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Response of groundnut varieties to planting densities of maize in groundnut/maize intercropping in Makurdi, Nigeria

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ABSTRACT

The field experiment was conducted out at the Teaching and Research farm of Joseph Sarwuan Tarka University in Makurdi. during the 2018 and 2019 farming seasons to evaluate the performance of three groundnut varieties (SAMNUT 23, SAMNUT 24 and SAMNUT 25) in intercropping with maize at three levels of intra-row spacings (50 cm, 75 cm and 100 cm). The experiment was laid out in factorial arrangement in a Randomized Complete Block Design (RCBD) in three replications. The study revealed that the highest groundnut pod yields (2276.55kg/ha in 2018 and 2355.11kg/ha in 2019) in the sole cropping system, whereas in intercropping, pod yield (2090.07kg/ha in 2018 and 2165.24kg/ha in 2019) of groundnut were highest when combined with maize at 100 cm intra-row spacing. Groundnut variety, SAMNUT 23 had pod yields (1991.68kg/ha and 1959.84kg/ha) superior to other varieties in intercropping in 2018 and 2019 respectively. Groundnut pod yields in intercropped irrespective of varieties was highest at 100 cm and least at 50 cm intra-row spacing of maize. The highest maize output (1524.85 kg/ha and 1645.95kg/ha grain yields) in 2018 and 2019 respectively were achieved at intra-row spacing of 50 cm in intercropping with Groundnut variety, SAMNUT 24. The highest Land Equivalent Ratio of 1.30 and 1.32 were observed in 2018 and 2019 respectively when maize planed at intra-row spacing of 75 cm was combined with the Groundnut variety, SAMNUT 23. SAMNUT 23 intercropped with maize at 75 cm intra-row spacing is thus recommended for optimal intercrop yield in Makurdi.

Keywords: Maize densities, Groundnut varieties, intercropping, growth, yield

INTRODUCTION

Intercropping is the cultivation of two or more crops on the same plot of land within a single year (Okpara *et al.,* 2005; Seran and Brintha, 2010). Farmers on small farms cultivate many crops to reduce the danger of total crop failure and to get a variety of produce to meet the family's food, income, and other needs (Ullah *et al*., 2007; Salisu *et al.,* 2023). Seran and Brintha (2010) reported that subsistence farmers in the tropics use intercropping as a crop production strategy. Recent study findings indicate that intercropping will continue to benefit these small-scale farmers for obvious reasons. Intercropping promotes food security, which is seen as more significant than food maximization as well as maintenance of sustainable agricultural development (Undie *et al.,* 2013; Stomph *et al.,* 2020; Dong *et al.,* 2022). It also controls weeds, boosts monetary returns to farmers, and yields greater than single cropping (Seran and Brintha, 2010). Groundnut (*Arachis hypogeal* L.) is a legume oil crop from the Fabaceae family. It is a good source of protein for humans and contains non-drying oil cake used in animal feed (Undie *et al.,* 2013). In Southeast Nigeria's, groundnut is commonly intercropped alongside maize, okra, and yam. They have the potential to improve soil fertility due to their capacity to develop root nodules that fix atmospheric nitrogen, benefitting from subsequent crops whether planted as a single culture or intercropped with other plants (Thilakarathna *et al.,* 2012).

Maize (*Zea mays* L.) is ranked as the world's third most important cereal crop for both human and animal consumption (FAO, 2015), contributing significantly to the economic prosperity of many developing nations. It is a significant carbohydrate source in the human diet and animal feed globally (Onasanya *et al.,* 2009; Salisu *et al.,* 2023).

The performance of groundnut-maize intercropping systems is primarily determined by crop variety selection and component crop planting densities, among other factors (Maitra *et al.,* 2020). Most intercropping experiments show that while the yield of a crop in a combination may be lower than that of the same crop grown alone, the overall productivity per unit area of land is typically higher for mixtures than for solo crops (Willey, 1979; Nyimas *et al.,* 2015).

When crops compete for resources needed for growth and development in intercropping circumstances, they are more prone to experience physiological dysfunction, which can lead to poor expression

of their yield potential (Zaki *et al.,* 2008). The competitive effects arise mostly from the plant population densities and their spatial arrangements in time dimensions which determine the degree of competition for light and soil nutrients arising again from varieties differing in growth habits and cycle. Muoneke *et al*., (2019) reported that optimum plant density and choice of suitable varieties are good measures of regulating competition among component crops for a profitable intercropping system. The authors observed that increasing plant density of the cereal component beyond a certain limit leads to decreasing legume component yields. Farming systems scientists are fully aware of these and have provided sound and general recommendations that could minimize those competitive effects especially, in cereal – legume mixtures involving maize and groundnut. However, standard spacing for maize and groundnut sole crops are well established. There still exists dearth of information on eco-typic environments represented by specific locations. In this wise, there is still a dearth of information regarding specific locations in Makurdi. The study's goal was to determine the effect of groundnut cultivars on maize planting densities as well as their intercrop benefits.

MATERIALS AND METHODS

Study Area:

The field experiment was conducted for two growing seasons (2018 and 2019) at the Teaching and Research Farm at the Federal University of Agriculture, Makurdi, Benue state, located at Latitude 7^0 $47^{'}$ $45^{''}$ N, and Longitude 8^0 $36^{'}$ $57^{''}$ E, at elevation altitude 98m above sea level within the southern guinea savanna agro-ecological zone of Nigeria. The rainy season lasts from April to October, with the dry season lasting five months (November to March). The average annual rainfall is 1140 mm yr-1 (Agada *et al*., 2016). The mean annual temperature ranges from 29 – 32 °C. February and March are marked as the hottest months.

Experimental Layout:

The site was done manually, with a 75 cm inter-row spacing. Groundnut was planted at the ridge crest with an intra-row spacing of 20 cm (133,333 plants per hectare). Maize was planted at the foot of ridges on the same day in three levels: 100 cm intra-row spacing (26,666 plants/ha), 75 cm intra-row spacing (35,556 plants/ha), and 50 cm intra-row spacing (53,333 plants/ha). Weeding was done manually at the appropriate time.

Experimental Treatments and Design:

The experimental factors included three groundnut cultivars (SAMNUT 23, SAMNUT 24 and SAMNUT 25) that were intercropped with maize (OBA SUPER - 6) at three levels of planting area. The three varieties of groundnut were maintained at optimum population of (133,333.33 plants/ha) in intercrop and in sole, while maize (one variety) varied at three populations (intra-row spacing of 100 cm 75 cm and 50 cm) laid out in a Randomized Complete Block Design (RCBD) and replicated 3 times. Sole maize was planted at 50 cm intra-row spacing).

The experiment consisted of 13 treatment combinations, which were replicated thrice, giving a total of 27 treatments combination on a land area 45 m x 14 m = 630 m^2. The soil samples were bulked together, air-dried, and analyzed at the Department of Soil Science Laboratory, Joseph Sarwuan Tarka University, Makurdi (JOSTUM) for routine soil analysis. 300 kg ssp/ha + 100 kg NPK 20:10:10/ha was applied basal application (broadcast before ridging) for groundnut plots while 300kg/ha NPK 20:10:10 was used to top dress the sole and the intercropped maize six weeks after planting (WAP).

Data Collection

The following traits were considered: Plant height (cm), leaf area index (m^2), number of branches, number of pods per plant; Number of seeds per pod; pod weight (g); 100 seeds weight (g); and seeds yield (kg/ha) for groundnut whereas plant height (cm); stem diameter (cm); leaf area index (m^2); Days till 50% tasseling. Cob length (cm); Cob diameter (cm); Cob weight. Weight of grains per cob; 100 grain weight (g); Total grain production (kg/ha) for maize.

Statistical Analysis

Data collected were subjected to analysis of variance (ANOVA) using GENSTAT statistical software 17.1DE (2015), and means were separated using Fisher's Least Significant Difference (F-LSD) at 5% level of probability. Land equivalent coefficient (LEC); %land saved and Land Equivalent Ratio (LER) was used to calculate the yield advantage. LER was calculated according to the formula (Ofori and Stern, 1987).

$$\text{LER} = \frac{\text{Yield of intercropped groundnut}}{\text{Yield of sole groundnut}} + \frac{Yield\ of\ intercropped\ maize}{Yield\ of\ sole\ maize}$$

RESULTS

Physico-chemical properties of the experimental soil and Meteorological Information for Makurdi, Nigeria (August to October) in Year 2018/2019

The meteorological information for Makurdi during the months of April to November in cropping seasons 2018/2019 cropping season is shown in Table 1. Rainfall occurred from the month of April to November in the cropping seasons of 2018/2019. The month of August for the both growing seasons recorded the highest amount of rainfall (245mm and 319mm). The average monthly temperature ranged from 22.00 ^{0}C to 36.10 ^{0}C in 2018 and 21.30^{0}C to 35.00^{0}C in 2019 while the average relative humidity ranged from 68% to 93% in 2018 and 76% to 96% in 2018 and 2019.

Table 1. Meteorological Data of Makurdi during 2018 and 2019 Cropping Seasons

	2018					2019			
Months	**Temperature (^{0}C)**		**Relative humidity**	**Total Rainfall (mm)**		**Temperature (^{0}C)**		**Relative humidity**	**Total Rainfall (mm)**
	Min	**Max**				**Min**	**Max**		
April	24.60	36.10	68.00	55.00		24.50	35.00	76.00	17.30
May	23.70	32.40	78.00	230.10		23.50	33.20	77.00	85.10
June	22.50	32.10	80.00	139.10		23.40	31.20	81.00	216.20
July	22.20	31.30	74.00	44.10		23.70	30.60	84.00	186.60
August	22.00	30.80	83.00	245.80		23.60	30.00	86.00	319.00
September	22.40	31.40	93.00	219.30		23.30	30.70	96.00	208.90
October	22.20	32.60	79.00	73.90		23.30	30.90	86.00	320.90
November	22.20	31.10	79.00	6.00		21.30	33.30	86.00	48.10
Total				**1013.30**					**1402.10**

Source: *Nigeria Meteorological Agency, Tactical Air Command Headquarters, Airforce Base, Makurdi, Benue State (2018 and 2019).*

Min = Minimum; Max = Maximum

Table 2 presents the physicochemical parameters of the soil at the experimental site for 2018/2019 cropping season. The total nitrogen content of the soil was 0.096%. Phosphorus levels were also low, ranging between 2.80 and 4.20 mg/kg, as were potassium levels, which were consistent at 0.25 cmol/kg. The soil's texture was classified as sandy loam.

Table 2. Physico-Chemical Properties of the Experimental Site (0-15cm) before Planting in Year 2018/2019 Season

Soil Parameters	**2018**	**2019**
pH (H_20)	6.18	6.48
%Sand	72.08	71.08
%Clay	16.00	17.20
% Silt	11.92	11.00
Textural	Sandy loam	Sandy loam
% O.C	0.48	0.51
% O.M	0.83	0.88
% N	0.096	0.096
E.C (cmol/kg-1)		
K	0.22	0.25
Na	0.20	0.24
Ca	2.90	2.80
Mg	2.60	2.70
CEC (cmol/kg^{-1})	7.02	7.10
Available P (mg/kg^{-1})	2.80	4.20
%Base Saturation	84.30	84.37

Source: Soil Science Laboratory, University of Agriculture, Makurdi, Nigeria

Groundnut Components:

The groundnut varieties and intra-row spacing of maize evaluated in the study had a significant effect on the measured vegetative growth parameters. The impact of groundnut varieties and intra-row spacing of maize on the height and number of branches of groundnut during the 2018 and 2019 cropping seasons at Makurdi is presented in Table 3 and Table 4. In both years, the SAMNUT 23 variety exhibited significantly greater plant height and a higher number of branches per plant compared to SAMNUT 24 and SAMNUT 25. The lowest plant height and number of branches per plant were observed in the SAMNUT 24 plots, which were significantly

different from the other varieties in both growing seasons (Table 3). Generally, plant height and the number of branches per plant decreased with decreasing spacing in the groundnut/maize intercrop (Table 4).

Table 3. Effect of Groundnut Varieties and Intra Row Spacing of Maize on Plant Height and Branches of Groundnut (*Arachis hypogaea* L.) in 2018 and 2019 Cropping Seasons at Makurdi

	Plant Height (cm)		Number of Branches	
Variety	**2018**	**2019**	**2018**	**2019**
SAMNUT 23	44.47	48.70	14.09	13.61
SAMNUT 24	35.63	39.13	11.37	8.57
SAMNUT 25	37.79	46.25	11.99	11.27
FLSD (0.05)	1.24	1.39	0.82	0.64
P-value	<0.001	<0.001	<0.001	<0.001
Intra-row spacing				
M_{100}	42.21	48.70	14.38	13.02
M_{75}	39.05	41.52	12.85	10.90
M_{50}	36.71	39.66	7.88	7.89
Sole	42.82	49.51	14.84	12.80
FLSD (0.05)	1.43	1.61	0.95	0.74
P-value	<0.001	<0.001	<0.001	<0.001

M_{100} = Maize at 100 cm × 75 cm; M_{75} = Maize at 75 cm × 75 cm; M_{50} = Maize at 50 cm × 75 cm FLSD (0.05) = Fisher's Least Significant Difference at 5% level of probability; Ns = Not significant; *P*-value = Probability value

Table 4. Interaction Effect of Groundnut Varieties and Intra Row Spacing of Maize on Height and Branches of Groundnut (*Arachis hypogaea* L.) in 2018 and 2019 Cropping Seasons at Makurdi, Nigeria

		Plant Height (cm)		Number of Branches	
Variety	**Intra row spacing**	**2018**	**2019**	**2018**	**2019**
SAMNUT 23	M_{100}	48.50	50.70	14.05	15.39
	M_{75}	40.09	45.86	12.20	13.33
	M_{50}	38.33	40.73	8.50	10.68
	Sole	48.65	50.63	14.15	15.06
SAMNUT 24	M_{100}	38.50	40.75	10.20	10.45
	M_{75}	30.09	34.80	9.48	10.20
	M_{50}	28.33	30.40	7.30	8.31
	Sole	38.65	40.80	10.70	10.15
SAMNUT 25	M_{100}	42.97	45.20	12.25	13.50
	M_{75}	38.50	40.15	11.80	11.58
	M_{50}	31.68	35.45	8.45	6.67
	Sole	42.35	44.30	12.60	13.34
	FLSD (0.05)	2.49	2.78	Ns	1.28
	P-value	<0.001	<0.001	0.101	0.015

M_{100} = Maize at 100 cm × 75 cm; M_{75} = Maize at 75 cm × 75 cm; M_{50} = Maize at 50 cm × 75 cm FLSD (0.05) = Fisher's Least Significant Difference at 5% level of probability; Ns = Not significant; *P*-value = Probability value

SAMNUT 23 Groundnut exhibited significantly higher pod length, number of pods per plant, and pod yield (Kg/ha) ($p \leq 0.05$) than the other two varieties in both sole and intercropping systems (Tables 5 and 6). Intercropped groundnut varieties combined with maize at 100 cm and 75 cm intra-row spacing produced significantly higher growth and yield parameters ($p \leq 0.05$) than at 50 cm intra-row spacing, which was similar to that in sole groundnut varieties in both growing seasons (Table 6). This could be due to the interception of more sunlight by groundnut varieties in sole and intercropped with wider maize intra-row spacing compared to low light interception in intercrops with closer maize intra-row spacing, as was the case with 50 cm. However, when compared to other treatments with larger maize intra-row spacings, the groundnut-maize intercrop at 50 cm intra-row spacing had the shortest pod length, fewest number of pods per plant, and lowest pod weight per plant in 2018 and 2019, respectively.

Table 5: Effect of Groundnut Varieties and Intra Row Spacing of Maize on Pod Length, number of pods per plant and Pod Weight of Groundnut (*Arachis hypogaea* L.) in 2018 and 2019 cropping seasons at Makurdi

	Pod length (cm)		Number of pods per plant		Pod weight per plant (g)	
Variety	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**
SAMNUT 23	3.00	3.16	40.23	48.83	143.37	146.29
SAMNUT 24	2.70	3.06	28.87	33.35	116.51	124.38
SAMNUT 25	2.67	2.87	32.66	39.82	132.41	138.35
FLSD (0.05)	Ns	Ns	1.15	0.99	1.08	1.08
P-value	0.081	0.109	<0.001	<0.001	<0.001	<0.001
Intra row spacing						
M_{100}	2.89	3.15	34.87	42.98	133.36	138.90
M_{75}	2.42	2.95	31.29	39.21	127.59	134.22
M_{50}	2.10	2.61	22.43	28.28	117.41	122.65
Sole	2.82	3.41	47.10	52.20	144.69	149.59
FLSD (0.05)	Ns	0.32	1.33	1.15	1.25	1.25
P-value	0.487	<0.001	<0.001	<0.001	<0.001	<0.001

M_{100} = Maize at 100 cm × 75 cm; M_{75} = Maize at 75 cm × 75 cm; M_{50} = Maize at 50 cm × 75 cm FLSD (0.05) = Fisher's Least Significant Difference at 5% level of probability; Ns = Not significant; *P*-value = Probability value

Table 6. Interaction Effect of Groundnut Varieties and Intra Row Spacing of Maize on Pod Length, number of pods per plant and Pod Weight of Groundnut (*Arachis hypogaea* L.) in 2018 and 2019 Cropping Seasons at Makurdi, Nigeria

		Pod length (cm)		Number of pods per plant		Pod weight per plant (g)	
Variety	**Intra row spacing**	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**
SAMNUT 23	M_{100}	3.01	3.09	40.00	51.28	146.99	148.88
	M_{75}	3.00	3.03	37.07	47.76	141.08	142.43
	M_{50}	2.67	2.95	30.51	35.83	131.51	135.13
	Sole	3.27	3.58	53.36	60.46	153.89	158.73
SAMNUT 24	M_{100}	2.80	3.25	30.79	35.67	120.77	127.74
	M_{75}	2.73	3.15	26.44	31.37	112.40	124.31
	M_{50}	2.73	2.72	15.61	22.47	99.26	106.91
	Sole	2.88	3.12	42.65	43.90	133.61	138.53
SAMNUT 25	M_{100}	2.69	3.18	33.83	42.00	132.30	140.06
	M_{75}	2.60	2.62	30.37	38.50	129.29	135.91
	M_{50}	2.47	2.15	21.16	26.53	121.46	125.91
	Sole	2.93	3.53	45.28	52.23	146.58	151.51
	FLSD (0.05)	Ns	Ns	2.30	Ns	2.17	2.16
	P-value	0.596	0.075	0.044	0.098	<0.001	<0.001

M_{100} = Maize at 100 cm × 75 cm; M_{75} = Maize at 75 cm × 75 cm; M_{50} = Maize at 50 cm × 75 cm FLSD (0.05) = Fisher's Least Significant Difference at 5% level of probability; Ns = Not significant; *P*-value = Probability value

The number of groundnut seeds per pod vary significantly only in 2018. SAMNUT 24 recorded the highest number of seeds per pod (1.94) but was not significantly different from that of SAMNUT 23 (1.86). The percentage seed weight only vary significantly among varieties in 2019: (SAMNUT 23; 45.94), (SAMNUT 24; 39.89) and (SAMNUT 25; 41.62) (Table 7 and 8). Harvest index from SAMNUT 23 plots when compared with other varieties was significantly higher SAMNUT 23 plots similarly recorded significantly higher pod yields in both growing seasons. Percentage seed weight, pod yield and harvest index were lowest in SAMNUT 24 compared with other groundnut varieties evaluated. SAMNUT 23 Variety recorded the highest pod yield in 2018, (1991.68 kg/ha) and (1959.84 kg/ha) in 2019, and harvest index in 2018, (54.48) and (51.74) in 2019 when compared with the other groundnut varieties (Table 9 and 10). Groundnut intercropped with maize at 50 cm spacing had the lowest yield and yield parameters in both growing seasons. The smallest number of seeds per pod was observed in maize intercropped with groundnut at a spacing of 50 cm, which may be attributed to increased competition for resources among the crops.

Table 7. Effect of Groundnut Varieties and Intra Row Spacing of Maize on number of seeds per pod and percent tage seed weight of groundnut (*Arachis hypogaea* L.) in 2018 and 2019 Cropping Seasons at Makurdi

	Number of seeds per Pod		Percentage seed weight (%)	
Variety	**2018**	**2019**	**2018**	**2019**
SAMNUT 23	1.86	1.86	42.03	45.94
SAMNUT 24	1.94	1.78	38.83	39.89
SAMNUT 25	1.93	1.84	40.79	41.62
FLSD (0.05)	0.09	Ns	Ns	2.55
P-value	0.171	0.642	0.382	<0.001
Intra-row spacing				
M_{100}	1.97	1.88	48.76	50.79
M_{75}	1.86	1.85	40.05	39.31
M_{50}	1.79	1.63	35,78	37.44
Sole	2.01	1.96	49.65	54.38
FLSD (0.05)	0.11	0.20	5.43	2.95
P-value	<0.001	0.018	<0.001	<0.001

M_{100} = Maize at 100 cm × 75 cm; M_{75} = Maize at 75 cm × 75 cm; M_{50} = Maize at 50 cm × 75 cm FLSD (0.05) = Fisher's Least Significant Difference at 5% level of probability; Ns = Not significant; *P*-value = Probability value

Table 8. Interaction Effect of Groundnut Varieties and Intra Row Spacing of Maize on number of seeds per pod and percentage seed weight of groundnut (*Arachis hypogaea* L.) in 2018 and 2019 Cropping Seasons at Makurdi, Nigeria

		Number of seeds per pod		Percentage seed weight (%)	
Variety	**Intra row spacing**	**2018**	**2019**	**2018**	**2019**
SAMNUT 23	M_{100}	1.89	1.93	49.65	54.80
	M_{75}	1.77	1.86	48.22	50.44
	M_{50}	1.72	1.68	42.20	45.34
	Sole	2.04	1.96	53.58	58.45
SAMNUT 24	M_{100}	2.03	1.85	50.45	53.42
	M_{75}	1.90	1.73	43.25	45.94
	M_{50}	1.80	1.62	38.75	40.50
	Sole	2.01	1.92	51.30	53.45
SAMNUT 25	M_{100}	1.97	1.97	49.80	52.90
	M_{75}	1.92	1.83	45.40	48.25
	M_{50}	1.84	1.58	40.20	42.65
	Sole	1.98	1.98	52.10	53.33
	FLSD (0.05)	Ns	Ns	Ns	Ns
	P-value	0.635	0.932	0.235	0.200

M_{100} = Maize at 100 cm × 75 cm; M_{75} = Maize at 75 cm × 75 cm; M_{50} = Maize at 50 cm × 75 cm FLSD (0.05) = Fisher's Least Significant Difference at 5% level of probability; Ns = Not significant; *P*-value = Probability value

Table 9. Effect of Groundnut Varieties and Intra Row Spacing of Maize on pod yield and harvest index of groundnut (*Arachis hypogaea* L.) in 2018 and 2019 Cropping Seasons at Makurdi

	Pod yield (kg/ha)		Harvest index	
Variety	**2018**	**2019**	**2018**	**2019**
SAMNUT 23	1991.68	1959.84	54.48	51.74
SAMNUT 24	1738.15	1800.19	50.10	48.53
SAMNUT 25	1631.24	1792.81	48.82	44.21
FLSD (0.05)	1.71	1.71	1.09	0.72
***P*-value**	<0.001	<0.001	<0.001	<0.001
Intra-row spacing				
M_{100}	2090.07	2165.24	54.74	49.91
M_{75}	1872.86	1901.01	51.33	46.82
M_{50}	908.62	982.43	44.46	43.60
Sole	2276.55	2355.11	54.12	52.31
FLSD (0.05)	1.98	1.98	1.26	0.83
***P*-value**	<0.001	<0.001	<0.001	<0.001

M_{100} = Maize at 100 cm × 75 cm; M_{75} = Maize at 75 cm × 75 cm; M_{50} = Maize at 50 cm × 75 cm FLSD (0.05) = Fisher's Least Significant Difference at 5% level of probability; Ns = Not significant; *P*-value = Probability value

Table 10. Interaction Effect of Groundnut Varieties and Intra Row Spacing of Maize on pod yield and harvest index of groundnut (*Arachis hypogaea* L.) in 2018 and 2019 Cropping Seasons at Makurdi, Nigeria

		Pod yield (kg/ha)		Harvest index	
Variety	**Intra row spacing**	**2018**	**2019**	**2018**	**2019**
SAMNUT 23	M_{100}	2285.78	2210.20	57.71	52.97
	M_{75}	2194.43	2205.17	56.55	49.97
	M_{50}	1090.10	1120.80	45.68	46.06
	Sole	2396.40	2390.35	57.98	57.95
SAMNUT 24	M_{100}	1908.10	1910.40	54.06	49.87
	M_{75}	1525.17	1624.75	49.96	47.30
	M_{50}	695.30	1012.94	43.51	44.79
	Sole	2036.84	2148.67	52.89	52.18
SAMNUT 25	M_{100}	2026.33	2044.11	52.44	46.90
	M_{75}	1698.97	1720.10	47.48	43.20
	M_{50}	940.46	948.69	43.88	39.95
	Sole	2196.40	2205.21	51.49	46.79
	FLSD (0.05)	3.42	3.42	2.18	1.45
	P-value	<0.001	<0.001	0.005	<0.001

M_{100} = Maize at 100 cm × 75 cm; M_{75} = Maize at 75 cm × 75 cm; M_{50} = Maize at 50 cm × 75 cm FLSD (0.05) = Fisher's Least Significant Difference at 5% level of probability; Ns = Not significant; P-value = Probability value

Maize Components:

The effects of groundnut varieties and intra-row spacing of maize on plant height, number of leaves per plant, and stem diameter are shown in Table 11. Maize planted as a sole crop appears to favor vegetative growth and yield more than when intercropped. Sole crop plants were the tallest, measuring 182.43 cm in 2018 and 183.28 cm in 2019, while the shortest plants were those intercropped at an intra-row spacing of 50 cm. Among the intercropped treatments, SAMNUT 25 with maize spaced at 100 cm was the tallest, reaching 183.32 cm in 2018 and 174.86 cm in 2019 (Table 11). Sole maize resulted in significantly higher ($p < 0.01$) plant height, number of leaves, and stem diameter, whereas maize at 50 cm intra-row spacing intercropped with groundnut exhibited the lowest plant height, number of leaves, and stem diameter during both growing seasons. Table 12 displays the number of days until 50% tasseling and the days until initial tasseling of maize. SAMNUT 23, when intercropped with maize at a 50 cm spacing, required more days (50.67) to attain tasseling.

Table 11. Effect of groundnut varieties and intra row spacing of maize on height, number of leaves and stem diameter of maize (*Zea mays* L.) in 2018 and 2019 cropping seasons at Makurdi

	Plant Height (cm)			Number of Leaves			Stem Diameter (cm^2)	
Treatment	**2018**	**2019**		**2018**	**2019**		**2018**	**2019**
G_1M_{100}	169.42	166.66		12.40	12.67		9.20	9.25
G_1M_{75}	165.48	162.55		11.85	12.10		8.40	8.50
G_1M_{50}	153.50	154.27		9.70	10.25		7.45	7.65
G_2M_{100}	177.28	168.60		12.45	12.90		10.05	9.90
G_2M_{75}	173.63	164.00		12.30	12.55		9.75	9.60
G_2M_{50}	165.08	154.53		11.02	11.25		9.25	9.10
G_3M_{100}	183.32	174.86		12.55	12.85		9.50	9.50
G_3M_{75}	176.00	163.77		12.13	12.30		8.80	9.20
G_3M_{50}	169.42	153.03		10.60	11.04		8.20	8.30
Sole	182.43	183.28		12.75	12.92		10.10	10.23
FLSD (0.05)	4.01	2.87		0.71	0.63		0.42	0.28
P-value	<0.001	<0.001		<0.001	<0.001		<0.001	<0.001

G_1 = SAMNUT 23; G_2 = SAMNUT 24; G_3 = SAMNUT 25; M_{100} = Maize at 100 cm × 75 cm; M_{75} = Maize at 75 cm × 75 cm; M_{50} = Maize at 50 cm × 75 cm FLSD (0.05) = Fisher's Least Significant Difference at 5% level of probability; Ns = Not significant; P-value = Probability value

Table 12. Effect of groundnut varieties and intra row spacing of maize on number of days to first tasseling, number of days to 50% tasseling and leaf area index of maize (*Zea mays* L.) in 2018 and 2019 cropping seasons at Makurdi

	Days to 1st Tasseling			Days to 50% Tasseling	
Treatment	**2018**	**2019**		**2018**	**2019**
G_1M_{100}	51.67	26.00		59.33	34.00
G_1M_{75}	47.33	24.00		59.67	39.67
G_1M_{50}	55.67	23.00		60.67	50.67
G_2M_{100}	45.33	26.67		60.00	39.67
G_2M_{75}	46.33	25.00		60.00	39.67
G_2M_{50}	46.33	25.67		58.67	37.33
G_3M_{100}	49.33	26.00		59.00	39.33
G_3M_{75}	44.00	23.67		60.00	38.31
G_3M_{50}	47.67	24.33		58.33	39.67
Sole	45.67	27.67		60.00	37.33
FLSD (0.05)	Ns	Ns		Ns	8.86
***P*-value**	0.150	0.449		0.618	0.034

G_1 = SAMNUT 23; G_2 = SAMNUT 24; G_3 = SAMNUT 25; M_{100} = Maize at 100 cm × 75 cm; M_{75} = Maize at 75 cm × 75 cm; M_{50} = Maize at 50 cm × 75 cm FLSD (0.05) = Fisher's Least Significant Difference at 5% level of probability; Ns = Not significant; P-value = Probability value

Tables 13 and 14 present data on the effects of groundnut intercropping and intra-row spacing of maize on the number of cobs, cob weight, and weight of seeds per cob. The population density of maize significantly affected the quantity of grains per cob (Table 13). The highest number of seeds per cob was recorded at 284.50 in maize with 100 cm spacing intercropped with SAMNUT 25 in 2018 and increased to 300.45 at the same spacing in 2019. Conversely, the lowest numbers of seeds per cob were observed at 234.50 in 2018 and 194.40 in 2019, respectively, when SAMNUT 25 was intercropped with maize spaced at 50 cm. The weights of 100 seeds from SAMNUT 23 in intercropping with maize spaced at 100 cm were highest at 38.01 g in 2018 and 36.44 g in 2019. Maize grain yield was highest in sole plots, with 2191.00 kg/ha in 2018 and 2250.45 kg/ha in 2019. In contrast, maize yield in SAMNUT 23 intercropped with maize spaced at 100 cm was lowest, at 544.50 kg/ha in 2018 and 692.80 kg/ha in 2019, which differed significantly from other treatments in both growing seasons (Table 14).

Table 13. Effect of groundnut varieties and intra row spacing of maize number of seeds per cob, cob weight and weight of seeds per maize (*Zea mays* L.) in 2018 and 2019 cropping seasons at Makurdi

	Number of Seeds Per Cob		Cob Weight per Plant (g)		Weight of Seeds per Cob	
Treatment	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**
G_1M_{100}	284.00	342.50	138.52	140.50	118.35	121.40
G_1M_{75}	280.20	339.60	132.10	133.80	110.80	112.35
G_1M_{50}	277.60	285.70	118.82	124.30	83.20	84.62
G_2M_{100}	284.90	333.90	143.40	144.25	123.98	124.90
G_2M_{75}	284.10	318.40	138.64	140.40	115.50	105.90
G_2M_{50}	266.60	254.60	125.20	130.50	102.82	105.90
G_3M_{100}	289.50	300.40	141.50	142.60	120.32	122.45
G_3M_{75}	246.60	223.60	133.57	135.90	112.20	115.30
G_3M_{50}	234.50	194.40	121.18	126.45	93.75	95.50
Sole	284.90	335.70	143.65	145.50	123.80	125.20
FLSD (0.05)	31.41	91.48	2.44	13.50	4.60	15.91
***P*-value**	0.003	0.025	<0.001	0.016	<0.001	<0.001

G_1 = SAMNUT 23; G_2 = SAMNUT 24; G_3 = SAMNUT 25; M_{100} = Maize at 100 cm × 75 cm; M_{75} = Maize at 75 cm × 75 cm; M_{50} = Maize at 50 cm × 75 cm FLSD (0.05) = Fisher's Least Significant Difference at 5% level of probability; Ns = Not significant; P-value = Probability value

Table 14. Effect of groundnut varieties and intra row spacing of maize on 100-seed weight and grain yield of maize (*Zea mays* L.) in 2018 and 2019 cropping seasons at Makurdi

	100-Seed Weight (g)		Grain Yield (kg/ha)	
Treatment	**2018**	**2019**	**2018**	**2019**
G_1M_{100}	38.01	36.44	544.50	692.80
G_1M_{75}	33.57	34.44	825.45	889.84
G_1M_{50}	27.83	28.41	1182.34	1320.25
G_2M_{100}	34.88	33.00	710.66	738.54
G_2M_{75}	27.08	30.10	940.45	988.62
G_2M_{50}	26.55	22.32	1524.85	1645.95
G_3M_{100}	33.52	34.17	685.75	704.37
G_3M_{75}	29.57	31.94	850.48	902.50
G_3M_{50}	20.76	24.47	1455.94	1488.56
Sole	37.60	32.24	2191.00	2250.45
FLSD (0.05)	3.29	2.61	3.38	3.43
***P*-value**	<0.001	<0.001	<0.001	<0.001

G_1 = SAMNUT 23; G_2 = SAMNUT 24; G_3 = SAMNUT 25; M_{100} = Maize at 100 cm × 75 cm; M_{75} = Maize at 75 cm × 75 cm; M_{50} = Maize at 50 cm × 75 cm FLSD (0.05) = Fisher's Least Significant Difference at 5% level of probability; Ns = Not significant; P-value = Probability value

Productivity Assessment of Groundnut/Maize intercropping System:

Land equivalent ratio (LER) values were greater than 1.0 in all intercrop combinations of groundnut cultivars and maize at various planting spacings (Table 15), indicating that intercropping benefits all treatments. Similarly, LER numbers were higher than 0.25, suggesting the yield benefit of intercropping different groundnut types with maize at varied planting densities in both growing seasons assessed. The highest LER values of 1.30 in 2018 and 1.32 in 2019 were observed in groundnut varieties SAMNUT 23 and SAMNUT 25 when maize was planted at a spacing of 75 cm. The highest land equivalent coefficient (LEC) value of 0.37 in 2018 was recorded in intercropping when SAMNUT 23 was intercropped with maize at a 75 cm spacing, while the highest value of 0.40 in 2019 was achieved with SAMNUT 25 at a 100 cm maize spacing. The largest percentage of land saved was achieved in intercropping when the groundnut variety SAMNUT 23 was intercropped with maize spaced at 75 cm, whereas the lowest percentage of land saved was obtained with a 50 cm intra-row spacing of maize intercropped with groundnut, regardless of the varieties tested. Values of LER less than 1.00 indicate an intercrop disadvantage, while values of LER equal to 1.00 imply no significant difference between the intercrop and sole crop. The highest LER values of 1.30 and 1.32 were recorded in groundnut varieties SAMNUT 23 and SAMNUT 25, respectively, when maize was planted at an intra-row spacing of 75 cm. Having both crops in the intercrop at this level of interaction is most advantageous, likely due to the greater efficiency of resource utilization at this treatment level. The highest percentage of land saved was achieved with SAMNUT 23 intercropped with maize spaced at 75 cm (23.08% in 2018 and 24.24% in 2019), while the lowest percentage of land saved occurred at a 50 cm intra-row spacing of maize intercropped with groundnut, regardless of the varieties assessed (Table 15).

Table 15. Land Equivalent Ratio (LER) and Land Equivalent Coefficient (LEC) and percentage (%) land saved of Intercropped Varieties with Maize at Different Planting Densities in Makurdi

	LER		LEC		%Land Saved	
Treatment	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**
G_1M_{100}	1.20	1.24	0.24	0.29	16.67	19.35
G_1M_{75}	1.30	1.32	0.35	0.37	23.08	24.24
G_1M_{50}	1.07	1.06	0.25	0.28	6.54	5.66
G_2M_{100}	1.26	1.20	0.40	0.29	20.63	16.67
G_2M_{75}	1.18	1.20	0.32	0.33	15.25	16.67
G_2M_{50}	1.04	1.02	0.24	0.34	3.84	16.67
G_3M_{100}	1.23	1.24	0.29	0.29	18.70	19.35
G_3M_{75}	1.16	1.18	0.30	0.31	13.79	15.25
G_3M_{50}	1.10	1.09	0.29	0.28	9.09	8.26

LER: Land Equivalent Ratio

LEC: Land Equivalent Coefficient

DISCUSSION

The meteorological data presented in table 1 is ideal for groundnut-maize production in the study location as well as the experimental soil condition as presented in table 2. Similar findings have been reported by Muhammad *et al.* (2011); Ijoyah *et al.* (2015) and Samson *et al.,* (2023)

The growth parameters of groundnut showed that sole cropping recorded the highest plant height and number of branches per plant in both growing seasons. These measurements were not significantly different from those of groundnut plants in plots with maize spaced at 100 cm and 75 cm. However, plots with maize at 50 cm intra-row spacing had the shortest plant height and the lowest number of branches per plant in both growing seasons, which was significantly different from the other intra-row spacings and the control. This suggests that the suppression of growth was due to insufficient light (N'tare and Williams, 1992; Mehdi, 2013). The number of branches seems to regulate both the number of leaves, which create photosynthetic area, and the number of pods that act as sinks (Reddy et al., 1992). Similar findings were reported by Tamiru (2014) and Salisu et al. (2023), who worked on groundnut-maize intercropping systems.

SAMNUT 23 Groundnut exhibited significantly higher pod length, number of pods per plant, and pod yield (kg/ha) ($p \leq 0.05$) than the other two varieties in both sole and intercropping systems (Tables 5 and 6). This was probably a varietal characteristic, which is in conformity with the findings of Ahmad and Mohammad (1997) and Atta et al. (2022), who worked on different maize varieties. Intercropped groundnut varieties combined with maize at 100 cm and 75 cm intra-row spacing produced significantly higher growth ($p \leq 0.05$) and yield parameters than at 50 cm intra-row spacing yet were similar to those in sole groundnut varieties in both growing seasons. This could be a result of the interception of more sunlight by the groundnut varieties when grown alone or intercropped with wider maize intra-row spacing compared to the lower light interception in intercrops with closer maize intra-row spacing, as observed at 50cm.When compared to other treatments with larger maize intra-row spacings, the groundnut-maize intercrop at a 50 cm intra-row spacing had the shortest pod length, the fewest number of pods per plant, and the lowest pod weight per plant in both 2018 and 2019. Overcrowding in treatments with the closest maize spacing (M50) promotes unhealthy competition among component species, resulting in low resource utilization and yield. Furthermore, the level of shading during grain filling has been higher at 50 cm maize spacing than at 100 cm, and more so than in sole cropping, which could cause a drastic reduction in the number of legume pods per plant and seeds per pod. The decrease in pods per plant might be due to the competitive effect of the maize component. Carruthers et al. (2002) attributed this situation to the reduction of photosynthesis due to shading by associated crops, leading legume plants to compensate by decreasing assimilate allocation to reproductive parts (grain production). Similarly, Kadir et al. (2021) affirmed that in maize-groundnut intercropping, efficient use of light is achieved through the complementary spacing between maize and groundnut plants.

In terms of yield and yield parameters measured Groundnut intercropped with maize at 50 cm had the lowest values in both growing seasons. The lowest number of seeds per pod was obtained in intercropped maize when spaced 50 cm. This lowest score in seeds per pod could be due to the higher competition for resources among the component crops. Higher number of seeds per pod in sole cropped groundnut might be as a result of less competition for resources per unit area under sole than in intercropping. This finding is in line with Ghosh, (2004) and Salisu *et al.* (2023). However, the current study contradicts the finding from Kadir *et al.* (2021) who reported that the total yield of intercropped crops was greater than sole cropping as shown by LER>1. The difference observed between the two studies could be accrued to environmental and soil conditions. Also, the difference in weather elements between the two growing seasons could be responsible for growing seasons' differential in numbers of seed per pod. The same inference could be drawn in respect of significant differences in percentage seed weight among varieties observed only in 2019.

Sole maize brought about significantly higher ($p < 0.01$) plant height, number of leaves and stem diameter, while maize at 50 cm intra-row spacing intercropped with groundnut had the lowest plant height, number of leaves and stem diameter in both growing seasons. This was most likely due to maize being more competitive in combinations when intercropped at a greater plant population density compared to a lower density. Plant height was projected to decrease as population density increased, according to Jagtap *et al.* (1988), due to intensive interplant competition for growth resources such as light and water. Salisu *et al.* (2023) also revealed that intercropping maize and groundnut ay 1:2 M-G ratio produced the highest yield of maize affirming more competition at greater plant population density. Similarly, the number of days until 50% tasseling and the days until initial tasseling of maize. SAMNUT 23 intercropped with maize at 50 cm spacing required more days (50.67) to attain tasseling. The population density of maize had a substantial influence on the quantity of grains per cob, number of seeds per cob was highest (284.50) in maize at 100 cm spacing intercropped with SAMNUT 25 in 2018 and (300.45) at the same spacing of maize in intercrop with SAMNUT 25 in 2019. The least number of seeds per cob (234.50) and (194.40) in 2018 and 2019 respectively were recorded in intercrop combination

SAMNUT 25 with maize spaced 50 cm. This could be as a result of intra and inter specific competition as reported by Verma *et al*. (1981), Whna and Tariah (1985). Similarly, Dong *et al.* (2022) affirmed that the interspecific root interactions in the intercropping of maize and peanut improved the soil microenvironment and provided the basis for high yield of the component crops.

The weights of 100 –seeds from SAMNUT 23 in intercropping with maize spaced at 100 cm were highest (38.01 cm) in 2018 and (36.44 cm) in 2019. Maize grain yield was highest in sole plots (2191.00 kg/ha) in 2018, (2250.45 kg/ha) in 2019; Maize yield in SAMNUT 23 intercropped with maize spaced at 100 cm were lowest (544.50 kg/ha) in 2018, (692.80 kg/ha) in 2019 which differ significantly from other treatment in both growing seasons. Population density had significant effect on the grain yield of maize. Grain yield increased as population density increased (Jagtap *et al*., 1998; Sun *et al.,* 2023).

The Land Equivalent Ratio (LER) were above 1.0 in all intercrop combinations of groundnut varieties with maize at different planting spaces, signifying intercropping advantages for all treatments. LEC figures were above 0.25, further indicating the yield advantage of intercropping combining groundnut varieties with maize at various planting densities in both growing seasons of trials. This indicates that all the intercropping combination were better in resource use efficiency compared to growing the two crops separately (Negesh and Molualem, 2014). The highest LER value of 1.30 and 1.32 recorded in groundnut varieties, SAMNUT 23 and SAMNUT 25 respectively were obtained when maize was planted at intra row spacing of 75 cm. It is most advantageous to have both crops in the intercrop at this level of interaction, this could be due to great efficiency of resources utilization at this treatment level. Ijoyah *et al.* (2015) reported that LER greater than 1.00 could be due to greater efficiency of resources utilization in intercropping. The greatest (%) percentage of land saved was achieved in SAMNUT 23 intercropped with maize spaced 75 cm (23.08) in 2018 and (24.24) in 2019, whereas the lowest (%) land saved was obtained at 50 cm, intra-row spacing of maize intercropping with groundnut independent of the varieties assessed.

CONCLUSION

From the analysis of the results, the highest Groundnut pod yields (2276.55kg/ha) in 2018 and (2355.11kg/ha) in 2019 were recorded in sole cropping system. However, the highest intercropping pod yields (2090.07kg/ha in 2018 and 2165.24kg/ha in 2019) of Groundnut was obtained when combined with maize spaced at100 cm intra-row. This is an indication of declining output of groundnut in intercropping compared to sole cropping. Pod yield (1991.68kg/ha in 2018 and 1959.84kg/ha in 2019) recorded in groundnut variety, SAMNUT 23 was superior compared to other groundnut varieties. Groundnut variety, SAMNUT 23 when combined with maize at intra-row spacing of 100 cm out yielded (2285.78kg/ha in 2018 and 2210.20kg/ha in 2019) other varieties in intercropping. Each of the groundnut varieties attained maximum yield in intercropping at 100 cm intra-row spacing of maize. On the other hand, least pod yield performances were recorded for each of the varieties at 50 cm intra-row spacing of maize.

The highest maize output in intercropping (1524.85kg/ha and 1645.95kg/ha grain yields) in 2018 and 2019 respectively were achieved at intra-row spacing of 50 cm in combination with groundnut variety, SAMNUT 24. This is significantly lower than the yield in sole cropping (2191.00kg/ha and 2250kg/ha) in 2018 and 2019 respectively. Land Equivalent Raito, LER due to interaction effect of variety x intra-row spacing was highest (1.30 and 1.32) in 2018 and 2019 respectively when maize spaced at 75 cm combined with SAMNUT 23. The least LER value (1.04 and 1.02) in 2018 and 2019 respectively were recorded in 50 cm intra-row spacing of maize intercropped with SAMNUT 24.

From the study, it can be recommended that groundnut variety SAMNUT 23 when intercrop with maize spaced at 100cm spacing is preferred for groundnut pod production and so recommended for farmers' higher preference for groundnut. And in intercropping advantage, groundnut variety SAMNUT 23 planted at M_{75} cm maize spacing performed better. It is most advantageous to have this variety in intercrop and this level of combination is also recommended.

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