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# Effects of Spatial Row Arrangement and Time of Planting Intercrops on Performance of Groundnut (*Arachis hypogaea* L.) under Maize (*Zea mays* L.)—Groundnut Intercropping System in Ejura

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## Abstract

In monoculture, crop failure due to biotic or abiotic causes can result in partial or total output failure. The yield, socio-economic, and environmental effects of intercropping on the farmer and the environment as a whole have not received much attention. There is a dearth of knowledge on the productivity of maize-groundnut intercrops in Ghana regarding the relative timing of planting and spatial arrangement of component crops. Therefore, the objective of the study was to determine the effects of spatial row arrangement and the time of planting intercrops on the productivity of groundnut under maize-groundnut intercropping. The 5 × 3 factorial field experiment was undertaken at the Miminaso community in the Ejura-Sekyedumase municipality of the Ashanti Region of Ghana during the 2020 cropping seasons. Treatments were evaluated in a Randomized Complete Block Design (RCBD) with three replicates. The levels of row arrangement of intercrops were: 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 and sole groundnut (M/G). The levels of time of introducing groundnut included simultaneous planting of intercrops (0 WAP), planting groundnut one week after planting maize (1 WAP) and planting groundnut two weeks after planting maize (2 WAP). There were significant ($P < 0.05$) treatment interactions for pod and seed yields of groundnut throughout the study. The highest groundnut pod yields of 1815.00 kg/ha and 2359.00 kg/ha were recorded by the 0WAP × 1M2G treatment in the major and minor seasons of 2020, respectively, while the highest groundnut seed yields of 741.00 kg/ha and 726.00 kg/ha were recorded in the major and minor rainy seasons of 2020 by 1WAP × G and 0WAP × G treatments, respectively. The highest seed yields of groundnut (404 kg/ha and 637 kg/ha for major and minor rainy seasons, respectively) were produced by 1WAP × 2M2G.

## Keywords

Intercropping, Groundnut, Maize, Growth, Yield, Time, Row Arrangement

## 1. Introduction

Groundnut's (*Arachis hypogaea* L.) botanical name is believed to have been derived from the Greek words *Arachis*, which means "legume", and *hypogaea*, which means "below the earth," and refers to the development of pods under the soil, according to Waale and Swanvelder [1]. *Arachis* is grown in tropical, subtropical, and temperate climates, and all species are geocarpic, opening their fruits underground [2].

About 80% of the 6 million tons of groundnuts produced in Africa, according to Tweneboah [3], are grown in the Savannah region south of the Sahara. Despite being grown in all of Ghana's agro-ecological zones, the majority of the crop's production and cultivation area are found in the north, in the Guinea and Sudan savanna agro-ecological zones [4].

Asibuo *et al.* [5] reported that the varieties currently grown in Ghana include Tirik, Florispan, Dagomba *Hypogaea*, F-Mix, Nkatepa, Kumawu early, Nkate kokoo, Baasare Fastigiata, Broni nkatee, Afu, Nkoranza local, Atebubu local, Aprewa, Kintampo local, Broni, Kofi Nsarko, Kowoka, Broni fufuo.

The groundnut plant, one of the three most significant grain legumes in West Africa, is an essential part of the farming systems that mostly rely on cereals [6]. However, in the dry savannas of West Africa, the husk and haulms after harvest are great sources of high-quality cattle feed. It is primarily farmed for food and as a source of revenue [6]. A total of 28.5 million hectares of peanuts were harvested globally in 2018, according to the estimate made by the [7], with 7.1 million hectares of those harvested in West Africa. The Northern Region of Ghana produces 95% of the nation's total amount of groundnuts [8].

Intercropping, a diversified planting pattern can effectively increase the diversity of agro-ecologies and maintain sustainable agricultural development [9]. The yield advantage of cereal and legume intercropping systems is evident in various intercropping patterns [10] [11]. Interspecific interactions are important for improved nutrient utilization and high crop yields in maize and peanut intercropping [12] [13] [14]. For instance, Jiao *et al.* [14] found that nitrogen accumulation per plant in intercropped peanut decreased significantly by 25% -

35%, while that in intercropped maize increased significantly at maturity. With the root barrier, the nitrogen accumulation per plant in intercropped maize and intercropped peanut is significantly lower than that without the barrier [14]. Through improved resource management, intercropping boosts productivity per unit area of land lowers risks, lessens weed competition, and stabilizes yield [15].

In recent years, conflict, climate unpredictability and extremes, economic barriers and depressions, and poverty and disparity have put the world off track from the goal of stopping global hunger and malnutrition by 2030 [16]. Thus, to achieve the Sustainable Development Goals, the growing demand for crop production requires the exploration of innovative ways to act in the context of the changing climate and loss of biodiversity [17]. Diversified crop cultivation has shown benefits for soil macro- and micro-organisms and improvement of crop yields; it is well known that intercropping and rotation are the indispensable practices of traditional agriculture and ever-present sustainable practices across different regional agroecosystems [18] [19] [20]. Beneficial interactions between cereal and legumes in strip intercropping have been reported, including high land-use efficiency, improvement of soil fertility, reduction in disease and pest incidence and production of stable crop yields. An ecological feature of cereal-legume intercropping is the improved utilization efficiency of natural resources, especially light. The photosynthetically active radiation (PAR) was significantly increased at the top of the soybean canopy and the photosynthetic rate (Pn) and radiation-use efficiency (RUE) of maize leaves close to the ear were significantly increased by optimizing maize row distance and gap width in maize-soybean strip intercropping [21] [22]. In addition, the interactions among roots in cereal and legume intercropping can promote nutritional efficiency such as nitration (N) [23] and use of phosphate (P) [24], iron (Fe) [25] and zinc (Zn) [26], and reduce fertilizer application [27]. Furthermore, pea-barley intercropping in rotation with durum wheat improved nitrogen-utilization efficiency and increased the overall sustainability of the rotation [28]. Other key ecological functions of cereal-legume intercrops are reduced land-surface wind speed and soil erosion [29].

Intercropping is influenced by a number of variables, including crop maturity, crop choice, planting density, planting timing, and the socio-economic level of the farmers and the area. The land is efficiently utilized in intercropping, and the land equivalent ratio (LER) is used to measure the land's productivity. Additionally, intercropping boosts soil conservation since it covers more territory than solitary cropping and increases soil fertility through atmospheric nitrogen fixation (150 tons/year) by legumes. In tropical regions, maize has been considered as the best component in most intercropping systems [30]. Recently, intercropping has gained recognition as a crop production method that may be advantageous [31]. Despite this, groundnut production on farmers' fields is poor due to a number of biotic and abiotic reasons, including the choice of low-yielding varieties, high input costs, and/or inaccessibility of inputs (seed, fertilizer, and inoculant) [32].

In monoculture, crop failure due to biotic or abiotic causes can result in partial or total output failure [33]. The yield, socio-economic, and environmental effects of intercropping on the farmer and the environment as a whole have not received much attention. Therefore, in order to lessen competition among or between component crops, it is important to properly examine and comprehend the most sustainable intercropping patterns. Furthermore, in order to convince farmers to switch to this sustainable agricultural system from monoculture, recommendations must be made both technically and economically. In the modern day, chemical pesticides, chemical fertilizers, hybrid seeds, and diverse equipment are particularly dependent on the world's agriculture. This modernization of agriculture, which prioritizes monoculture over sustainability, soil health, diseases, and pests, is partly the result of the inability to precisely quantify the economic advantages of intercropping. There is a dearth of knowledge about the productivity of maize-groundnut intercrops in Ghana regarding the relative timing of planting and spatial row arrangement of component crops. The main objective of the study was, therefore, to determine the effects of spatial row arrangement and time of planting intercrops on the productivity of groundnut under a maize-groundnut intercropping system.

## 2. Materials and Methods

### 2.1. Experimental Site

The experiment was conducted at the Miminaso community, a farming community in Ejura-Sekyedumase municipality of the Ashanti Region of Ghana during the 2020 cropping season. The experiment was conducted on-farm on latitude 07˚24'N and longitude 01˚21'W (Ejura Agromet station). The area is situated in Ghana's transitional agroecological zone [34].

The area experiences a bimodal annual rainfall distribution pattern with a mean value of 1049 mm. In the major season, rains start in late March and end in the middle of July. The agro-ecology is characterized by short dry spells in August. The minor rainy season starts from September to the latter part of November. The mean minimum and maximum temperatures are about 20.5˚C and 37.9˚C, respectively. Mean relative humidity is 63%. The area has an annual evapotranspiration of 52.1 ml with monthly values ranging from 4.9 to 10.3 ml in the major dry season and 1.9 to 3.9 ml in the rainy season. The soil is moderately drained sandy loam, less to coarse-textured, with fairly low moisture holding capacity. The vegetative cover of the area is dominated by *Panicum maximum* and *Ageratum conyzoides* [34].

### 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 planting the groundnut intercrop were evaluated in a Randomized Complete Block Design

(RCBD). The treatments were replicated three times. Thus, there were fifteen treatment combinations in each block and forty-five 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 and sole groundnut (M/G).

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

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

### 2.3. Land Preparation and Field Layout

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 soil to a fine tilth during the 2020 major and minor cropping seasons. Two weeks after ploughing, the regrowths were cleared with a systemic weedicide called sunphosate at a rate of 10 ml per litre of water. The weedicide was applied 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.

### 2.4. Sources of Planting Materials

The groundnut seeds (Chinese variety) were procured from CSIR-Crops Research Institute (CSRI), while seed maize (Lake 601 variety) was obtained from the RMG Seed Company

### 2.5. Plant Culture

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 21$^{st}$ April, 2020 and 14$^{th}$ 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.

Groundnut was harvested on 20th and 27th July, 2020 in the major rainy season, while in the minor rainy season, it was harvested on 23rd and 30th November, 2020.

## 2.6. Data Collection

### 2.6.1. Soil Sampling and Analysis and Climatic Data

Soil samples were collected with an auger from the experimental site to a depth of 30 cm for routine analysis before tillage. The air-dried soil samples were sieved (2 mm) before analysis. The results of the soil test are presented in **Table 1**. Temperature, relative humidity and rainfall figures at the experimental site are shown in **Table 2**.

### 2.6.2. Soil pH

This was determined in a 1:2.5 soil to distilled water (soil: water) ratio using the glass electrode HT9017 pH meter [35].

### 2.6.3. Organic Matter

Organic carbon was determined by the Walkley-Black method. The organic carbon (0.87%) was multiplied by 1.724 (Van Bemmelen factor) to give the organic matter content [36].

**Table 1.** Initial physico-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)<br>Soil texture<br>Sandy loam | 106 |

KNUST Soil Science Laboratory (2020).

**Table 2.** Temperature, relative humidity and rainfall figures at the experimental site in 2020.

| Month | Maximum ˚C | Minimum ˚C | Relative humidity % | Monthly total rainfall (mm) |
|---|---|---|---|---|
| January | 35.5 | 20.5 | 48 | 0.0 |
| February | 37.5 | 22.9 | 39 | 0.0 |
| March | 36.4 | 25.2 | 42 | 78.3 |
| April | 35.3 | 24.5 | 40 | 112.6 |
| May | 35.0 | 24.5 | 39 | 247.4 |
| June | 32.0 | 23.2 | 41 | 222.9 |
| July | 30.1 | 23.0 | 44 | 56.2 |
| August | 31.2 | 22.0 | 43 | 57.3 |
| September | 31.5 | 22.7 | 41 | 178.2 |
| October | 32.1 | 23.0 | 59 | 86.2 |
| November | 35.5 | 23.4 | 56 | 9.4 |
| December | 35.9 | 23.6 | 58 | 0.0 |
| Total | 408.5 | 278.5 | 550 | 1,048.5 |
| Mean | 34 | 23.2 | 28 | |

Ejura Meteorological Station (2020).

#### 2.6.4. Total Nitrogen

The macro-Kjeldahl digestion, distillation, and titration method was used to estimate total nitrogen [37]. Total N was calculated using the formula:

$$\text{Total } N \text{ in the sample} = \frac{14(A-B)\times N\times 100}{1000\times W}$$

where,

$A$ = Volume of standard acid used in titration

$B$ = Volume of standard acid used in blank titration

$N$ = Normality of the standard acid

$W$ = Weight of soil sample used

#### 2.6.5. Available Phosphorus

Bray no.1 solution (HCL; $NH_4F$ mixture) was used to extract the readily acid-solution forms of P. Phosphorus in the sample was determined using a spectrophotometer and blue ammonium molybdate as a reducing agent [38].

#### 2.6.6. Extraction of Exchangeable Cations

Concentrations of cations in the soil were determined in 1.0M ammonium acetate ($NH_4OAc$) extract. A 10 g sample was transferred into a leaching tube and leached with a 250 ml of buffered 1.0M ammonium acetate ($NH_4OAc$) solution at pH 7 [39].

### 2.7. Plant Sampling

Data on vegetative parameters were collected two weeks after planting at an interval of two weeks until 6 weeks after planting, while yield data were collected at harvest.

#### 2.7.1. Canopy Spread

This was determined by using the metre rule to measure the canopy length and breadth of each of the six selected plants, after which the results were added and divided by two. The canopy spreads for all the six plants were summed up and the mean was determined by dividing the total by six.

#### 2.7.2. Number of Branches per Plant

Number of branches per plant was determined by visually counting all the branches of the six selected plants and dividing the total by six.

#### 2.7.3. Days to 50% Flowering

Number of days from the planting date to the day when 50% of the plants have started producing flowers were recorded.

#### 2.7.4. Number of Pods per Plant

Number of pods per plant was determined by visually counting all the matured and well-filled pods of the six selected plants and dividing the total by six.

#### 2.7.5. Number of Seeds per Pod

Six matured and well-filled pods were randomly selected from each plot, shelled and the seeds from the six selected pods were divided by six to get the number of seeds per pod.

#### 2.7.6. 100-Seed Weight

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

#### 2.7.7. Pod Weight per Plant

This was determined by drying all the matured and well-filled pods of the six selected groundnut plants to a moisture content of about 12% and dividing the total weight by six.

#### 2.7.8. Shelling Percentage

This is the proportion of seed weight to pod weight expressed in a form of percentage.

#### 2.7.9. Pod Yield

Data were recorded in each plot after oven-drying the pods for 3 days at a temperature of 60˚C and converted into $kg \cdot ha^{-1}$.

$$\text{Thus,}\quad \text{pod yield in kg}\cdot\text{ha}^{-1} = \frac{\text{Yield/plot}}{\text{plot size}} \times 10000$$

#### 2.7.10. Seed Yield

Data were recorded in each plot after oven-drying the seeds for 3 days at temperature of 60˚C and converted into $kg \cdot ha^{-1}$.

$$\text{Thus, seed yield in kg} \cdot \text{ha}^{-1} = \frac{\text{Yield/plot}}{\text{plot size}} \times 10000$$

### 2.8. Statistical 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) [40]. The Least Significant Difference (LSD) was used to determine treatment differences at a 5% level of probability.

## 3. Results

### 3.1. Vegetative Growth

#### 3.1.1. Number of Branches per Plant

In the major season of 2020, number of branches per plant was significantly ($P < 0.05$) affected by row arrangements of maize-groundnut intercrops at 2 and 6 weeks after planting (**Table 3**). At 2 weeks after planting, sole groundnut plants significantly ($P < 0.05$) produced more branches than the groundnut plants from the other row arrangements, except groundnut plants from the 1 row of maize and 1 row of groundnut arrangements. All other treatment differences were similar. At 6 weeks after planting, sole groundnut plants significantly produced more branches than the groundnut plants from the other row arrangements, except groundnut plants from the 2 rows of maize and 2 rows of groundnut arrangements. All other treatment differences were similar. Groundnut plants from the 1 row of maize and 2 rows of groundnut arrangements produced the lowest number of branches per plant.

Time of introducing groundnut into the maize-groundnut intercropping system significantly ($P < 0.05$) affected number of branches per groundnut plant on all the days of sampling (**Table 3**). At all sampling periods, the highest number of branches per plant was observed in groundnut plants planted on the same day with the maize intercrop (0 WAP), while the lowest value was noticed in groundnut plants sown 2 weeks after planting the maize intercrop (2 WAP). Simultaneous planting of maize and groundnut intercrops (0 WAP) did not differ significantly from planting the groundnut intercrop a week after planting the maize intercrop (1 WAP) in terms of number of branches per plant, but each of these treatments varied significantly ($P < 0.05$) from planting the groundnut intercrop 2 weeks after planting the maize intercrop (2 WAP). This trend was noticed across all the sampling periods.

Treatment interaction effect for the number of branches per plant was significant ($P < 0.05$) at all sampling periods in the major season of 2020 (**Table 3**). At the last sampling period, the interactions between simultaneous planting of maize and groundnut (0 WAP) and 1M1G or 2M1G in maize-groundnut row arrangements and the interaction between planting of groundnut a week after planting of maize (1 WAP) and 2M2M and sole groundnut (G) in maize-groundnut row arrangements were the highest. The lowest treatment interactions were observed

Table 3. Effect of maize-groundnut intercropping on number of branches of groundnuts in the major season of 2020.

| Treatment | Number of branches per plant<br>Weeks After Planting | | |
|---|---|---|---|
| | 2 | 4 | 6 |
| **Row arrangement (R)** | | | |
| 1M1G | 3.22b | 6.44a | 8.78a |
| 1M2G | 2.56a | 6.67a | 8.67a |
| 2M1G | 2.89a | 6.78a | 9.00a |
| 2M2G | 2.89a | 7.56a | 9.33ab |
| Sole groundnut (G) | 3.56b | 7.22a | 10.00b |
| **LSD (5%)** | 0.61 | NS | 0.86 |
| **Time of planting groundnuts (T)** | | | |
| 0 WAP | 3.53b | 7.60b | 9.93b |
| 1 WAP | 3.07b | 7.40b | 9.47b |
| 2 WAP | 2.47a | 5.80a | 8.07a |
| **LSD (5%)** | 0.47 | 1.23 | 0.668 |
| **Interactions (R × T)** | | | |
| 0 WAP × 1M1G | 4.00b | 6.67ab | 10.00bc |
| 0 WAP × 1M2G | 3.00ab | 7.33b | 9.67 abc |
| 0 WAP × 2M1G | 4.00b | 8.00b | 10.00bc |
| 0 WAP × 2M2G | 3.00ab | 8.33b | 9.67abc |
| 0 WAP × G | 3.67b | 7.67ab | 10.33c |
| 1 WAP × 1M1G | 3.33b | 8.33b | 9.33bc |
| 1 WAP × 1M2G | 2.67ab | 6.67ab | 9.33bc |
| 1 WAP × 2M1G | 2.67ab | 6.33ab | 8.67b |
| 1 WAP × 2M2G | 3.00ab | 8.33b | 10.00bc |
| 1 WAP × G | 3.67b | 7.33b | 10.00bc |
| 2 WAP × 1M1G | 2.33a | 4.33a | 7.00a |
| 2 WAP × 1M2G | 2.00a | 6.00a | 7.00a |
| 2 WAP × 2M1G | 2.00a | 6.00a | 8.33a |
| 2 WAP × 2M2G | 2.67ab | 6.00a | 8.33a |
| 2 WAP × G | 3.33b | 6.67ab | 9.67ab |
| **LSD (5%)** | 1.05 | 2.73 | 1.49 |
| **CV (%)** | 20.8 | 23.6 | 9.8 |

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

in planting of groundnut 2 weeks after planting of maize (2 WAP) in either 1M1G or 1M2G maize-groundnut row arrangements (2 WAP × 1M1G or 2 WAP × 1M2G) at the last sampling period.

In the minor season of 2020, row arrangement of maize-groundnut intercrops had no significant ($P > 0.05$) effects on number of branches per plant. However, time of planting groundnut in the maize-groundnut intercropping system affected it significantly ($P < 0.05$) at 4 and 6 weeks after planting (Table 4). The highest number of branches per plant was observed in groundnut plants planted on the same day with the maize intercrop (0 WAP), while the lowest value was

Table 4. Effect of maize-groundnut intercropping on number of branches of groundnuts in the minor season of 2020.

| Treatment | Number of branches per plant Weeks After Planting | | |
|---|---|---|---|
| | 2 | 4 | 6 |
| **Row arrangement (R)** | | | |
| 1M1G | 2.22a | 6.67a | 8.56a |
| 1M2G | 2.33a | 6.44a | 8.44a |
| 2M1G | 2.00a | 6.33a | 8.00a |
| 2M2G | 2.33a | 6.33a | 9.11a |
| Sole groundnut (G) | 2.44a | 7.33a | 9.22a |
| **LSD (5%)** | NS | NS | NS |
| **Time of planting groundnut (T)** | | | |
| 0 WAP | 2.40a | 7.73b | 9.60b |
| 1 WAP | 2.33a | 7.40b | 9.33b |
| 2 WAP | 2.07a | 4.73a | 7.07a |
| **LSD (5%)** | NS | 0.84 | 0.94 |
| **Interactions (R × T)** | | | |
| 0 WAP × 1M1G | 2.67a | 8.33c | 10.00bc |
| 0 WAP × 1M2G | 2.33a | 7.00bc | 10.00bc |
| 0 WAP × 2M1G | 2.00a | 8.00bc | 9.00bc |
| 0 WAP × 2M2G | 2.33a | 6.67bc | 9.33bc |
| 0 WAP × G | 2.67a | 8.67c | 9.67bc |
| 1 WAP × 1M1G | 2.00a | 7.67bc | 9.67bc |
| 1 WAP × 1M2G | 2.67a | 8.00bc | 9.00bc |
| 1 WAP × 2M1G | 2.00a | 7.33bc | 9.33bc |
| 1 WAP × 2M2G | 2.33a | 7.67bc | 10.33c |
| 1 WAP × G | 2.67a | 6.33b | 8.33bc |
| 2 WAP × 1M1G | 2.00a | 4.00a | 6.00a |
| 2 WAP × 1M2G | 2.00a | 4.33a | 6.33a |
| 2 WAP × 2M1G | 2.00a | 3.67a | 5.67a |
| 2 WAP × 2M2G | 2.33a | 4.67a | 7.67ab |
| 2 WAP × G | 2.00a | 7.00bc | 9.67bc |
| **LSD (5%)** | NS | 1.87 | 2.11 |
| **CV (%)** | 22.0 | 16.9 | 14.6 |

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

noticed in groundnut plants sown 2 weeks after planting the maize intercrop (2 WAP). Simultaneous planting of maize and groundnut intercrops (0 WAP) did not differ significantly ($P > 0.05$) from planting the groundnut intercrop a week after planting the maize intercrop (1 WAP) in terms of number of branches per plant, but each of these treatments varied significantly ($P < 0.05$) from planting the groundnut intercrop 2 weeks after planting the maize intercrop (2 WAP) (Table 4). This trend was similar at both 4 and 6 weeks after planting (Table 4). Treatment interactions for number of branches per plant were significant at the last two sampling periods in the minor season of 2020 (Table 4). At the last sampling period, the interactions between planting of groundnut a week after planting of maize and 2:2 in maize-groundnut row arrangements (1 WAP × 2M2G) were the highest. The lowest treatment interactions were observed in planting of groundnut 2 weeks after planting of maize in 2M1G maize-groundnut row arrangements (2 WAP × 2M1G) at the last sampling period.

#### 3.1.2. Canopy Diameter

In the major season of 2020, row arrangement of maize-groundnut intercrops had no significant effects on canopy diameter of groundnut plants, but time of introducing groundnut into the maize-groundnut intercropping system affected it significantly at 2 and 6 weeks after planting (Table 5).

Table 5. Effect of maize-groundnut intercropping on canopy diameter of groundnuts in the major season of 2020.

| Treatment | Canopy diameter (cm) Weeks After Planting | | |
|---|---|---|---|
| | 2 | 4 | 6 |
| **Row arrangement (R)** | | | |
| 1M1G | 13.26a | 22.17a | 32.27a |
| 1M2G | 12.48a | 22.21a | 28.74a |
| 2M1G | 12.76a | 21.83a | 33.66a |
| 2M2G | 12.76a | 22.75a | 31.19a |
| Sole groundnut (G) | 13.24a | 22.88a | 32.31a |
| **LSD (5%)** | NS | NS | NS |
| **Time of planting groundnuts (T)** | | | |
| 0 WAP | 13.59b | 23.71a | 35.64b |
| 1 WAP | 13.48b | 22.44a | 31.50ab |
| 2 WAP | 11.63a | 20.96a | 27.76a |
| **LSD (5%)** | 0.65 | NS | 4.78 |
| **Interactions (R × T)** | | | |
| 0 WAP × 1M1G | 14.40c | 26.59b | 37.26a |
| 0 WAP × 1M2G | 13.40bc | 23.17ab | 32.17ab |
| 0 WAP × 2M1G | 13.33bc | 19.90ab | 44.16c |
| 0 WAP × 2M2G | 12.90b | 24.65ab | 32.20a |
| 0 WAP × G | 13.90bc | 24.23ab | 32.43a |
| 1 WAP × 1M1G | 13.67bc | 20.45ab | 32.51a |
| 1 WAP × 1M2G | 12.70a | 21.33ab | 30.83a |
| 1 WAP × 2M1G | 13.63bc | 23.57ab | 29.69a |
| 1 WAP × 2M2G | 13.47bc | 21.55ab | 32.30a |
| 1 WAP × G | 13.93bc | 25.30ab | 32.19a |
| 2 WAP × 1M1G | 11.70a | 19.47a | 27.04a |
| 2 WAP × 1M2G | 11.33a | 22.13ab | 23.23a |
| 2 WAP × 2M1G | 11.30a | 22.03ab | 27.13a |
| 2 WAP × 2M2G | 11.90a | 22.07ab | 29.08a |
| 2 WAP × G | 11.90a | 19.10a | 32.30a |
| **LSD (5%)** | 1.45 | 7.14 | 10.68 |
| **CV (%)** | 6.7 | 19.1 | 20.2 |

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, the widest copies were observed in groundnut plants planted on the same day with the maize intercrop, while the lowest value was noticed in groundnut plants sown 2 weeks after planting the maize intercrop. At the first sampling period, simultaneous planting of maize and groundnut intercrops did not differ significantly from planting the groundnut intercrop a week after planting the maize intercrop in terms of canopy diameter, but each of these times of planting the groundnut intercrop varied significantly ($P < 0.05$) from planting the groundnut intercrop 2 weeks after planting the maize intercrop. At the third sampling period, a similar trend occurred, except that planting the groundnut a week and two weeks after planting the maize were similar in canopy diameter.

Treatment interactions for canopy diameter of groundnut plants in the major season of 2020 were significant ($P < 0.05$) at all sampling periods (**Table 5**). The highest treatment interaction effects were observed in simultaneous planting of maize and groundnut in either 1M:1G or 2M:1G maize-groundnut row arrangements (0 WAP × 1M1G or 0 WAP × 2M1G). The lowest treatment interaction effects were observed in planting of groundnut 2 weeks after planting of maize in 2M1G or 1M2G maize-groundnut row arrangements (2 WAP × 2M1G or 2 WAP × 1M2G) or when groundnut was sown as a sole crop 2 weeks after planting maize.

In the minor season of 2020, row arrangement of maize-groundnut intercrops had significant effects on canopy diameter of groundnut plants at 4 weeks after planting, while time of introducing groundnut into the maize-groundnut intercropping system affected it significantly at 4 and 6 weeks after planting (**Table 6**).

At the first sampling period, sole groundnut plants had the widest canopies and differed significantly from the intercropped groundnut plants, except those from the 2M2G row arrangement. All other treatment variations were similar. Groundnut plants that were introduced into the maize-groundnut intercropping system in a 2M1G row arrangement 2 weeks after planting maize gave the smallest canopies.

At the second and third sampling periods, the widest copies were noticed in groundnut plants planted on the same day with the maize intercrop, while the lowest value was noticed in groundnut plants sown 2 weeks after planting the maize intercrop. Simultaneous planting of maize and groundnut intercrops did not differ significantly from planting the groundnut intercrop a week after planting the maize intercrop in terms of canopy diameter, but each of these times of planting the groundnut intercrop varied significantly ($P < 0.05$) from planting the groundnut intercrop 2 weeks after planting the maize intercrop.

There were significant ($P < 0.05$) treatment interaction effects for canopy diameter of groundnut plants in the minor season of 2020 at all the sampling periods (**Table 6**). At the first sampling period, the highest treatment interaction effects were observed in simultaneous planting of maize and groundnut in 2M:2G maize-groundnut row arrangements (0 WAP × 2M2G). At the second and third sampling periods, the highest treatment interaction effects were observed when

**Table 6.** Effect of maize-groundnut intercropping on canopy diameter of groundnuts in the minor season of 2020.

| Treatment | Canopy diameter (cm) Weeks After Planting | | |
|---|---|---|---|
| | 2 | 4 | 6 |
| **Row arrangement (R)** | | | |
| 1M1G | 14.33a | 23.07a | 30.48a |
| 1M2G | 14.52a | 22.86a | 30.09a |
| 2M1G | 14.44a | 22.45a | 31.32a |
| 2M2G | 16.36a | 23.64ab | 32.42a |
| Sole groundnut (G) | 14.40a | 24.79b | 32.51a |
| **LSD (5%)** | NS | 1.66 | NS |
| **Time of planting groundnuts (T)** | | | |
| 0 WAP | 15.39a | 24.03b | 32.41b |
| 1 WAP | 14.77a | 24.99b | 33.08b |
| 2 WAP | 14.27a | 21.07a | 28.60a |
| **LSD (5%)** | NS | 1.282 | 2.159 |
| **Interactions (R × T)** | | | |
| 0 WAP × 1M1G | 15.23a | 23.07b | 33.47b |
| 0 WAP × 1M2G | 15.20a | 23.53b | 30.07b |
| 0 WAP × 2M1G | 14.80a | 23.08b | 32.00b |
| 0 WAP × 2M2G | 17.76b | 25.20bc | 33.19b |
| 0 WAP × G | 13.97ab | 25.27bc | 33.32b |
| 1 WAP × 1M1G | 14.50ab | 24.80b | 33.23b |
| 1 WAP × 1M2G | 14.47ab | 25.73bc | 33.71b |
| 1 WAP × 2M1G | 15.40ab | 25.37bc | 33.34b |
| 1 WAP × 2M2G | 14.67ab | 24.97b | 33.47b |
| 1 WAP × G | 14.83ab | 24.07b | 31.68b |
| 2 WAP × 1M1G | 13.25a | 21.33ab | 24.73a |
| 2 WAP × 1M2G | 13.90ab | 19.30a | 26.50a |
| 2 WAP × 2M1G | 13.13a | 18.90a | 28.63ab |
| 2 WAP × 2M2G | 16.67ab | 20.77a | 30.61b |
| 2 WAP × G | 14.40ab | 25.03bc | 32.52b |
| **LSD (5%)** | 3.99 | 2.87 | 4.83 |
| **CV (%)** | 16.1 | 7.3 | 9.2 |

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

groundnut was planted one week after planting maize in 1M2G maize-groundnut row arrangement. The lowest treatment interaction effects were observed in planting of groundnut 2 weeks after planting of maize in 2M1G or 1M1G maize-groundnut row arrangements (2 WAP × 2M1G or 2 WAP × 1M1G) or when groundnut was sown as a sole crop 2 weeks after planting maize.

## 3.2. Yield and Yield Components

### 3.2.1. Shelling Percentage, Number of Pods per Plant and Number of Seeds per Pod

Shelling percentage, number of pods per plant and number of seeds per pod are presented in Table 7. Treatment main effects were not significant (P > 0.05) for shelling percentage. However, there were significant (P < 0.05) treatment interaction effects for shelling percentage of groundnut throughout the study. The highest shelling percentage was noticed in 1 WAP × 2M2G in the major season of 2020 (82.5%) and in 0 WAP × G in the minor season of 2020 (85.2%), while the least shelling percentage was observed in 0 WAP × 1M2G in both seasons of the trial (54.6% and 54.3%).

Row arrangement of intercrops significantly (P < 0.05) affected number of pods per plant in the major season of 2020, but in the minor season of 2020 it

Table 7. Effect of maize-groundnut intercropping on shelling percentage, number of pods per plant and number of seeds per pod of groundnut in the major and minor seasons of 2020.

| Treatment | Shelling % | | No. of pods/plant | | No. of seeds/pod | |
|---|---|---|---|---|---|---|
| | 2020 major season | 2020 minor season | 2020 major season | 2020 minor season | 2020 major season | 2020 minor season |
| **Row arrangement (R)** | | | | | | |
| 1M1G | 70.4a | 75.4a | 23.11bc | 23.44a | 2.33b | 2.11a |
| 1M2G | 66.3a | 68.4a | 21.67b | 23.00a | 2.00a | 2.00a |
| 2M1G | 72.1a | 74.4a | 19.11a | 21.67a | 2.00a | 2.22ab |
| 2M2G | 77.8a | 75.8a | 22.33b | 23.33a | 2.11ab | 2.22ab |
| Sole groundnut (G) | 75.7a | 78.1a | 24.33c | 23.56a | 2.11ab | 2.44b |
| **LSD (5%)** | NS | NS | 1.18 | NS | 0.30 | 0.29 |
| **Time of planting groundnuts (T)** | | | | | | |
| 0 WAP | 73.8a | 72.5a | 24.00c | 24.73c | 2.20a | 2.40b |
| 1 WAP | 75.4a | 78.0a | 23.07b | 23.00b | 2.13a | 2.13ab |
| 2 WAP | 68.2a | 72.8a | 19.27a | 21.27a | 2.00a | 2.07a |
| **LSD (5%)** | NS | NS | 0.92 | 1.59 | NS | 0.23 |
| **Interactions (R × T)** | | | | | | |
| 0 WAP × 1M1G | 76.8ab | 75.7ab | 24.67cd | 26.33b | 2.33ab | 2.33ab |
| 0 WAP × 1M2G | 54.6a | 54.3a | 23.67c | 24.67b | 2.00a | 2.00a |
| 0 WAP × 2M1G | 79.3ab | 70.8ab | 21.00bc | 20.33a | 2.00a | 2.00a |
| 0 WAP × 2M2G | 81.9b | 76.5b. | 24.33cd | 25.67b | 2.33ab | 2.67bc |
| 0 WAP × G | 76.2ab | 85.2b | 26.33d | 26.67b | 2.33ab | 3.00c |
| 1 WAP × 1M1G | 77.8ab | 81.5b | 24.33c | 23.67b | 2.67b | 2.00a |
| 1 WAP × 1M2G | 74.6ab | 78.2b | 22.67c | 24.67b | 2.00a | 2.00a |
| 1 WAP × 2M1G | 68.1ab | 79.8b | 19.00b | 25.33b | 2.00a | 2.67b |
| 1 WAP × 2M2G | 82.5b | 76.4b | 24.00cd | 22.33ab | 2.00a | 2.00a |
| 1 WAP × G | 74.1ab | 74.0ab | 25.33cd | 19.00a | 2.00a | 2.00a |
| 2 WAP × 1M1G | 56.6ab | 69.0ab | 20.33b | 20.33a | 2.00a | 2.00a |
| 2 WAP × 1M2G | 69.8ab | 72.8ab | 18.67ab | 19.67a | 2.00a | 2.00a |
| 2 WAP × 2M1G | 68.7ab | 72.6ab | 17.33a | 19.33a | 2.00a | 2.00a |
| 2 WAP × 2M2G | 69.0ab | 74.5ab | 18.67a | 22.00a | 2.00a | 2.00a |
| 2 WAP × G | 76.9ab | 75.1ab | 21.33bc | 25.00b | 2.00a | 2.33ab |
| **LSD (5%)** | 25.34 | 21.90 | 2.05 | 3.56 | 0.51 | 0.50 |
| **CV (%)** | 20.9 | 17.6 | 5.5 | 9.3 | 14.5 | 13.7 |

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

had no significant effect on it. Sole groundnut was significantly ($P < 0.05$) higher than the intercropped row arrangements in number of pods per plant. The 2M1G treatment was significantly lower than the other treatments. 1M1G differed significantly from the other intercropped arrangements, except 2M2G. 1M2G did not vary from 2M2G, but differed from 2M1G.

Significant ($P < 0.05$) differences occurred throughout the study among the three treatments for time of introducing the groundnut into the intercropping system in terms of number of pods per plant. Simultaneous planting of maize and groundnut intercrops culminated in the highest number of pods per plant, while planting the groundnut intercrop 2 weeks after planting the maize intercrop gave the least value.

Significant ($P < 0.05$) treatment interaction effects for number of pods per plant were noticed in both seasons of the trial. Number of pods per plant was highest in 0 WAP × G throughout the study, while it was lowest in 2 WAP × 2M1G and 1 WAP × G in the major and minor seasons of 2020, respectively.

Row arrangement of intercrops significantly ($P < 0.05$) affected number of seeds per pod in both seasons of the trial. In the major season of 2020, 1M1G was highest in number of seeds per pod and was similar to 2M1G and 2M2G, but differed from 1M2G and 2M1G. All other treatment means were similar. 1M2G and 2M1G recorded the least number of seeds per pod. In the minor season of 2020, the sole groundnut recorded the highest number of seeds per pod and varied significantly from 1M1G and 1M2G, but was similar to 2M1G and 2M2G. All the intercropped groundnuts were similar in number of seeds per pod. The least number of seeds per pod was given by 1M2G treatment.

Time of planting groundnut intercrops affected the number of seeds per pod in the minor season of 2020, but in the major season of 2020 it had no significant ($P > 0.05$) effect on it. 0 WAP treatment gave the highest number of seeds per pod and varied significantly from 1 WAP and 2 WAP. 1 WAP and 2 WAP were similar in the number of seeds per pod. 2 WAP gave the least number of seeds per pod.

Significant ($P < 0.05$) treatment interaction effects for number of seeds per pod were noticed in both seasons of the trial. In the major season of 2020, 1 WAP × 1M1G treatment combination gave the highest number of seeds per pod of 2.67, while either 0 WAP × 2M2G or 1 WAP × 2M1G treatment combination gave the highest number of seeds per pod of 2.67 in the minor season of 2020. The least value was noticed in different treatment combinations throughout the study.

#### 3.2.2. Pod and Seed Yields

Pod and seed yields are presented in Table 8. Treatment application had no significant ($P > 0.05$) effect on pod yield in both seasons of the trial. However, seed yield varied significantly ($P < 0.05$) with row arrangement and time of introducing groundnut into the intercropping system in both seasons of the trial. In the major season of 2020, sole groundnut treatment was significantly ($P < 0.05$)

**Table 8.** Effect of maize-groundnut intercropping on seed and pod yields of groundnut in the major and minor seasons of 2020.

| Treatment | Seed yield (kg/ha) | | Pod yield (kg/ha) | |
|---|---|---|---|---|
| | 2020 major season | 2020 minor season | 2020 major season | 2020 minor season |
| **Row arrangement (R)** | | | | |
| 1M1G | 283a | 437a | 421a | 574a |
| 1M2G | 335a | 478ab | 886a | 1157a |
| 2M1G | 253a | 407ab | 420a | 543a |
| 2M2G | 290a | 488ab | 370a | 637a |
| Sole groundnut (G) | 617b | 589b | 821a | 742a |
| **LSD (5%)** | 128.5 | 148.4 | NS | NS |
| **Time of planting groundnuts (T)** | | | | |
| 0 WAP | 372b | 528b | 740a | 999a |
| 1 WAP | 434b | 546b | 617a | 695a |
| 2 WAP | 261a | 365a | 394a | 499a |
| **LSD (5%)** | 98.5 | 148.4 | NS | NS |
| **Interactions (R × T)** | | | | |
| 0 WAP × 1M1G | 337a | 526ab | 444a | 696a |
| 0 WAP × 1M2G | 389b | 581b | 1815a | 2359a |
| 0 WAP × 2M1G | 207ab | 344ab | 256a | 485a |
| 0 WAP × 2M2G | 259ab | 463ab | 315a | 596a |
| 0 WAP × G | 667c | 726b | 870a | 856a |
| 1 WAP × 1M1G | 296ab | 507ab | 389a | 626a |
| 1 WAP × 1M2G | 319ab | 541b | 400a | 681a |
| 1 WAP × 2M1G | 407b | 585b | 796a | 741a |
| 1 WAP × 2M2G | 407b | 637b | 500a | 830a |
| 1 WAP × G | 741c | 459ab | 1000a | 596a |
| 2 WAP × 1M1G | 215ab | 278a | 430a | 400a |
| 2 WAP × 1M2G | 296ab | 311a | 444a | 430a |
| 2 WAP × 2M1G | 144a | 293a | 207a | 404a |
| 2 WAP × 2M2G | 204ab | 363ab | 296a | 485a |
| 2 WAP × G | 444b | 581b | 593a | 774a |
| **LSD (5%)** | 222.6 | 257.0 | NS | NS |
| **CV (%)** | 37.4 | 32.0 | 106.4 | 93.6 |

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

higher in seed yield than its intercropped counterparts. All the intercropped treatments were similar. In the minor season of 2020, sole groundnut treatment was better in seed yield than its intercropped counterparts and differed significantly ($P < 0.05$) from 1M1G and 2M1G treatments, but was similar to 1M2G and 2M2G treatments. All other treatment differences were not different from one another. Two rows of maize and one row of groundnut (2M1G) treatment recorded the lowest seed yield throughout the study.

The highest seed yield of groundnut was found in the groundnut intercrop that was planted a week after planting the maize intercrop, whereas the lowest value was noticed in groundnut plants sown 2 weeks after planting the maize intercrop. Simultaneous planting of maize and groundnut intercrop did not differ significantly from planting the groundnut intercrop a week after planting the maize intercrop in terms of seed yield, but either of them varied significantly ($P < 0.05$) from planting the groundnut intercrop 2 weeks after planting the maize intercrop.

There were significant ($P < 0.05$) treatment interaction effects for pod and seed yields of groundnut throughout the study (**Table 8**). The highest pod yields of 1815.00 kg/ha and 2359.00 kg/ha were given by 2WAP × 1M2G in the major and minor seasons of 2020, respectively, while the lowest value was associated with 2WAP × 2M1G in the major season of 2020 (207.00 kg/ha) and 2WAP × 1M1G in the minor season of 2020 (400.00 kg/ha). In the major season of 2020, 1WAP × G gave highest treatment interaction effect for seed yield of 741.00 kg/ha, while the treatment combination of 2WAP × 2M1G resulted in the lowest seed yield of 144 kg/ha. In the minor season of 2020, 0WAP × G gave the highest seed yield of 727.00 kg/ha, whereas the lowest seed yield of 278.00 kg/ha was given by 2WAP × 1M1G. The row arrangement of 1 WAP × 2M2G, which resulted in the groundnut seed yield of 407 kg/ha and 637 kg/ha in the major and minor seasons of 2020, respectively, followed the sole groundnut (**Table 8**).

## 4. Discussion

### 4.1. Treatment Effects on Vegetative Growth of Groundnuts

Due to less interspecific competition for scarce resources, including water, nutrients, light, and space, single groundnut plants generated noticeably more branches than intercropped groundnut plants (**Table 3** and **Table 4**). This suggests that the row intercropping technique was a threat to the cooperation since it was competitive. The sole groundnuts developed more branches than the intercrops because there was less intraspecific competition. Similar outcomes were found by Konlan *et al.* [41] when three groundnut varieties were interplanted with maize in the Guinea Savanna Region of Ghana. The sole groundnut plants experienced no mutual shading effects from maize plants and as a result of this, their leaves were fully exposed to irradiance, which may have increased photosynthesis and subsequent translation of assimilates into branching.

Intercropping with the spatial row arrangement of 2M2G, 1M1G and 2M1G increased branching in groundnuts when the crop mixtures were established at the same time or when groundnuts were planted a week after planting the maize (**Table 3** and **Table 4**). The results could be ascribed to sufficient time the intercropped groundnut plants received for growth before the intercropped maize outgrew them. The increased number of branches observed in the intercropped groundnut plants could be due to low intraspecific competition for available resources following low groundnut populations. A similar observation was made by Dokli [42] who reported that, maize-groundnut intercropping increased vegetative growth of intercropped groundnut.

In the major season of 2020, the widest canopies were observed in simultaneous planting of maize and groundnut in either 1M:1G or 2M:1G maize-groundnut row arrangements (0 WAP × 1M1G or 0 WAP × 2M1G) as shown in **Table 5**. Competition for soil nutrients, water, light and space between the two intercrops may be low when they were planted at the same time and that could have promoted production of wide canopies in the intercropped groundnuts relative to the sole groundnut plants. Groundnut populations in the intercrop mixtures with the spatial row arrangement of 1M1G and 2M1G were low and that could have minimized intra plant competition for available growth resources.

In the minor season of 2020, the widest canopies were produced when groundnut plants were planted one week after planting maize in 1M2G maize-groundnut row arrangement probably because the interval between the time of planting the intercrops may be too short to allow the intercropped maize to outgrow the intercropped groundnut (**Table 6**). As a result, the shading effects of the maize on the groundnut were low, culminating in the ability of the former to utilize space, light, soil moisture and soil nutrients effectively for high photosynthesis and efficient partitioning and usage of photoassimilates.

The morphological differences between the intercrop components resulted in their ability to occupy different niches (**Tables 3-6**). Thus, environmental resources could be more efficiently utilized and converted to biomass by mixed stands of crops than by pure stands. Therefore, in the present study, more PAR interception and also a greater water extraction by intercrops could be the major reason for the wider canopies observed for intercropping over sole cropping when the groundnut intercrop was introduced into the intercropping system at different times. The results of this present study are in accordance with those of Willey [43] and Keating and Carberry [44] who found that, efficient resource utilization by intercrops was considered as the biological basis for obtaining growth benefits.

### 4.2. Treatment Effects on Yield and Yield Components of Groundnuts

The proportion of total dry matter synthesized that has been allocated to seeds is known as the shelling percentage, which serves as a crop yield index. According to Ramesh and Sabale [45], this parameter is impacted by genetic and environmental variables that alter the partitioning, accumulation, and photosynthesis of dry matter.

Generally, the sole groundnut crops increased shelling percentage and number of pods per plant over the intercropped groundnuts probably because of increased number of branching observed in the sole groundnut crops that could have increased plant canopy and interception of irradiance (**Table 7**). This might have encouraged pegging and podding, resulting in an increase in number of pods per plant with heavy seeds. Again, the plant populations for the sole groundnut cropping were higher than the intercropped groundnut. Due to this situation, there might be a complete ground cover that may have conserved soil moisture, checked growth of weeds and soil erosion, resulting in an increase in formation of branches, pegs and pods. The results of the present study are in accordance with those of Santo *et al.* [46] who found that, shelling percentage of groundnut increased with increasing plant population. They reported that, the high plant population could have reduced weed growth and competition for resources, leading to improved dry matter partitioning in favour of shelling percentage.

The highest shelling percentage was noticed in 1 WAP × 2M2G in the major season of 2020 (82.5%) and in 0 WAP × G in the minor season of 2020 (85.2%). In the minor season of 2020, 1 WAP × 1M1G treatment combination followed 0 WAP × G in terms of shelling percentage (**Table 7**). Planting groundnuts and maize at the same time (0 WAP) or planting groundnuts a week after planting maize (1 WAP) could not give the maize plants any competitive advantage over the groundnut plants. This is because the groundnut plants were able to form a good root system, which may have supported uptake of water and nutrients, resulting in proper growth and allocation of assimilates to the economic parts of the plant. The earlier planted crop could not suppress the growth and yield of the later planted crop. Early root development, which exploits nutrients in succeeding soil horizons considerably earlier than slow or later developing species, was a crucial determinant of competitive capability with faster-growing species, according to Eagles [47].

Due to less intercrop competition for sunlight, soil nutrients, water, and space, the spatial row arrangements of 1M1G and 2M2G had higher shelling percentages than the other treatments. This is due to the fact that there was insufficient competition for the available growth resources due to the difference in plant population between the two crop combinations. This supports the findings by Islam *et al.* [48] when they evaluated the outcomes of intercropping hybrid maize and sweet potato. Similar findings were also observed by Lemlem [49], while assessing the impacts of intercropping maize with cowpea and lablab.

Results of number of pods per plant and number of seeds per pod (**Table 7**) revealed that, interaction between time of introducing groundnuts into the intercropping system and the spatial row arrangement was favourable when the groundnuts and maize crops were planted simultaneously in one row of maize and one row of groundnuts (0 WAP × 1M1G). This is because the spatial row arrangement of one row of maize and one row of groundnut (1M1G) had a higher plant population than the other intercropping systems. The increased plant population may have caused a rapid canopy closure to control weeds, erosion, evapotranspiration and to increase soil nutrients due to leaf fall and biological nitrogen fixation. According to Shibbles *et al.* [50] and Agasimani *et al.* [51], narrow row cultivation required greater plant densities to ensure faster canopy growth and to successfully compete against weeds, leading to higher pod and grain yields. Because the two crop mixtures were planted on the same day, each of them was exposed to similar environmental conditions and for that matter there were no vast variations in their ability to access growth resources.

The highest pod yields of 1815.00 kg/ha and 2359.00 kg/ha were recorded by 2WAP × 1M2G in the major and minor seasons of 2020, respectively, while the highest seed yield of 741.00 kg/ha and 726.00 kg/ha was recorded in the major and minor seasons of 2020, respectively by 1WAP × G and 0WAP × G, respectively (**Table 8**). Plant populations were relatively high in the sole groundnut crops and the one row of maize and two rows of groundnut (1M2G) and this may have accounted for the high pod and seed yields due to the relative increase in number of pods and shelling percentage noticed in these treatments. In one row of maize followed by two rows of groundnuts, Mandal *et al.* [52] observed a greater yield of groundnut than in a monoculture, and that is consistent with the findings of the present study.

Because the two crop mixtures were planted on the same day, each of them had equal opportunities to access growth resources such as light, soil nutrients, water and space. The combined effect of adequate growth resources and optimum plant population per unit area could have caused the relative increase in pod and seed yields observed in treatment combinations of 2WAP × 1M2G, 1WAP × G and 0WAP × G. The variability in plant population per unit area and interspecific competition that took place in these treatments were the major causes of the variations in pod and seed yields across the intercropping systems. This supports the findings of Islam *et al.* [48], who indicated that variations in plant population are mostly responsible for variances in intercrop yields in spatial arrangements between two crops.

Generally, the minor rainy season trial outperformed the major rainy season trial in terms of pod and grain yields, which may have been caused by favourable rainfall distribution, appropriate temperature, suitable soil-water relationships, and efficient dry matter partitioning in the minor season of 2020, which led to better vegetative and reproductive growth.

## 5. Conclusions and Recommendations

### 5.1. Summary of Study

- Intercropping with the spatial row arrangement two rows of maize and two rows of groundnut (2M2G), 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 branching and canopy diameter in groundnuts.
- 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.
- Planting groundnut intercrop within the first two weeks of planting maize

increased groundnut yield and yield components.

### 5.2. Conclusions

- Intercropping with the spatial row arrangement of two rows of maize and two rows of groundnut (2M2G), 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 groundnuts, while groundnut seed yield was increased by two rows of maize and two rows of groundnut (2M2G) spatial arrangements.
- Planting groundnuts within the first week of planting maize increased groundnut seed yield.
- Planting groundnuts within the first week of planting maize increased groundnut seed yield in two rows of maize and two rows of groundnut (2M2G) arrangements.

### 5.3. Recommendations

- Farmers should adopt the spatial row arrangement of two rows of maize followed by two rows of groundnut (2M2G) as it consistently increased shelling percentage and seed yield of groundnuts. Famers should plant groundnuts within the first week of planting maize in groundnut-maize intercropping systems in the spatial row arrangement of two rows of maize followed by two rows of groundnut (2M2G).
- 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.

## Data Availability

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

## Conflicts of Interest

The authors declare that there are no conflicts of interest concerning the publication of this article.

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