

Tillage systems and crop combination effect on the growth and yield of maize in a maize/groundnut intercropping systems

C.I. Oyewole^{1,*}, H. Shuaib¹, S.E. Attah¹, E.A. Agahiu¹ and A.N. Oyewole-Ezeogueri²

¹ Department of Crop Production, Kogi State University, Kogi State 272102, Nigeria

² Department of History and International Studies, Kogi State University, Kogi State 272102, Nigeria

* Corresponding author: oyewole.ci@ksu.edu.ng

Submission: 24 May 2023

Revised: 9 January 2024

Accepted: 12 January 2024

ABSTRACT

Background and Objectives: This study aimed to assess the impact of crop combination and tillage practices on weed suppression, yield, and yield components in a maize/groundnut intercropping system.

Methodology: The experiment involved five intercropping patterns and three tillage practices. These treatments were arranged in a randomized complete block design with four replications, employing tillage practices in the main plot and intercrop combinations in the subplot.

Main Results: Significantly ($P < 0.05$), crop combination influenced maize height at 3, 5, 7, and 9 weeks after planting (WAP) for both the 2020 and 2021 cropping seasons. Sole maize plots exhibited the greatest heights (144.64 and 170.90 cm for 2020 and 2021, respectively), while intercropping one row of maize with two rows of groundnut resulted in shorter crops (121.35 and 150.07 cm for 2020 and 2021, respectively). In 2020, tillage practices significantly affected maize height at 3 and 7 WAP ($P < 0.05$), but this effect was not observed in 2021. Intercrop combinations, tillage practices, and their interactions had no significant ($P > 0.05$) impact on the average number of leaves. Generally, tillage practices did not significantly affect maize leaf areas at 5, 7, and 9 WAP in 2020 or at 3 and 7 WAP in 2021. However, interactions between intercrop combinations and tillage practices significantly affected leaf areas at 3, 5, 7, and 9 WAP in 2021 but not in 2020. Days to 50 percent tassel and 50 percent silking were not significantly influenced by crop combination or tillage practices in either year, with no significant interactions observed. Stover yield significantly ($P < 0.05$) responded to planting patterns and tillage practices in both cropping seasons. However, the 100-seed weight was not significantly ($P > 0.05$) influenced by intercrop combinations, tillage practices, or their interactions in both seasons.

Conclusions: Planting seeds on flat surfaces yielded the highest grain yield, while ridge planting yielded the lowest grain yield in both seasons. Generally, intercropping proved advantageous compared to sole cropping, with Land Equivalent Ratios (LERs) exceeding unity, making it a recommended practice for the study area.

Keywords: Maize height, leaf number, leaf area, maize yield, yield components, harvest index, LER

Thai J. Agric. Sci. (2023) Vol. 56(3): 178–195

INTRODUCTION

Among the modern agro-management techniques, crop combination is one of the crucial factors for improving crop yield. In the growing of maize, different crop combination methods are practiced. Ridge planting can be considered as an alternative to no-tillage practices. Abdullah *et al.* (2008) documented that the ridge method of planting significantly increased the yield of maize crops compared with other planting methods. However, it was observed that conventional flat planting has some disadvantages for spring maize.

Over the years, maize has become an important crop, taking over acreages from traditional crops such as millet and sorghum (Attah and Oyewole, 2013). In the past few decades, maize production has increased tremendously in the tropical rainforest (FAO, 2012). The crop serves as a staple food for more than 300 million people in less developed countries such as Africa and Latin America. It accounts for a daily total of about 15–20% of calories in the diets of 20 of these less-developed countries (Ologunde and Ogunlela, 1984; Adetimirin *et al.*, 2008). Maize is commonly intercropped with various crops in the farming systems in Nigeria. Thus, the main objective of this study was to evaluate the effect of tillage practice on growth, yield, and yield components of maize/groundnut intercrop in the study area, as well as ascertain the weed control potentials of the treatment.

Weed infestation is highly important among biotic factors responsible for low maize grain yield. Generally, at least 75% of the time spent by farmers on their farms is spent on weed control, with other cultural operations accounting for about 25% of farmers' time. Noting that worldwide maize production is lowered by up to 40% by competition from weeds, which are the most important pest group of this crop (Chikoye *et al.*, 2005).

It has been observed that the yield of maize obtained in Nigeria is far below expectation due to numerous factors which include weed infestation, low soil fertility, and availability of labor. Yield losses of between 60–80% have been attributed to uncontrolled weed infestation in maize

(Lagoke *et al.*, 1998), and this finding is consistent with that of Imoloame and Omolaiye (2016), who reported 89% yield loss in maize as a result of uncontrolled weed infestation. There is no reliable study of worldwide damage due to weeds. However, it is widely known that losses caused by weeds have exceeded the losses from any category of agricultural pests, such as insects, nematodes, diseases, and rodents.

Good tillage practice can successfully control weed incidence on farmer's plots (Oyewole and Ibikunle, 2010). Tillage is used for a variety of purposes, including the preparation of seedbeds, reducing soil compaction, incorporating crop residues, and controlling weeds (Liu *et al.*, 2008). Additionally, to ensure normal plant growth, the soil must be in such a condition that roots can have enough air, water, and nutrients (Husnjak *et al.*, 2002). The practice of modifying the state of the soil to provide conditions favorable for crop growth is referred to as tillage. The task of tillage is to prepare soils for productive use or to place the soil in the best physical condition for the crop to grow (Liu *et al.*, 2008). Tillage is crucial for crop establishment, growth, and yield (Atkinson *et al.*, 2007). A good soil management program protects the soil from water and wind erosion, provides a good, weed-free seedbed for planting, destroys hardpans or compacted layers that may limit root development, and allows maintenance or even an increase of organic matter (Wright *et al.*, 2008). Many farmers perform tillage operations without being aware of the effect of these operations on soil physical properties and crop responses (Ozpinar and Isik, 2004).

There are two major tillage systems, the conventional and conservation tillage practice (Srivastava *et al.*, 2006). The conventional tillage system is based on a high intensity of soil engagement and inversion of the soil. It is used to prepare the seedbed (improving seed-soil contact), facilitating regular, unvarying early plant emergence (Josa *et al.*, 2010). Alternatively, conservation tillage is any tillage or sowing system, which leaves at least 30% of the field covered with crop residue after planting. In such soils, erosion is reduced by at least

50% as compared with bare, fallow soils (Karayel, 2009). Due to high population pressure and other human activities competing with agriculture for the limited available land, the need to maximize land productivity in the humid tropics has become more evident (Steiner, 1991), which is not achievable with monoculture as practiced in Nigeria. As pointed out earlier, the main objective of the study was to evaluate the effects of planting patterns and tillage practice on weed suppression, yield, and yield components of maize/groundnut intercrop. Specific objectives include interactions between planting patterns and tillage practice on growth, yield, and yield components of the mixture.

MATERIALS AND METHODS

The experiment was conducted during the rainy seasons of 2020 and 2021 at latitude 7°30' and longitude 7°09' E in the Southern Guinea Savannah agro-ecological zone of Nigeria. The experiment was conducted at the Kogi State University Anyigba Students' Research and Demonstration Farm. The experimental treatment consisted of five intercropping patterns: sole maize, sole groundnut, two rows of maize and one row of groundnut, two rows of groundnut and one row of maize, one row of maize and one row of groundnut, and three tillage practice methods (planting on flat land, planting on ridge and zero tillage). Tillage practices consisted of conventional plow and harrow, no ridge but to form an even flat surface with a gentle gradient, and ridging where the land was plowed, harrowed, and ridged 75 cm apart. Finally, there was zero tillage, where the land was left uncultivated and without weeds. The treatment: tillage practices and crop combination completely randomized were laid out in a factorial experiment with four replications. Tillage practice was the main plot treatment, while crop combination was the subplot factor. Plot sizes that measured 3 m × 4.5 m (sixty plots) were used for the experiment. One improved variety of maize (TZESR) and one local variety of groundnuts (Angba-Chido) obtained from the International Institute of Tropical Agriculture (IITA), Ibadan and Agricultural Development Project (ADP) Anyigba, Kogi State,

respectively were used. NPK 15:15:15 (compound fertilizer containing 15% each of N, P, and K) was applied to all the plots as a basal application (45 kg N/ha, 45 kg P₂O₅ and 45 kg K₂O/ha) and top dressed with Urea (46% N) at 6 weeks after planting (WAP).

Percentage seedling emergence was determined two weeks after planting. This was calculated as ratios of seeds germinating relative to the number of seeds sown expressed in percentage. Subsequently, five plants were randomly selected and tagged from the net plot (2.5 m × 4.0 m) for height measurement, average numbers of leaves per plant, and leaf areas, following the methods outlined by Oyewole *et al.* (2015a; 2015b) and Musa and Usman (2016), at 3, 5, 7, and 9 WAP. Other parameters determined were days to emergence of the first tassel, cob girth (cm), cob length (cm) using a veneer caliper, number of seeds per cob, 100-seed weight (g), grain yield (kg/ha), shelling percentage, stover yield (kg/ha), and harvest index (%). The measurement methods adhered to the protocols outlined by Donald (1958), Oyewole (2011), and Oyewole *et al.* (2015a; 2015b), all conducted from the net plot dimensions of 2.5 m × 4.0 m. For grain yield (kg/ha), all the shelled grains per net plot were weighed in the lab using an electronic scale. The total weight obtained per net plot (10 m²) extrapolated to hectare as shown below:

$$\text{Total weight per net plot} = \frac{10,000 \text{ m}^2}{10\text{m}^2} \times \text{harvested weight (kg)}$$

For stover yield (kg/ha), the total above-ground dry matter after the harvest of the cobs was bulked together and weighed per net plot. The total weight was recorded for each net plot extrapolated to a hectare. The harvest index (HI) was calculated by the formula given by Donald (1958). Crops were harvested at 120 days after seed sowing for both maize and groundnut stands.

$$\text{HI} = \frac{\text{Economic yield (seed)}}{\text{Biological yield (seed + stover)}} \times 100$$

The advantages of maize-groundnut intercropping were evaluated using the land equivalent ratios (LER). The LER was used to

quantify the land-use efficiency of the intercropping system, which is the relative land area of a sole crop required to produce the yield achieved in intercropping (Willey and Osiru, 1972). Where $LER > 1$, the intercropping favors the growth and yield of the mixture, but in contrast, where $LER < 1$, there is no intercropping advantage (Zhang *et al.*, 2011). LER of the sole crop was taken as unity. LER was calculated as:

$$LER_{\text{groundnut}} = \frac{\text{Yield of groundnut in the intercrop}}{\text{Yield of groundnut in the sole crop}}$$

Analysis of Data

The collected data were subjected to analysis of variance (ANOVA) as described for a 3×5 factorial design in a complete randomized design using the Statistical Analysis System (SAS, 1998). Means that were found to be statistically significant at a 5% probability level were separated using the least significant difference (LSD) test.

RESULTS AND DISCUSSION

Effect of Intercrop Combination, Tillage Practice, and Their Interactions on Maize Height

Crop combination had a significant influence ($P < 0.05$) on average maize heights at 3, 5, 7, and 9 WAP (Table 1) in the 2020 and 2021 cropping seasons, while tillage practice significantly influenced ($P < 0.05$) average maize heights at 3 and 7 WAP only in the 2020 cropping season but had no significant ($P > 0.05$) effect on average maize heights in the 2021 cropping season. Final data collected on crop combination (9 WAP) show better height performance in the 2021 cropping season compared with the 2020 cropping season, probably as a result of more favorable rainfall at the time of planting in the former. Generally, there were consistent interactions between crop combination and tillage practice on average maize heights throughout the period of data collection in

both cropping seasons (Tables 1–3), with better performances majorly obtained when the crops were sown on the flat.

Generally, in the 2020 cropping season, except at 3 WAP, sole-cropped maize consistently had the tallest average height, followed by a combination of two maize rows to one groundnut row. In the 2021 cropping season, sole maize plots, gave better height performances at 3, 5, 7, and 9 WAP, closely followed by combining two maize rows to one groundnut row at 7 and 9 WAP. Considering the difference in the vegetative structure of the associating crops; maize being erect, while groundnut is prostrate, the expected effect resulting from intercropping should arise from the maize components; thus, the more the maize population per unit area in the intercrop, the higher the competition for solar radiation cumulating in taller maize stands (Oyewole, 2010; 2011). This must have accounted for taller maize crops in sole-cropped plots, consistent with previous observations (Oyewole *et al.*, 2005; 2006; Oyewole, 2011). The poor height performance observed in the zero-tillage treatment compared with the other treatments in the 2020 cropping season strongly supported the need for some level of soil tillage before seed sowing in the experimental area, as tillage enhances root penetration into the soil, thus improving water and nutrient scavenging ability of the crop. Repeated trials conducted in the 2021 cropping season, which revealed better performance in zero tillage compared with crops sown on ridges, did not lay credence to the aforementioned. Better height performance in crops sown on the flat indicates that water availability played a critical role in the outcomes of tillage practice within and between seasons regarding plant heights. When water is limited, planting seeds on the flat is encouraged to mitigate the effect of water on crop height.

Table 1 Effect of intercrop combination, tillage practice, and their interactions on average height (cm) of maize

Treatment	Average height (cm)								
	2020 cropping season			2021 cropping season					
	3 WAP	5 WAP	7 WAP	9 WAP	3 WAP	5 WAP	7 WAP	9 WAP	
Planting pattern (P)									
Sole maize	18.76 ± 1.06 ^{ab}	51.90 ± 2.01 ^a	108.20 ± 4.67 ^a	144.64 ± 4.88 ^a	30.67 ± 2.42 ^a	48.59 ± 3.67 ^a	96.29 ± 4.00 ^a	170.90 ± 3.00 ^a	
2 maize:1 g/nut	19.98 ± 1.04 ^{ab}	44.17 ± 1.49 ^{ab}	86.61 ± 2.45 ^b	129.44 ± 3.11 ^{bc}	25.28 ± 2.23 ^b	38.08 ± 3.23 ^b	80.98 ± 3.94 ^b	156.46 ± 2.56 ^b	
2 g/nut:1 maize	16.81 ± 1.02 ^b	38.07 ± 1.34 ^b	77.25 ± 2.33 ^b	121.35 ± 3.00 ^c	26.02 ± 2.00 ^b	38.97 ± 2.89 ^b	80.17 ± 3.52 ^b	150.07 ± 2.11 ^b	
1 maize:1 g/nut	20.42 ± 1.04 ^a	41.57 ± 1.32 ^{ab}	81.82 ± 2.16 ^b	128.09 ± 3.21 ^c	25.77 ± 1.78 ^b	38.90 ± 2.11 ^b	79.84 ± 2.65 ^b	153.69 ± 2.00 ^b	
LSD (0.05)	2.621*	7.899*	10.726*	15.717*	1.531*	3.513*	6.418*	12.827*	
Tillage practice (T)									
Ridge	14.56 ± 1.03 ^b	32.11 ± 2.00	70.89 ± 4.22 ^b	104.62 ± 3.87	26.61 ± 1.45	39.69 ± 2.56	82.20 ± 3.87	154.70 ± 2.98	
Flat	17.20 ± 1.05 ^a	36.00 ± 2.03	78.08 ± 3.55 ^a	110.72 ± 3.86	27.27 ± 1.34	41.45 ± 2.41	86.65 ± 3.81	161.73 ± 2.18	
Zero tillage	13.83 ± 1.02 ^b	31.31 ± 2.01	63.36 ± 3.33 ^c	98.77 ± 2.12	26.92 ± 1.22	42.27 ± 2.33	84.12 ± 3.00	156.91 ± 2.01	
LSD (0.05)	1.033*	5.117 ^{ns}	5.305*	6.178 ^{ns}	2.148 ^{ns}	3.722 ^{ns}	2.972 ^{ns}	9.931 ^{ns}	
Interaction									
P × T	*	*	*	*	*	*	*	*	
CV (%)	20.9	28.9	18.4	18.2	8.6	13.0	11.5	12.3	

Note: WAP = weeks after planting, g/nut = groundnut, LSD = least significant difference, CV = coefficient of variation. * Significant at 5% level of probability, NS = not significant at 5% level of probability. Means followed by the same letter(s) are not statistically different at 5% level of probability. Note the interaction effects marked (*) are contained on Tables 2 and 3 below.

Table 2 Interaction effect between intercrop combination and tillage practice on average height (cm) of maize in 2020 cropping season

Planting pattern	Tillage practice		
	Ridge	Flat	Zero tillage
3 WAP			
Sole maize	17.23 ± 2.66 ^{de}	21.35 ± 2.00 ^c	17.70 ± 2.15 ^e
2 maize:1 g/nut	17.43 ± 2.62 ^{de}	24.46 ± 2.01 ^b	18.06 ± 2.45 ^d
2 g/nut:1 maize	21.92 ± 2.29 ^c	13.22 ± 1.34 ^g	15.30 ± 2.33 ^f
1 maize:1 g/nut	16.22 ± 2.01 ^{ef}	26.97 ± 2.03 ^a	18.07 ± 2.12 ^d
SE (±)		1.596	
5 WAP			
Sole maize	33.60 ± 2.91 ^{ef}	47.43 ± 2.90 ^{bc}	44.65 ± 2.13 ^c
2 maize:1 g/nut	38.44 ± 2.15 ^d	49.07 ± 1.99 ^{abc}	44.99 ± 1.22 ^c
2 g/nut:1 maize	53.15 ± 2.19 ^a	32.33 ± 3.56 ^g	28.73 ± 2.21 ^g
1 maize:1 g/nut	35.37 ± 2.34 ^{def}	51.17 ± 3.34 ^{ab}	38.17 ± 2.00 ^{de}
SE (±)		4.794	
7 WAP			
Sole maize	92.48 ± 1.44 ^c	119.05 ± 2.78 ^a	113.08 ± 2.89 ^{ab}
2 maize:1 g/nut	67.67 ± 0.89 ^g	109.39 ± 3.23 ^b	82.77 ± 3.00 ^d
2 g/nut:1 maize	82.25 ± 0.67 ^{de}	66.83 ± 3.12 ^g	82.68 ± 3.10 ^d
1 maize:1 g/nut	74.41 ± 2.97 ^f	95.14 ± 2.23 ^c	75.90 ± 2.15 ^{ef}
SE (±)		6.513	
9 WAP			
Sole maize	133.96 ± 1.22 ^c	155.04 ± 1.00 ^a	144.91 ± 2.22 ^b
2 maize:1 g/nut	113.92 ± 1.90 ^g	144.69 ± 1.21 ^b	125.66 ± 2.31 ^{ef}
2 g/nut:1 maize	128.05 ± 2.00 ^{de}	110.51 ± 1.32 ^g	125.49 ± 2.56 ^{ef}
1 maize:1 g/nut	117.90 ± 2.21 ^{fg}	143.35 ± 2.00 ^b	127.07 ± 3.00 ^{ef}
SE (±)		9.532	

Note: WAP = week after planting, g/nut = groundnut, SE = standard error. Means followed by the same letter(s) are not statistically different at 5% level of probability.

Effect of Crop Combination, Tillage Practice, and Their Interactions on Average Number of Leaves and Leaf Area in Maize

The importance of this parameter is based on the fact that leaves are important organs for photosynthesis. Therefore, any operation affecting leaf number or area may likely influence photosynthesis. Such an influence could be positive or negative. Photosynthesis is vital in photosynthate

accumulation in green plants, thus ensuring food and feed for humans and animals.

Intercrop combination, tillage practice, and their interactions did not influence the average number of leaves in the maize crop (Table 4). Similar observations were made by Oyewole (2010; 2011) and Oyewole *et al.* (2005; 2006). Crop combination, however, significantly influenced ($P < 0.05$) leaf areas at 3, 5, 7, and 9 WAP (Table 5) in the 2020

cropping season, supporting the findings of Oyewole (2010; 2011) and Oyewole *et al.* (2005; 2006), where crop combination in an intercrop system readily influenced leaf areas in millet or maize-based intercrop systems. Such influence on leaf area may translate into yield variation (Oyewole *et al.*, 2005; 2006; Oyewole, 2010; 2011). The observed intercrop combination influence on leaf area in the

2020 cropping season is not unconnected with the variation between sole crop and other cropping patterns. In the repeated trial, the 2021 cropping season, intercrop combination did not influence leaf area (Table 5), an indication that the observed intercrop combination influences on leaf area is not a definite outcome and could vary with season.

Table 3 Interaction effect between intercrop combination and tillage practice on average height (cm) of maize in 2021 cropping season

Planting pattern	Tillage practice		
	Ridge	Flat	Zero tillage
3 WAP			
Sole maize	29.77 ± 3.01 ^c	31.23 ± 2.11 ^a	31.00 ± 2.32 ^b
2 maize:1 g/nut	25.01 ± 2.11 ^g	25.71 ± 2.33 ^{ef}	25.11 ± 2.00 ^g
2 g/nut:1 maize	26.64 ± 1.45 ^{de}	25.37 ± 2.55 ^{fg}	26.05 ± 3.11 ^{def}
1 maize:1 g/nut	25.02 ± 2.11 ^g	26.80 ± 2.12 ^d	25.50 ± 2.12 ^{fg}
SE (±)		0.936	
5 WAP			
Sole maize	47.31 ± 2.00 ^{bc}	49.84 ± 2.91 ^a	48.61 ± 4.12 ^{ab}
2 maize:1 g/nut	30.93 ± 3.12 ^h	40.63 ± 2.00 ^{ef}	42.69 ± 3.00 ^{de}
2 g/nut:1 maize	45.45 ± 3.55 ^c	32.98 ± 2.11 ^{gh}	38.50 ± 3.98 ^f
1 maize:1 g/nut	35.07 ± 1.11 ^g	42.36 ± 2.88 ^{de}	39.26 ± 3.07 ^f
SE (±)		2.133	
7 WAP			
Sole maize	92.33 ± 2.11 ^c	102.20 ± 2.00 ^a	94.35 ± 2.22 ^b
2 maize:1 g/nut	76.47 ± 1.76 ^f	84.15 ± 1.00 ^e	82.31 ± 1.00 ^e
2 g/nut:1 maize	88.16 ± 2.11 ^d	74.84 ± 1.00 ^{fg}	77.52 ± 2.11 ^f
1 maize:1 g/nut	71.83 ± 2.22 ^g	85.41 ± 2.11 ^{de}	82.30 ± 2.76 ^e
SE (±)		3.891	
9 WAP			
Sole maize	163.09 ± 2.33 ^{bc}	181.59 ± 2.00 ^a	168.03 ± 2.45 ^b
2 maize:1 g/nut	155.93 ± 1.00 ^{de}	154.01 ± 2.02 ^{de}	159.45 ± 2.17 ^{cd}
2 g/nut:1 maize	153.64 ± 2.00 ^{ef}	149.50 ± 2.87 ^f	147.06 ± 2.66 ^f
1 maize:1 g/nut	146.13 ± 2.34 ^f	161.83 ± 2.34 ^{bc}	153.10 ± 2.78 ^{ef}
SE (±)		7.785	

Note: WAP = week after planting, g/nut = groundnut, SE = standard error. Means followed by the same letter(s) are not statistically different at 5% level of probability.

Data collected on tillage practice indicates that tillage only significantly ($P < 0.05$) influenced leaf areas in maize at 3 WAP in 2020, but not at any other time in both seasons. The early observed effect of tillage practice on leaf area at 3 WAP in 2020 can be judged coincidental. No significant interactions ($P > 0.05$) were observed throughout the period of data collection on leaf areas in 2020 (Table 5). However, in the 2021 cropping season there were observed significant interactions ($P < 0.05$) between crop combination and tillage practice on leaf areas at 3, 5, 7, and 9 WAP (Table 6). While it could be generally deduced that intercrop combination or tillage practice may not influence the number of leaves in maize as shown in the trial, such deduction may not hold for leaf areas; as treatment combination (crop combination and tillage practice) significantly influenced leaf areas in 2021.

Effect of Planting Pattern, Tillage Practice, and Their Interactions on Crop Development, Yield and Yield Components

Days to 50 percent tassel, as well as 50 percent silk formation, did not respond significantly ($P > 0.05$) to intercrop combination as well as tillage practice in the 2020 and 2021 cropping seasons (Table 7). No significant interactions ($P > 0.05$) were observed between planting patterns and tillage practice on these parameters in both seasons. Stover yield responded significantly to planting patterns and tillage practice in the 2020 and 2021 cropping seasons (Table 8). In the 2020 cropping

season, the highest stover weight (2.23 t/ha) was obtained in the sole crop which was followed by the planting of one row of maize to one row of groundnut. The lowest stover yield was observed when combining one row of maize with two rows of groundnuts. In the 2021 cropping season, sole maize still gave the highest stover yield (2.02 t/ha), followed by cropping two rows of maize to one row of groundnut with the least stover yield still obtained when one row of maize was cropped with two rows of groundnut. For the tillage treatment, the best response was obtained when maize was planted on the flat, while sowing maize on ridges, consistently gave the poorest response relative to stover yield in the 2020 and 2021 cropping seasons. There were consistent interactions between planting patterns and tillage practice on stover yield (Tables 8–10).

The expectation is that all meaningful variations resulting from the imposed treatment should translate into yield variations. Data taken on cobs reveal that the number of cobs per plant did not respond to intercrop combination, tillage practice, or their interactions in the 2020 and 2021 cropping seasons (Table 11). However, cob length and girth responded significantly to intercrop combination in both seasons (Table 11) but not to the tillage practice investigated. That sole plots gave the best cob length and girth in both seasons could be attributed to population per unit area, which did not negatively impact the environment of plant nutrients, in the soil and the above-ground environment to produce meaningful negative effects regarding the treatment of these parameters.

Table 4 Effect of planting pattern and tillage practice on the average number of leaves in maize in Anyigba

Treatment	Number of leaves								
	2020 cropping season			2021 cropping season			2021 cropping season		
	3 WAP	5 WAP	7 WAP	9 WAP	3 WAP	5 WAP	7 WAP	9 WAP	9 WAP
Planting pattern (P)									
Sole maize	6.70 ± 0.1	9.28 ± 1.1	14.29 ± 1.0	15.28 ± 1.1	6.70 ± 0.0	9.28 ± 1.0	14.29 ± 1.0	15.28 ± 1.0	15.28 ± 1.0
2 maize:1 g/nut	7.02 ± 1.1	9.19 ± 1.0	12.51 ± 1.2	14.10 ± 1.1	7.02 ± 1.1	9.19 ± 1.0	12.51 ± 1.0	14.10 ± 1.0	14.10 ± 1.0
2 g/nut:1 maize	6.50 ± 1.1	9.91 ± 1.1	12.17 ± 1.0	13.80 ± 1.1	6.50 ± 1.0	9.91 ± 1.1	12.17 ± 1.0	13.80 ± 1.0	13.80 ± 1.0
1 maize:1 g/nut	6.80 ± 0.9	9.19 ± 1.2	12.86 ± 1.1	14.13 ± 0.7	6.80 ± 1.0	9.19 ± 1.0	12.86 ± 1.0	14.13 ± 0.0	14.13 ± 0.0
LSD (0.05)	0.862 ^{ns}	1.225 ^{ns}	2.690 ^{ns}	3.631 ^{ns}	0.786 ^{ns}	1.492 ^{ns}	2.627 ^{ns}	1.561 ^{ns}	1.561 ^{ns}
Tillage practice (T)									
Ridge	5.39 ± 1.1	6.00 ± 0.9	9.94 ± 1.0	11.17 ± 1.1	5.39 ± 1.0	6.00 ± 1.0	9.94 ± 1.0	11.17 ± 1.0	11.17 ± 1.0
Flat	5.62 ± 1.1	7.55 ± 1.1	10.75 ± 2.1	11.80 ± 1.1	5.62 ± 1.0	7.55 ± 1.2	10.75 ± 1.0	11.80 ± 1.0	11.80 ± 1.0
Zero tillage	5.20 ± 0.9	7.23 ± 1.0	10.41 ± 1.4	11.43 ± 1.1	5.20 ± 1.0	7.23 ± 1.0	10.41 ± 1.0	11.43 ± 1.0	11.43 ± 1.0
LSD (0.05)	0.374 ^{ns}	1.705 ^{ns}	2.485 ^{ns}	2.432 ^{ns}	0.739 ^{ns}	1.223 ^{ns}	1.634 ^{ns}	0.913 ^{ns}	0.913 ^{ns}

Note: WAP = weeks after planting, g/nut = groundnut, LSD = least significant difference. NS = not significant at 5% level of probability.

Table 5 Effect of planting pattern, tillage practice, and their interactions on leaf area (cm²) in maize in Anyigba

Treatment	Leaf area (cm ²)									
	2020 cropping season					2021 cropping season				
	3 WAP	5 WAP	7 WAP	9 WAP	3 WAP	5 WAP	7 WAP	9 WAP		
Planting pattern (P)										
Sole maize	87.33 ^a	335.75 ^a	460.76 ^a	466.84 ^a	44.85	202.34	347.27	393.73		
2 maize:1 g/nut	44.85 ^b	202.34 ^b	347.27 ^b	393.73 ^b	41.55	176.84	315.00	394.94		
2 g/nut:1 maize	41.55 ^b	176.84 ^b	315.00 ^b	394.94 ^b	51.98	213.71	361.56	394.94		
1 maize:1 g/nut	51.98 ^b	213.71 ^b	361.56 ^b	394.94 ^b	44.85	202.34	347.27	393.73		
LSD (0.05)	9.265*	53.785*	61.529*	47.239*	12.852 ^{ns}	48.562 ^{ns}	58.890 ^{ns}	42.630 ^{ns}		
Tillage practice (T)										
Ridge	38.83 ^b	168.35	287.29	316.01	60.72	134.85	330.22	372.90		
Flat	50.17 ^a	203.71	304.09	335.83	68.49	162.42	366.01	412.86		
Zero tillage	46.42 ^{ab}	185.13	299.37	322.76	69.52	160.94	339.52	378.63		
LSD (0.05)	9.196*	37.631 ^{ns}	45.642 ^{ns}	33.600 ^{ns}	9.268 ^{ns}	21.736 ^{ns}	36.478 ^{ns}	31.852 ^{ns}		
Interaction										
P x T	ns	ns	ns	ns	*	*	*	*		
CV (%)	24.6	21.7	24.1	15.9	21.9	21.9	16.1	12.9		

Note: WAP = weeks after planting, g/nut = groundnut, LSD = least significant difference. * Significant at 5% level of probability, NS = not significant at 5% level of probability. Means followed by the same letter(s) are not statistically different at 5% level of probability. Note the interaction effects marked (*) are contained on Table 6 below.

Table 6 Interaction effect between planting pattern and tillage practice on average leaf area (cm²) in 2021 cropping season

Planting pattern	Tillage practice		
	Ridge	Flat	Zero tillage
3 WAP			
Sole maize	69.32 ^b	99.26 ^a	93.41 ^a
2 maize:1 g/nut	33.61 ^{fg}	55.73 ^c	45.22 ^{de}
2 g/nut:1 maize	51.32 ^{cd}	30.68 ^g	42.66 ^e
1 maize:1 g/nut	39.92 ^{ef}	65.20 ^b	50.81 ^{cd}
SE (±)		7.804	
5 WAP			
Sole maize	294.19 ^c	376.15 ^a	336.92 ^b
2 maize:1 g/nut	157.99 ^{hi}	254.46 ^d	194.58 ^{fg}
2 g/nut:1 maize	227.98 ^{de}	132.19 ⁱ	170.36 ^{gh}
1 maize:1 g/nut	161.59 ^{hi}	255.73 ^d	223.80 ^{ef}
SE (±)		29.478	
7 WAP			
Sole maize	452.63 ^a	471.72 ^a	457.92 ^a
2 maize:1 g/nut	329.70 ^{def}	374.11 ^b	338.01 ^{cde}
2 g/nut:1 maize	295.02 ^f	305.31 ^{ef}	344.67 ^{bcd}
1 maize:1 g/nut	359.11 ^{bcd}	369.33 ^{bc}	356.26 ^{bcd}
SE (±)		35.740	
9 WAP			
Sole maize	456.79 ^a	480.36 ^a	463.39 ^a
2 maize:1 g/nut	364.93 ^d	410.55 ^b	405.72 ^{bc}
2 g/nut:1 maize	383.62 ^{cd}	359.72 ^d	363.17 ^d
1 maize:1 g/nut	374.73 ^d	428.56 ^b	381.55 ^{cd}
SE (±)		25.851	

Note: WAP = week after planting, g/nut = groundnut, SE = standard error. Means followed by the same letter(s) are not statistically different at 5% level of probability.

Other yield components, such as seeds per row and 100-seed weight, did not respond significantly to intercrop combination, tillage practice as well and their interactions in both cropping seasons. In the 2020 cropping season, cob weight per ha, and seeds per cob responded significantly to intercrop combination, but not to tillage practice or the interactions between intercrop combination and tillage practice. However, in 2021, those parameters responded significantly to intercrop combination, tillage practice, and their interactions. The highest grain yield per ha was generally obtained in sole plots in 2020

and 2021, with two rows of maize to one row of groundnut giving the lowest grain yield in both trials (Table 12).

Planting seeds on the flat gave the best grain yield, with seeds planted on ridges giving the lowest grain yield in both seasons (Table 12). The response of the intercrop combination and tillage practice to water availability determined treatment outcomes, particularly as it relates to yield. Intercropping was generally advantageous, with intercropping maize and groundnut at 1:1 row giving the highest LER and intercropping maize and groundnut at 2:1 row giving the lowest LER.

Table 7 Effect of planting pattern, tillage practice, and their interactions on crop development

Treatment	2020 cropping season		2021 cropping season	
	Days to 50 percent tassel	Days to 50 percent silking	Days to 50 percent tassel	Days to 50 percent silking
Planting pattern (P)				
Sole maize	57.08 ± 2.0	64.75 ± 2.0	56.17 ± 1.0	61.92 ± 2.0
2 maize:1 g/nut	55.75 ± 1.0	63.42 ± 2.0	56.50 ± 1.0	62.58 ± 1.0
2 g/nut:1 maize	57.08 ± 1.0	63.83 ± 2.0	57.25 ± 2.0	62.50 ± 1.0
1 maize:1 g/nut	56.17 ± 1.0	63.42 ± 1.0	56.75 ± 1.0	63.92 ± 1.0
LSD	2.325 ^{ns}	1.817 ^{ns}	1.252 ^{ns}	2.062 ^{ns}
Tillage practice (T)				
Ridge	45.45 ± 1.0	51.20 ± 0.0	45.45 ± 1.0	50.75 ± 0.0
Flat	44.55 ± 1.0	50.40 ± 1.0	45.45 ± 1.0	49.90 ± 1.0
Zero tillage	45.65 ± 1.0	51.65 ± 2.0	45.10 ± 1.0	49.90 ± 1.0
LSD	1.02 ^{ns}	1.40 ^{ns}	0.97 ^{ns}	1.59 ^{ns}
Interaction P × T	ns	ns	ns	ns
CV (%)	3.5	4.3	0.97	1.59

Note: g/nut = groundnut, LSD = least significant difference, CV = coefficient of variation, NS = not significant at 5% level of probability.

Table 8 Effect of planting pattern, tillage practice, and their interactions on stover (maize) and haulm yield (groundnut)

Treatment	2020 cropping season		2021 cropping season	
	Stover yield (maize) t/ha	Haulm yield (groundnut) t/ha	Stover yield (maize) t/ha	Haulm yield (groundnut) t/ha
Planting pattern (P)				
Sole maize	2.23 ^a	-	2.02 ^a	-
Sole groundnut	-	0.96 ^a	-	0.86
2 maize:1 g/nut	1.12 ^b	0.48 ^b	1.10 ^{bc}	0.40
2 g/nut:1 maize	0.98 ^b	0.49 ^b	0.92 ^c	0.36
1 maize:1 g/nut	1.13 ^b	0.51 ^b	1.06 ^{bc}	0.36
LSD	0.34 [*]	0.12 [*]	0.27 [*]	0.10 ^{ns}

Table 8 Cont.

Treatment	2020 cropping season		2021 cropping season	
	Stover yield (maize) t/ha	Haulm yield (groundnut) t/ha	Stover yield (maize) t/ha	Haulm yield (groundnut) t/ha
Tillage practice (T)				
Ridge	0.99 ^b	0.42	0.86 ^b	0.41
Flat	1.29 ^a	0.51	1.11 ^a	0.39
Zero tillage	1.00 ^b	0.53	1.09 ^a	0.39
LSD	0.263 [*]	0.902 ^{ns}	0.21 [*]	0.79 ^{ns}
Interaction P × T	*	ns	*	ns
CV (%)	27.4	28.9	22.3	21.1

Note: g/nut = groundnut, LSD = least significant difference, CV = coefficient of variation. * Significant at 5% level of probability, NS = not significant at 5% level of probability. Means followed by the same letter(s) are not statistically different at 5% level of probability. Note the interaction effects marked (*) are contained in Tables 9 and 10 below.

Table 9 Interaction effect between planting pattern and tillage practice on stover yield in 2020 cropping season

Planting pattern	Tillage practice		
	Ridge	Flat	Zero tillage
Sole maize	1.96 ^b	2.45 ^a	2.29 ^a
2 maize:1 g/nut	0.95 ^e	1.29 ^d	1.11 ^d
2 g/nut:1 maize	1.15 ^d	0.96 ^{de}	0.84 ^e
1 maize:1 g/nut	0.88 ^e	1.73 ^c	0.78 ^e
SE (±)		0.202	

Note: g/nut = groundnut, SE = standard error. Means followed by the same letter(s) are not statistically different at 5% level of probability

Table 10 Interaction effect between planting pattern and tillage practice on stover yield in 2021 cropping season

Planting pattern	Tillage practice		
	Ridge	Flat	Zero tillage
Sole maize	1.73 ^c	2.28 ^a	2.05 ^b
2 maize:1 g/nut	0.95 ^{gh}	1.13 ^{ef}	1.23 ^{de}
2 g/nut:1 maize	0.85 ^{hi}	0.78 ⁱ	1.13 ^{ef}
1 maize:1 g/nut	0.78 ⁱ	1.35 ^d	1.05 ^{fg}
SE (±)		0.163	

Note: g/nut = groundnut, SE = standard error. Means followed by the same letter(s) are not statistically different at 5% level of probability.

Table 11 Effect of planting pattern, tillage practice, and their interactions on the number of seeds per row, number of cobs per plant, cob length and cob girth in 2020 and 2021 cropping seasons

Treatment	2020 cropping season					2021 cropping season				
	Cobs per plant	Cob length (cm)	Cob girth (cm)	Seeds per row	100-seed weight (g)	Cobs per plant	Cob length (cm)	Cob girth (cm)	Seeds per row	100-seed weight (g)
Planting pattern (P)										
Sole maize	1.60	12.92 ^a	3.34 ^a	27.42	13.30	1.50	20.29 ^a	6.50 ^a	40.50	27.63
2 maize:1 g/nut	1.50	10.81 ^b	3.13 ^{ab}	24.58	13.50	1.45	15.37 ^b	5.00 ^b	36.00	27.63
2 g/nut:1 maize	1.30	10.63 ^b	3.00 ^b	22.67	13.50	1.22	16.09 ^b	5.11 ^b	35.54	27.39
1 maize:1 g/nut	1.40	11.09 ^b	3.20 ^{ab}	23.71	13.50	1.32	15.92 ^b	5.10 ^b	35.57	27.63
LSD	0.897 ^{ns}	1.57 [*]	0.303 [*]	6.822 ^{ns}	2.214 ^{ns}	0.151 ^{ns}	1.443 [*]	0.244 [*]	5.382 ^{ns}	2.975 ^{ns}
Tillage practice (T)										
Ridge	1.40	8.79	2.55	19.15	11.00	1.20	13.08	4.13	38.59	22.74
Flat	1.42	9.40	2.58	19.15	11.80	1.30	14.70	4.63	38.50	22.75
Zero tillage	1.30	9.09	2.48	20.00	11.30	1.34	12.83	4.27	37.40	22.94
LSD	0.061 ^{ns}	1.225 ^{ns}	0.233 ^{ns}	4.171 ^{ns}	1.730 ^{ns}	0.044 ^{ns}	2.114 ^{ns}	0.183 ^{ns}	4.161 ^{ns}	1.89 ^{ns}
Interaction										
P x T	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
CV (%)	24.1	21.0	14.4	23.2	23.9	27.4	12.9	6.6	22.2	6.0

Note: g/nut = groundnut, LSD = least significant difference, CV = coefficient of variation. * Significant at 5% level of probability, NS = not significant at 5% level of probability. Means followed by the same letter(s) are not statistically different at 5% level of probability.

Table 12 Effect of planting pattern, tillage practice, and their interactions on cob weight, seeds per cob, and grain yield in 2020 and 2021 cropping seasons

Treatment	2020 cropping season				2021 cropping season			
	Cob weight (t/ha)	Seeds per cob	Grain yield (t/ha)	Land equivalent ratio	Cob weight (t/ha)	Seeds per cob	Grain yield (t/ha)	Land equivalent ratio
Planting pattern (P)								
Sole maize	207.33 ^a	316.25 ^a	2.37 ^a	-	954.32 ^a	2,492.33 ^a	5.95 ^a	
2 maize:1 g/nut	107.59 ^b	256.75 ^b	1.57 ^b	1.28	437.65 ^c	1,133.50 ^b	4.54 ^b	1.19
2 g/nut:1 maize	108.67 ^b	254.83 ^b	1.70 ^b	1.29	472.22 ^b	1,199.25 ^b	4.77 ^b	1.28
1 maize:1 g/nut	103.27 ^b	271.17 ^b	1.70 ^b	1.38	481.48 ^b	1,205.42 ^b	4.65 ^b	1.32
LSD	23.527*	51.000*	0.44*	-	32.660*	271.050*	0.346*	
Tillage practice (T)								
Ridge	87.51	216.05	1.37	1.06	414.44 ^c	1026.65 ^b	3.88	1.38
Flat	101.19	223.80	1.53	1.25	515.19 ^a	1434.95 ^a	4.08	1.40
Zero tillage	95.07	219.55	1.51	1.28	477.78 ^b	1156.70 ^b	3.99	1.42
LSD	33.715 ^{ns}	39.510 ^{ns}	0.344 ^{ns}		22.757*	209.951*	0.265 ^{ns}	
Interaction								
P x T	ns	ns	*		*	*	*	
CV (%)	21.4	28.2	26.0		25.4	27.3	10.3	

Note: g/nut = groundnut, LSD = least significant difference, CV = coefficient of variation. * Significant at 5% level of probability, NS = not significant at 5% level of probability. Means followed by the same letter(s) are not statistically different at 5% level of probability.

CONCLUSIONS

Generally, it should be expected that meaningful variations resulting from the imposed treatment should eventually translate into yield variations among the treatment components. The significant effect of intercrop combination on grain yield per ha justified this expectation. In addition, cob length and girth responded significantly to intercrop combination in both seasons but not to tillage practice. That sole plot gave the best cob length, girth, and grain yield in both seasons, indicating that intra-plant competition among the maize crop for nutrients and solar radiation did not attain a negative level to task the environment. The highest grain yields per ha were generally obtained in sole plots, with two rows of maize to one row of

groundnut giving the lowest grain yield. Planting seeds on the flat gave the best grain yield, with seeds planted on ridges giving the lowest grain yield in both seasons, with water probably as the limiting factor. Intercropping was generally advantageous, in terms of land use efficiency. Intercropping was generally advantageous. Intercropping is recommended for the experimental area despite the sole crop giving the highest yields.

ACKNOWLEDGEMENTS

We acknowledge the Department of Crop Production, Kogi State University, Anyigba, the Faculty of Agriculture of the same institution, and the University for providing the enabling environment to conduct this research.

REFERENCES

- Abdullah, G. Hassan, I.A. Khan, S.A. Khan and H. Ali. 2008. Impact of planting methods and herbicides on weed biomass and some agronomic traits of maize. *Pak. J. Weed Sci. Res.* 14(3-4): 121–130.
- Adetimirin, V.O., I. Vroh-Bi, C. The, A. Menkir, S.E. Mitchell and S. Kresovich. 2008. Diversity analysis of elite maize inbred lines adapted to West and Central Africa using SSR markers. *Maydica.* 53: 143–149.
- Atkinson, B.S., D.L. Sparkes and S.J. Mooney. 2007. Using selected soil physical properties of seedbeds to predict crop establishment. *Soil Tillage Res.* 97(2): 218–228. <https://doi.org/10.1016/j.still.2007.09.017>.
- Attah, E.S. and C.I. Oyewole. 2013. Effect of planting pattern on the performance of intercropped maize (*Zea mays*) and egusi melon (*Colocynthis citrullus*) in Anyigba, Kogi State, pp. 25–28. *In: Proceedings of the 1st National Conference of the Crop Science Society of Nigeria.* University of Nigeria Nsukka, Enugu State, Nigeria.
- Chikoye, D., U.E. Udensi and A. Fontem Lum. 2005. Evaluation of a new formulation of atrazine and metolachlor mixture for weed control in maize in Nigeria. *Crop Prot.* 24(11): 1016–1020. <https://doi.org/10.1016/j.cropro.2005.02.011>.
- Donald, C.M. 1958. The interaction of competition for light and for nutrients. *Aust. J. Agric. Res.* 9: 421–435. <https://doi.org/10.1071/AR9580421>.
- FAO (Food and Agricultural Organization of the United Nations). 2012. FAOSTAT. Available Source: <https://www.fao.org/faostat/en/>.
- Husnjak, S., D. Filipović and S. Košutić. 2002. Influence of different tillage systems on soil physical properties and crop yield. *Rostlinná Výroba.* 48(6): 249–254.
- Imoloame, E.O. and J.O. Omolaiye. 2016. Impact of different periods of weed interference on growth and yield of maize (*Zea mays* L.). *Trop. Agric.* 93(4): 245–257.

- Josa, R., M. Ginovart and A. Solé. 2010. Effects of two tillage techniques on soil macroporosity in sub-humid environment. *Int. Agrophys.* 24(2): 139–147.
- Karayel, D. 2009. Performance of a modified precision vacuum seeder for no-till sowing of maize and soybean. *Soil Tillage Res.* 104(1): 121–125. <https://doi.org/10.1016/j.still.2009.02.001>.
- Lagoke, S.T.O., S.O. Adeosun, K.A. Elemo, V.O. Chude and J.A.Y. Shebayan. 1998. Herbicide evaluation for the control of weeds in maize at Samaru, pp. 90–91. *In: Report on Cereals Research Cropping Scheme Meeting.* Institute for Agricultural Research, Zaria, Nigeria.
- Liu, J., D.A. Lobb, Y. Chen and R.L. Kushwaha. 2008. Steady-state models for the movement of soil and straw during tillage with a single sweep. *Trans ASABE.* 51(3): 781–789. <https://doi.org/10.13031/2013.24514>.
- Musa, U.T. and T.H. Usman. 2016. Leaf area determination for maize (*Zea mays* L.), okra (*Abelmoschus esculentus* L.) and cowpea (*Vigna unguiculata* L.) crops using linear measurements. *J. Biol. Agric. Healthc.* 6(4): 103–111.
- Ologunde, O.O. and V.B. Ogunlela. 1984. Relationship of plant density and nitrogen fertilization to maize performance in the Southern Guinea Savanna of Nigeria. *Samaru Journal of Agricultural Research.* 2(1–2): 99–109.
- Oyewole, C.I. 2010. Maize (*Zea mays* L.) - okra (*Abelmoschus esculentus* (L.) Moench) intercrop as affected by cropping pattern in Kogi State, Nigeria. *Continental J. Agronomy.* 4: 1–9.
- Oyewole, C.I. 2011. Yield and Economic Implication of Intercropping Millet and Groundnut: Effects of Cropping Pattern, P and K on Growth and Yield of Millet and Groundnut in Mixture in Sudan Savanna. LAP Lambert Academic Publishing, Saarbrucken, Deutschland.
- Oyewole, C.I. and B.A.O. Ibikunle. 2010. The germination of corn weed (*Rottboellia cochinchinensis* Lour Clayton) seed: Induction and prevention of germination in seed. *Thai J. Agric. Sci.* 43(1): 47–54.
- Oyewole, C.I., E.S. Attah and M.D. Magaji. 2006. Economic and yield advantages of intercropping: a case study of millet (*Pennisetum glaucum*) – groundnut (*Arachis hypogaea*) system in Sudan savanna agro-ecological zone of Nigeria. *Confluence Journal of Environmental Studies.* 1(1): 12–20.
- Oyewole, C.I., J.O. Maha, O.A. Olushepe and M.U. Tanko. 2015a. Spacing effect on leaf area formation in maize: 1. Correlation studies in growth, development, yield components and yield. *Journal of Global Agriculture and Ecology.* 3(3): 137–143.
- Oyewole, C.I., M.D. Magaji, A.I. Yakubu, S.A. Ibrahim and A. Singh. 2005. Intercropping millet with groundnut implication for food security in Nigeria. *Bulletin of Science Association of Nigeria.* 26: 131–137.
- Oyewole, C.I., O.A. Olushepe and M.U. Tanko. 2015b. Correlation studies in growth, yield components and yield in maize (*Zea mays*) in Anyigba, Kogi State, Nigeria. *Journal of Global Agriculture and Ecology.* 2(2): 47–51.
- Ozpinar, S. and A. Isik. 2004. Effects of tillage, ridging and row spacing on seedling emergence and yield of cotton. *Soil Tillage Res.* 75(1): 19–26. <https://doi.org/10.1016/j.still.2003.07.004>.
- SAS (Statistical Analysis System). 1998. SAS Users Guide. Statistical Analysis Institute, North Carolina, USA.

- Srivastava, A.K., C.E. Goering, R.P. Rohrbach and D.R. Buckmaster. 2006. Engineering Principles of Agricultural Machines. 2nd Edition. American Society of Agricultural Biological Engineers, Michigan, USA.
- Steiner, K.G. 1991. Overcoming soil fertility constraints to crop production in West Africa: Impact of traditional and improved cropping systems on soil fertility, pp. 69–91. *In*: A.U. Mokwunye, (Ed.), Alleviating Soil Fertility Constraints to Increased Crop Production in West Africa. Springer Dordrecht, Dordrecht, Netherlands.
- Willey, R.W. and D.S.O. Osiru. 1972. Studies on mixtures of maize and beans (*Phaseolus vulgaris*) with particular reference to plant population. *J. Agric. Sci.* 79(3): 517–529. <https://doi.org/10.1017/S0021859600025909>.
- Wright, D., J. Marois, J. Rich and R. Sprenkel. 2008. Field Corn Production Guide. Institute of Food and Agricultural Sciences, University of Florida, Florida, USA.
- Zhang, G., Z. Yang and S. Dong. 2011. Interspecific competitiveness affects the total biomass yield in an alfalfa and corn intercropping system. *Field Crops Res.* 124(1): 66–73. <https://doi.org/10.1016/j.fcr.2011.06.006>.