0.04a	3117a	4528b
2M1G	0.04a	0.04a	4093a	4825b
2M2G	0.04a	0.03a	4411a	5098b
Sole maize (M)	0.04a	0.03a	4043a	5264b
LSD (5%)	NS	NS	NS	1168.4
Time of planting groundnuts (T)				
0 WAP	0.04a	0.04a	4400a	5268a
1 WAP	0.04a	0.04a	3733a	5776a
2 WAP	0.04a	0.03a	4004a	3848b
LSD (5%)	NS	NS	NS	905.1
Interactions (R × T)				
0 WAP × 1M1G	0.03a	0.04a	4656a	5744b
0 WAP × 1M2G	0.04a	0.04a	4019a	4496ab
0 WAP × 2M1G	0.04a	0.04a	3630a	4870ab
0 WAP × 2M2G	0.04a	0.04a	4733a	5411ab
0 WAP × M	0.04a	0.04a	4963a	5819bb
1 WAP × 1M1G	0.04a	0.03a	3981a	5000ab
1 WAP × 1M2G	0.04a	0.04a	2019a	5589b
1 WAP × 2M1G	0.04a	0.04a	4370a	5796b
1 WAP × 2M2G	0.04a	0.03a	4722a	6152b
1 WAP × M	0.04a	0.03a	3574a	6341b
2 WAP × 1M1G	0.03a	0.03a	5056a	4570ab
2 WAP × 1M2G	0.04a	0.04a	3315a	3500a
2 WAP × 2M1G	0.04a	0.04a	4278a	3807ab
2 WAP × 2M2G	0.04a	0.03a	3778a	3730ab
2 WAP × M	0.03a	0.03a	3593a	3633a
LSD (5%)	NS	NS	NS	2023.8
CV (%)	12.00	12.40	45.30	24.40

Within column means with different letters differed significantly ($P < 0.05$). LSD-Least Significant Difference; CV-Coefficient of Variation; NS-Not Significant.

Table 10. Effects of maize-groundnut intercropping on shelling percentage of maize and land equivalent ratio in the major and minor seasons of 2020.

Treatment	Shelling percentage (%)		LER	
	2020 major season	**2020 minor season**	**2020 major season**	**2020 minor season**
Row arrangement (R)				
1M1G	72.90a	70.56a	1.96a	1.98a
1M2G	68.50a	69.36a	1.54a	1.86a
2M1G	68.70a	72.41a	2.03a	1.92a
2M2G	75.10a	73.60a	1.92a	2.12a
Sole maize (M)	73.20a	70.77a	-	-
LSD (5%)	NS	NS	NS	NS
Time of planting groundnuts (T)				
0 WAP	74.00a	72.71a	1.79a	1.68a
1 WAP	70.90a	71.87a	1.65a	2.55b
2 WAP	70.10a	69.44a	2.24a	1.71a
LSD (5%)	NS	NS	NS	0.50
Interactions (R × T)				
0 WAP × 1M1G	72.00ab	73.61ab	1.90ab	1.76ab
0 WAP × 1M2G	74.60ab	69.72ab	1.78ab	1.62a
0 WAP × 2M1G	67.30a	75.02b	1.29ab	1.36a
0 WAP × 2M2G	76.70b	72.75ab	1.97ab	1.63a
0 WAP × M	79.30b	72.44ab	-	-
1 WAP × 1M1G	75.00a	69.94ab	1.52ab	2.42abc
1 WAP × 1M2G	67.50a	72.06ab	0.97a	2.26abc
1 WAP × 2M1G	64.70a	73.07ab	1.89ab	2.84bc
1 WAP × 2M2G	74.60ab	74.20ab	1.86ab	3.05c
1 WAP × M	72.80ab	70.05ab	-	-
2 WAP × 1M1G	71.60ab	68.11ab	2.47ab	1.77ab
2 WAP × 1M2G	63.20a	66.30a	1.87ab	1.52a
2 WAP × 2M1G	74.20ab	69.13ab	2.93b	1.56a
2 WAP × 2M2G	73.90ab	73.84ab	1.92ab	1.69a
2 WAP × M	67.50a	69.83ab	-	-
LSD (5%)	12.04	8.20	1.68	1.12
CV (%)	10.00	6.90	53.1	33.7

Within column means with different letters differed significantly ($P < 0.05$). LSD-Least Significant Difference; CV-Coefficient of Variation; NS-Not Significant.

LER, while 0 WAP treatment recorded the lowest LER. The effects of 0 WAP and 2 WAP were similar. There were significant ($P < 0.05$) treatment interaction effects with the highest LER of 3.05 being associated with 1 WAP × 2M2G, whereas the least LER of 1.36 was noticed in 0 WAP × 2M1G.

4. Discussion

4.1. Treatment Effects on Vegetative Growth of Maize

The tallest plants produced by the 2M1G treatment could be ascribed to the relative increase in plant population, which may have caused competition for light, resulting in tallness of maize plants. The 1M1G treatment resulted in relatively tall maize plants probably because the groundnut plants were aggressive enough to outcompete the maize plants for available growth resources like soil moisture, nutrients, light and space. In an attempt to offset the competition for light, the intercropped maize plants grew taller than the sole maize plants. Spatial arrangement did not significantly affect maize plant height in maize-mung beans intercropping [33]. Conversely, Nyoki and Ndakidemi [34] found that sole maize outstripped maize intercropped with legumes in plant height in their research with other legumes including cowpea and lablab. Similarly, Jaja and Ikechukwu [35] reported that sole maize plants grew taller than intercropped maize plants.

[36] asserted that it is preferable to sow a weak competitor in a mixture early relative to the aggressor in order to improve its performance. Thwala and Ossom [37] reported that groundnut plants could do better than maize plants in crop mixtures because of the aggressiveness of the former. To this end, sowing maize and groundnuts concurrently or sowing maize a week before planting groundnuts will enable the maize plants to successfully withstand the aggressiveness of the groundnut plants to reduce competition for space, water, nutrients and irradiance. This situation might have accounted for the ability of the intercropped maize to grow relatively tall when the groundnut was simultaneously planted with the maize or introduced a week after sowing the maize. The earlier planted component (maize) had an initial competitive advantage over the later (groundnut) one as ever reported by Okpara [38] and Ekwere *et al.* [39].

The maize plants in the spatial row arrangements, except 2 rows of maize and 2 rows of groundnuts (2M2G) increased leaf formation in intercropped maize plants when groundnuts were introduced within the first two weeks of planting the maize. This is because the maize plants could have benefited a lot from the association in terms of their ability to access water and nutrients from the soil. The complete ground cover might have suppressed growth of weeds, checked erosion, improved water and nutrient retention ability of the soil. This situation may have generally increased photosynthesis and efficient partitioning of assimilates, resulting in improved vegetative growth. Introducing the intercropped groundnuts within the first two weeks of planting the maize was not sufficient to make the groundnut plants aggressive over the maize plants.

The largest leaf area of maize (389.8 cm^2) recorded by 0 WAP × 1M2G in the major season of 2020 and by 0 WAP × 1M1G in the minor season of 2020 (493.4 cm^2) could be ascribed to increase in leaf length and width observed in these treatment combinations.

4.2. Treatment Effects on Phenology, Yield and Yield Components of Maize

Generally, intercropping shortened days to flowering (silking and tasselling) in maize plants when groundnuts were introduced within the first two weeks of planting the maize. Because intercropping systems utilize resources more efficiently than monocropping systems do, they significantly increase crop productivity [40]. When the component crops are compatible, this is achievable. Intercropping ensures a complete ground cover, which might have smothered growth of weeds, checked erosion, improved water and nutrient retention ability of the soil. This situation may have generally increased photosynthesis and efficient allocation of assimilates, resulting in improved vegetative growth. Introducing the intercropped groundnuts within the first two weeks of planting the maize was not sufficient to make the groundnut plants competitive over the maize plants.

In both seasons of the trial, row arrangement of intercrops and time of introducing groundnut into the intercropping system had no significant ($P > 0.05$) effects on number of cobs per plant. This implies that there was little inter-specific competition between the two contributing crops for the available resources. The results of this study are in line with those of Bhatnagar *et al.* [41].

Since leaf area controls the ability of the plant to capture sunlight for photosynthesis [42], the increased leaf area following good leaf development associated with 0 WAP × 1M2G treatment combination, resulted in high photosynthetic activity and production of heavy cobs. Sole maize crops with relatively high plant populations per unit area might be more efficient in resource partitioning in favour of formation of heavy cobs than the intercropped maize, leading to relatively high shelling percentage and grain yield. Alom *et al.* [43] found that the yield of maize was higher in monoculture than it was in the maize-groundnut system's intercrop. Egbe [44] found results of a similar kind in other legumes such as soybean.

The treatment combination of 1 WAP × 2M2G recorded maize grain yield of 6152 kg/ha and this was followed by 0 WAP × 1M1G with maize grain yield of 5819 kg/ha. The 1M1G and 2M2G could have caused a complete ground cover, which might have controlled weeds, checked erosion, improved water and nutrient retention ability of the soil. This situation may have generally increased photosynthesis and efficient allocation of assimilates, resulting in improved vegetative growth that may have translated into economic yield. Introducing the crop components simultaneously or planting groundnut a week after planting the maize crop could have encouraged vigorous growth of the maize plants. As a result, the maize had a competitive advantage over the groundnut crop as ever reported by Okpara [38] and Ekwere *et al.* [39]. The combined effects of this competitive advantage of maize over groundnut in the intercropping system and the ability of the crop mixtures to conserve soil moisture and nutrients, check weed growth and erosion could have increased seed weight, shelling percentage and grain yield.

In a related study, Bugilla *et al.* [45] found that the spatial row arrangement of one row of maize and one row of groundnut (1M1G), one row of maize and two rows of groundnut (1M2G) and two rows of maize and two rows of groundnut (2M2G) increased shelling percentage, number of pods per plant, number of seeds per pod, pod and seed yields of groundnut. They further indicated that planting groundnut intercrop within the first two weeks of planting maize increased groundnut yield and yield components.

4.3. Treatment Effects on Land Equivalent Ratio

Values of the land equivalent ratio (LER) greater than one imply that intercropping has higher yield potentials than monoculture. If the LER is less than 1, more land must be used for the intercrop in order to match the productivity of the monoculture [46]. The highest LER of 2.93 was associated with 2 WAP × 2M1G in the major season**,** whereas in the minor season of 2020, the highest LER of 3.05 was associated with 1 WAP × 2M2G. Generally, the LERs of all the spatial row arrangements of the crop components in the intercropping system were greater than 1 irrespective of the time of introducing the groundnut into the intercropping system, except a situation in the major season of 2020 where a LER of 0.97 was noticed in 1M2G treatment when groundnut was planted a week after planting the maize crop. However, it was observed that, LERs relatively increased when the groundnut intercrop was introduced into all the spatial arrangements of intercrop rows a week after the maize was planted. This means that all the spatial row arrangements had yield advantages over the sole cropping system when groundnut was introduced into the intercropping system within the first two weeks of planting the maize crop, but the performance of the intercropping system was enhanced in the minor season of 2020 when groundnut was planted a week after planting the maize.

In the major season of 2020, LERs obtained ranged from 0.97 to 2.93, while LERs ranged from 1.36 to 3.05 in the minor season of 2020. The LERs obtained in this study were greater than the range of LERs (0.9 - 1.12) obtained by Konlan *et al.* [47] in assessing the effects of maize–groundnut intercropping. The relatively high LERs obtained in the minor season were reflected in the equivalent high grain yields of maize obtained in the minor season. The results could be ascribed to favourable soil-water relations and well distributed rainfall observed in the minor season of 2020, which may have increased photosynthesis and efficiency of dry matter partitioning. The findings of this study are in line with reports by Ennin *et al.* [48] who indicated that cereal-legume intercropping resulted in higher productivity than sole cropping under limited moisture conditions because of increased water use efficiency.

5. Conclusions and Recommendations

5.1. Conclusions

- Intercropping with the spatial row arrangement of one row of maize and one row of groundnut (1M1G), one row of maize and two rows of groundnut (1M2G) and two rows of maize and one row of groundnut (2M1G) increased vegetative growth in maize, while maize seed yield was increased by planting groundnuts within the first one week of planting maize (1 WAP) in two rows of maize and two rows of groundnut (2M2G) spatial row arrangements.
- The highest land equivalent ratio was associated with 2 WAP × 2M1G and 1 WAP × 2M2G in the major and minor seasons, respectively. Generally, land equivalent ratio was greater than one in all the spatial row arrangements of the crop components in the intercropping system irrespective of the time of introducing the groundnut into the intercropping system.

5.2. Recommendations

- Farmers should plant groundnuts within the first week of planting maize (1 WAP) in groundnut-maize intercropping systems in the spatial row arrangement of two rows of maize followed by two rows of groundnut (2M2G) as it had the highest land equivalent ratio and consistently increased shelling percentage and seed yield of maize.
- Further studies on row arrangements of one row of maize and two rows of groundnut (1M2G), two rows of maize and one row of groundnut (2M1G) and one row of maize and one row of groundnut (1M1G) and two rows of maize and two rows of groundnut (2M2G) should be undertaken in different agro-ecologies to confirm the consistency of the findings of this study.

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Data Availability

The data used to support the findings of this research could be obtained from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of this article.

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