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Productivity of Maize-Cowpea Intercrops as Influenced by Cowpea Varieties and Row Arrangement in the Sudan Savannah of Kano, Nigeria

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Abstract
This field study was conducted during the 2023 rainy season at two sites in Kano State, Nigeria, to evaluate maize–cowpea intercropping performance as influenced by different row arrangements (RA) and cowpea varieties. A split-plot design with three replications was used, assessing four intercropping arrangements (1:1, 1:2, 2:1, and 2:2) and two cowpea varieties (SAMPEA 19 and SAMPEA 21), alongside sole crops. Results indicated that SAMPEA 21 significantly ($p < 0.001$) enhanced maize vegetative growth, particularly in the 1M:1C arrangement, which produced the tallest plants and highest maize grain yield (2.3 t ha^{-1}) at BUK. In contrast, at Minjibir, the 1:2 arrangement significantly ($p < 0.05$) reduced maize yield (0.95 t ha^{-1}). Although yield components other than grain yield were not significantly affected ($p > 0.05$) by variety or row arrangement, intercropping systems generally improved land use efficiency. The 1M:1C arrangement with SAMPEA 21 consistently recorded the highest land equivalent ratio (LER), reaching 1.64 at BUK and 1.58 at Minjibir. The study concludes that a 1M:1C intercropping system using SAMPEA 21 optimizes productivity and resource use in the Sudano-Sahelian agroecological zone and is therefore recommended for adoption by farmers in the region.

Keywords: Cereal-Legume Intercrop, Crop Yield Optimization, Land Productivity, Planting Pattern, Sudano-Sahelian Agro-Ecology

Introduction
Intercropping is a well-established practice in diverse cropping systems that involves the simultaneous cultivation of two or more crops on the same piece of land, arranged in a way that ensures their lifecycles overlap both temporally and spatially (Moreira et al., 2024). Growing multiple crops together offers several benefits, including more efficient use of growth resources such as nutrients, light, and water, thereby promoting soil health (Martin et al., 2018; Gardarin et al., 2022). It also contributes to more stable yields from the component species (Rahman et al., 2021). Additional advantages include pest and disease reduction, erosion control, improved soil fertility, reduced crop losses due to weed infestations, and higher economic returns (Maitra et al., 2021).

Cowpea (*Vigna unguiculata* [L.] Walp.) is an important annual herbaceous legume indigenous to Africa. It was first domesticated in southern Africa before spreading to East and West Africa and parts of Asia (Swamy, 2023). Cowpea plays a vital role in the livelihoods of millions across West and Central Africa. It is also valued as a green manure crop, enhancing soil fertility through symbiotic nitrogen fixation and providing effective ground cover (Mndzebele et al., 2020). Its ability to fix atmospheric nitrogen via root nodules allows it to thrive in relatively poor soils, with over 85% sand, less than 0.2% organic matter, and low phosphorus levels, thus contributing significantly to soil fertility improvement (Anago et al., 2023).

Maize (*Zea mays* L.) is the cereal with the highest global production. In 2023, global maize production was estimated at approximately 1.23 billion metric tons (USDA, 2023). It serves as a staple food for about 50% of the population in Sub-Saharan Africa. According to Ekpa et al. (2019), in many regions of Sub-Saharan Africa, maize consumption can reach up to 450 grams per person per day. The crop has a wide range of uses, including direct

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human consumption, industrial food processing, starch production, and as forage for animal feed (Ranum et al., 2019; Erenstein et al., 2022).

Maize–legume intercropping offers several advantages over sole cropping and intercropping with other crop combinations (Mudare et al., 2022). These benefits are largely attributed to symbiotic associations and complementary interactions between species, which enable more efficient utilization of limited resources such as nutrients, water, and light (Brooker et al., 2015; Maitra et al., 2020). Maize, when grown alone with wide spacing, tends to encourage weed infestation and increases crop–weed competition (Laguardia et al., 2018). However, intercropping maize with a legume such as cowpea can significantly suppress weed growth, while also enhancing nitrogen availability through biological nitrogen fixation, which benefits the maize crop.

Additionally, the differing root architectures of maize and cowpea reduce competition for soil nutrients and water. Maize generally has deeper roots, while cowpea roots are relatively shallow, allowing both crops to extract resources from different soil layers (Rodriguez *et al.*, 2020). The performance of cowpea varieties under different row arrangements presents a complex agronomic challenge. Limited research has examined the interactions between specific cowpea varieties and planting arrangements when intercropped with maize. This is especially important given that most improved cowpea varieties were developed under sole cropping systems, and their performance in intercropping contexts remains underexplored. Considering the growth habits and structural differences among cowpea varieties is essential for optimizing intercropping outcomes.

This study aimed to evaluate different row arrangements and cowpea varieties in a maize-cowpea intercropping system, with the goal of identifying the most effective combination for optimal performance and compatibility.

Materials and Methods

Site description

Field trials were conducted during the 2023 rainy season at two locations in Kano State, Nigeria: The Research and Teaching Farm of the Faculty of Agriculture, Bayero University, Kano (Latitude 11°58'N, Longitude 8°25'E, and 475 m above sea level), and the Institute for Agricultural Research Farm, Minjibir (Latitude 12°10′42"N, Longitude 8°39′33"E). Both sites are characterized by sandy loam soil and receive an average annual rainfall ranging from 400 to 650 mm.

Treatments and Experimental design

The treatments consisted of four row arrangements (1:1, 1:2, 2:1, and 2:2) of maize (SAMMAZ 27) alternated with two cowpea varieties (SAMPEA 19 and SAMPEA 21), along with sole maize and sole cowpea plots as controls. The experiment was laid out in a split-plot design with three replications. Row arrangements were assigned to the main plots, while cowpea varieties were assigned to the subplots. Each plot comprised twelve ridges, each 5 meters in length, giving a gross plot size of 5 m × 9 m (45 m²). The net plot area consisted of the eight inner ridges, measuring 5 m × 6 m (30 m²). Alleyways of 1.0 meter between plots and 2.0 meters between replications were provided to facilitate movement and minimize interference between plots.

The cowpea and maize varieties used in the study were sourced from the International Institute of Tropical Agriculture (IITA), Kano station. The characteristics of the varieties are described below:

SAMMAZ 27 (EV99DT-W-STR)

This is an early maturing maize variety that is drought-tolerant and resistant to *Striga hermonthica*, with a yield potential of 5.5 t/ha (IAR, 2009).

SAMPEA 19 (IT08K-150-12)

An early maturing cowpea variety, resistant to *Alectra vogelii* and bacterial blight, and tolerant to Striga gesnerioides and drought. The seeds are large, white with a brown eye, and have a rough seed coat (testa). The plant is semi-erect and well adapted to Sudano-Sahelian agro-ecologies, with a yield potential of 2.7 t/ha (IAR, 2018).

SAMPEA 21 (IT13K-1308-5)

This is an early maturing cowpea variety, resistant to Striga gesnerioides and bacterial blight, and tolerant to drought. The seeds are medium-sized with a white seed coat. The plant is erect, with a yield potential of 2.85 t/ha (IITA, 2022).

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Cultural Practices

The land was cleared of debris and harrowed twice to achieve a fine tilth, after which ridges were made. The field was then marked into appropriate plot sizes, replicated three times. Each replication consisted of eleven plots, resulting in a total of thirty-three experimental plots. Sowing was done immediately once soil moisture was deemed adequate to support seed germination. Three maize seeds per hole and two cowpea seeds per hole were sown on ridges spaced 0.75 m between rows and 0.25 m within rows. Maize seedlings were thinned to two plants per stand two weeks after planting, while cowpea seedlings were left as sown.

Maize received a band application of 400 kg/ha NPK 15-15-15 at two weeks after sowing (WAS), providing 60 kg each of nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O). An additional 60 kg/ha of nitrogen was applied as a side dressing using urea (46% N) at six weeks after sowing. Cowpea received a starter dose of 133 kg/ha NPK 15-15-15 (equivalent to 20 kg each of N, P_2O_5, and K_2O) at two weeks after sowing. In intercropped plots, half of the recommended dose (66.5 kg ha^{-1}) was applied per crop, while sole plots received the full dose (133 kg ha^{-1}).

Integrated weed management, combining chemical and manual methods, was used to ensure proper crop establishment. Glyphosate (5 L ha^{-1}) was applied two weeks before land preparation using a 16 L capacity knapsack sprayer calibrated at a pressure of 2.1 kg m^{-2}, delivering a spray volume of 250 L ha^{-1}. Hoe weeding was carried out at three and six weeks after sowing. Insect pests in cowpea were controlled by spraying a mixture of Cypermethrin (Cymbush 10 EC) and 500 g a.i.ha^{-1} of dimethoate in 100 liters of water, applied at the flowering and pod formation stages using a knapsack sprayer. Maize was harvested at physiological maturity when the cobs were dry. The stalks were cut using a machete, and the cobs detached and sun-dried further before shelling. Grain yield was determined from crops harvested from the net plots. Cowpea was harvested later, once the leaves had turned yellow and the pods were sufficiently dry, by manual picking.

Data collection and Data analysis

Agronomic data for maize were collected on the following parameters: plant height, number of leaves per plant at tasseling, crop growth rate, shoot dry matter, number of cobs per plant, total cob yield (t ha^{-1}), grain yield (t ha^{-1}), and stover yield (t ha^{-1}). For cowpea, the parameters measured included plant height, number of branches per plant, canopy spread, crop growth rate, shoot dry matter, number of pods per plant, pod weight (t ha^{-1}), kernel yield (t ha^{-1}), and stover yield (t ha^{-1}). Vegetative data were collected from three randomly selected and tagged plants within the net plot. Yield data were collected from the net plant population in each replicate and averaged. The collected data were subjected to analysis of variance (ANOVA) using Statistical Analysis Software (SAS). Significant treatment means were separated using Student-Newman-Keuls (SNK) test at 5% level of probability.

Results and Discussion

Effect of Cowpea varieties and Row Arrangement on the vegetative traits of maize in Maize-Cowpea intercrop

Table 1 presents the effect of row arrangement and cowpea varieties on the vegetative growth of maize at Minjibir. Plant height was significantly ($p < 0.001$) affected by cowpea variety, with SAMPEA 21 producing taller maize plants than SAMPEA 19. Plant height also varied significantly with row arrangement, as the 1M:1C pattern produced the tallest maize plants, though differences with other arrangements were not statistically significant. The superior performance of maize intercropped with SAMPEA 21 suggests that cowpea varieties differ in their interaction with maize, likely due to variations in growth habit, canopy structure, or nutrient use. This aligns with the findings of Kussie et al. (2024), who reported that cowpea variety selection in intercrops can influence maize growth due to differences in competitive ability and resource efficiency. The advantage of the 1M:1C arrangement may be attributed to improved light interception and reduced intra-species competition, enhancing maize growth, as supported by Dimande et al. (2024).

The variety × row arrangement interaction on maize plant height (Table 2) revealed that SAMPEA 19 × 1M:1C and SAMPEA 21 × 2M:2C significantly resulted in producing taller maize plants (132.9 cm and 131.8 cm, respectively). These were closely followed by SAMPEA 21 × 2M:1C (124.3 cm), although statistically at par with the rest of the interaction combinations. The lowest plant heights were observed in SAMPEA 19 × 1M:2C (105.3 cm) and SAMPEA 19 × 2M:1C (107.8 cm), suggesting that these configurations may have limited maize growth.

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SAMPEA 21 × 2M:2C and SAMPEA 19 × 1M:1C ability to support more favorable maize growth, could be due to complementary resource use and less shading or root competition. This aligns with the findings of Adam et al. (2025), who reported that denser or more balanced row configurations enhance resource sharing in intercrops. Additionally, the equal row condition may create a more beneficial microclimate or root interaction for maize growth (Alabi et al., 2024). On the other hand, the lower plant height in obtained in SAMPEA 19 × 1M:2C and 2M:1C suggests that the cowpea variety may compete more aggressively in those configurations, potentially limiting maize access to light or nutrients. Similar results were found in studies that highlighted the role of variety-specific canopy architecture in influencing intercrop dynamics (Asibi et al., 2024).

Table 1: Effect of Row Arrangement and varieties on Vegetative traits of maize in a Maize-Cowpea Intercrop during the 2023 rainy season at BUK and Minjibir

Treatment	BUK				Minjibir			
	Plant height (cm)	Number of leaves plant^{-1}	Crop growth rate (gwk^{-1})	Shoot dry matter (g)	Plant height (cm)	Number of leaves plant^{-1}	Crop growth rate (gwk^{-1})	Shoot dry matter (g)
Variety (V)								
SAMPEA 19	150.6	9.7	12.7	32.91	115.3^{b}	9.3	5.4	17.08
SAMPEA 21	148.6	10.1	13.4	32.89	122.6^{a}	9.9	5.1	16.54
P value	0.74	0.24	0.86	0.99	0.02	0.31	0.75	0.81
SE±	4.10	0.26	2.50	3.80	1.78	0.24	1.07	2.19
Row Arrangement (RA)								
1M:1C	155.6	10.4	9.2	27.82	126.2^{a}	9.9	6.5	15.76
1M:2C	146.7	9.4	17.7	39.48	110.0^{b}	9.5	4.0	11.27
2M:1C	150.4	10.1	12.5	34.20	116.0^{ab}	10.0	7.3	19.14
2M:2C	148.8	9.9	12.6	30.09	123.4^{ab}	9.5	6.8	17.73
P value	0.64	0.30	0.45	0.48	0.01	0.61	0.45	0.36
SE±	2.82	0.22	2.07	3.83	4.01	0.33	1.70	3.59
Interaction								
V x RA	0.99	0.67	0.19	0.24	0.01	0.49	0.33	0.24

Means in the same column followed by the same letter(s) are not significantly different at 5% level of probability using Student-Newman Keuls Test, 1M:1C= 1 row of maize to1 row of cowpea, 1M:2C= 1 row of maize to 2 row of cowpea, 2M:1C= 2 rows of maize to 1 row of cowpea, 2M:2C= 2 rows of maize to 2 rows of cowpea

Table 2: Interaction between Cowpea varieties and Row arrangement on plant height of Maize at Minjibir in a Maize-Cowpea intercrop during 2023 rainy season

Treatment	Row Arrangement			
	1M:1C	1M:2C	2M:1C	2M:2C
Variety				
SAMPEA 19	132.9^{a}	105.3^{c}	107.8^{c}	115.1^{bc}
SAMPEA 21	119.7^{b}	114.7^{bc}	124.3^{ab}	131.8^{a}
SE±		3.57		

Means in the same column followed by the same letter(s) are not significantly different at 5% level of probability using Student-Newman Keuls Test, 1M:1C= 1 row of maize to1 row of cowpea, 1M:2C= 1 row of maize to 2 rows of cowpea, 2M:1C= 2 rows of maize to 1 row of cowpea, 2M:2C= 2 rows of maize to 2 rows of cowpea

Effect of Cowpea varieties and Row Arrangement on the yield and yield related components of maize in Maize-Cowpea intercrop

The effect of cowpea varieties and row arrangement (RA) on the yield and yield components of maize in a maize-cowpea intercrop at BUK and Minjibir is presented in Table 3. Results show that cowpea varieties did not significantly ($p > 0.05$) influence the yield or yield components of maize in the intercrop. Similarly, row arrangement had no significant effect on maize yield and its components at both locations, except for grain yield. At BUK, the 1M:1C row arrangement significantly produced the highest grain yield (2.3 t ha^{-1}), followed closely by 2M:1C (2.0 t ha^{-1}), while 1M:2C and 2M:2C arrangements resulted in lower yields.

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At Minjibir, the 1M:2C arrangement significantly ($p < 0.001$) resulted in the lowest maize grain yield (0.95 t ha^{-1}), whereas other row arrangements produced higher yields ranging from 1.12 to 1.21 t ha^{-1}. The interaction between cowpea variety and row arrangement was not significant for any of the measured yield or yield-related variables.

Findings from this study suggest that intercropping maize and cowpea in a 1:1 row arrangement significantly enhances overall productivity compared to other row arrangements at both locations. This is supported by higher Land Equivalent Ratio (LER) values, indicating more efficient land use. These results are consistent with the findings of Farah et al. (2024), who reported a LER greater than 1 in a maize–cowpea intercropping system, demonstrating its land-saving advantage and increased productivity.

Furthermore, the complementary interaction between the two crops was evident. Cowpea benefited from the partial shading provided by maize, which helped smoother weed growth and conserve soil moisture. This ecological synergy was similarly emphasized by Akter Suhi et al. (2022) and Adebayo et al. (2024), who reported that a 1:1 row pattern resulted in the highest grain yield of cowpea among different planting arrangements. Likewise, Biruk et al. (2022) observed that the 1M:1C row arrangement improved land use efficiency by up to 55.8% and provided greater economic returns compared to other intercropping patterns.

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Table 3: Effect of Cowpea Varieties and Row arrangements on Yield and yield component of Maize in a Maize-Cowpea Intercrop during the 2023 Rainy season at BUK and Minjibir

Treatment	**BUK**				**Minjibir**			
	Number of cobs plant^{-1}	Total cobs weight (t ha^{-1})	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Number of cobs plant^{-1}	Total cobs weight (t ha^{-1})	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})
Variety (V)								
SAMPEA 19	1.1	89.4	1.92	6.33	1.1	87.5	1.11	4.19
SAMPEA 21	1.1	82.4	1.90	7.45	1.1	77.5	1.10	4.22
P value	0.33	0.85	0.551	0.091	0.32	0.52	0.52	0.68
SE±	0.02	6.26	0.030	0.420	1.00	5.56	0.015	0.315
Row arrangement (RA)								
1M:1C	1.2	93.0	2.3a	8.33	1.1	86.0	1.21a	5.02
1M:2C	1.1	81.7	1.6c	6.83	1.1	84.5	0.95b	4.02
2M:1C	1.0	72.8	2.0b	6.56	1.0	73.2	1.13.8a	3.65
2M:2C	1.1	87.2	1.7c	5.85	1.1	77.7	1.12.5a	4.12
P value	0.15	0.47	<0.001	0.08	0.25	0.30	0.0002	0.24
SE±	0.05	7.96	0.061	0.750	0.03	5.40	0.034	0.214
Interaction								
V x RA	0.910	0.352	0.191	0.342	0.774	0.483	0.186	0.061

Means in the same column followed by the same letter(s) are not significantly different at 5% level of probability using Student-Newman Keuls Test, 1M:1C= 1 row of maize to1 row of cowpea, 1M:2C= 1 row of maize to 2 rows of cowpea, 2M:1C= 2 rows of maize to 1 row of cowpea, 2M:2C= 2 rows of maize to 2 rows of cowpea

Means in the same column followed by the same letter(s) are not significantly different at 5% level of probability using Student-Newman Keuls Test, 1M:1C= 1 row of maize to1 row of cowpea, 1M:2C= 1 row of maize to 2 rows of cowpea, 2M:1C= 2 rows of maize to 1 row of cowpea, 2M:2C= 2 rows of maize to 2 rows of cowpea

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Effect of Cowpea varieties and Row Arrangement on the vegetative traits of cowpea in Maize-Cowpea intercrop

The effects of cowpea varieties and row arrangements (RA) on cowpea vegetative traits in a maize-cowpea intercrop at BUK and Minjibir are presented in Table 4. Results show that cowpea variety had no significant effect ($p > 0.05$) on the number of branches per plant, crop growth rate (CGR), or shoot dry weight at either location. However, it significantly influenced canopy spread, with SAMPEA 21 exhibiting a wider spread than SAMPEA 19. This may be attributed to differences in morphological traits and varietal responses to environmental conditions due to genetic variability. These findings support Muhammad (2023), who reported that growth and yield variations among cowpea varieties are largely determined by genetic differences.

Row arrangement had no significant ($p > 0.05$) effect on vegetative traits at BUK, except for canopy spread. In contrast, at Minjibir, row arrangement significantly affected all vegetative traits except shoot dry weight. The 1M:2C RA produced the highest canopy spread at BUK, although differences were not statistically distinct from other arrangements. The 1M:1C RA resulted in more branches per plant, while the 2M:2C RA produced higher canopy spread and significantly greater CGR compared to the 1M:2C RA, which showed the lowest CGR. These outcomes align with findings by Ahmad et al. (2022) and Oyewole et al. (2021), who reported that a 2:2 row arrangement enhances land equivalent ratio (LER), light interception, and yield stability by reducing competition and promoting better resource complementarity between maize and cowpea.

Table 4: Effect of Cowpea Varieties and Row Arrangement on Vegetative Traits of cowpea in a Maize-Cowpea Intercrop during the 2023 Rainy Season at BUK and Minjibir

	BUK				**Minjibir**			
Treatment	Number of branches plant^{-1}	Canopy spread plant^{-1} (cm)	Crop growth rate (g wk^{-1})	Shoot dry matter (g)	Number of branches plant^{-1}	Canopy spread plant^{-1} (cm)	Crop growth rate (g wk^{-1})	Shoot dry matter (g)
Variety (V)								
SAMPEA 19	7.8	53.9^{b}	7.7	35.2	7.0	40.8^{b}	1.7	10.9
SAMPEA 21	8.2	62.6^{a}	6.8	35.8	6.9	49.1^{a}	2.2	11.9
P value	0.34	<0.001	0.70	0.88	0.56	0.04	0.34	0.83
SE±	0.22	0.45	1.73	2.69	0.18	0.36	0.41	0.95
Row arrangement (RA)								
1M:1C	7.5	50.5^{ab}	6.3	38.0	7.5^{a}	41.0^{ab}	1.8^{bc}	10.3
1M:2C	7.0	57.7^{a}	5.1	34.1	6.6^{ab}	38.6^{ab}	1.0^{c}	8.5
2M:1C	7.3	48.8^{ab}	8.8	32.7	6.5^{ab}	37.5^{ab}	2.6^{b}	12.7
2M:2C	7.3	43.3^{b}	8.9	37.3	5.7^{b}	42.4^{a}	5.1^{a}	15.3
P value	0.23	<0.001	0.64	0.72	0.02	<0.001	0.005	0.07
SE±	0.28	1.55	3.45	5.38	0.18	1.29	1.89	3.22
Interaction								
V x RA	0.55	0.28	0.86	0.72	0.04	0.32	0.53	0.38

Means in the same column followed by the same letter(s) are not significantly different at 5% level of probability using Student-Newman Keuls Test, 1M:1C= 1 row of maize to1 row of cowpea, 1M:2C= 1 row of maize to 2 row of cowpea, 2M:1C= 2 rows of maize to 1 row of cowpea, 2M:2C= 2 rows of maize to 2 rows of cowpea.

A significant interaction between cowpea variety and row arrangement (V × RA) was observed at Minjibir (Table 5), where the SAMPEA 21 × 2M:1C combination produced a higher crop growth rate (CGR), comparable to other interaction combinations. In contrast, SAMPEA 19 × 1M:2C and SAMPEA 19 × 2M:2C produced lower CGR. This suggests that cowpea growth traits like branching are influenced more by the interaction of variety and row arrangement than by either factor alone, supporting findings that highlight genotype-specific responses to agronomic practices (Kanu et al., 2022). The enhanced branching observed with SAMPEA 21 × 2M:1C likely improved photosynthetic surface area, contributing to higher CGR, in line with studies showing that optimal row arrangements paired with suitable genotypes improve light interception and biomass accumulation (Kamai et al., 2022).

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Conversely, the lower CGR in certain SAMPEA 19 combinations reflects reduced adaptability to specific row patterns, aligning with findings that suboptimal spacing limits canopy development and yield potential (Adebayo et al., 2021).

Table 5: Interaction between Cowpea varieties and Row arrangement on Number of Cowpea branches per plant in a Maize-Cowpea intercrop in Minjibir during 2023 Rainy season

Treatment	Row arrangement			
	1M:1C	1M:2C	2M:1C	2M:2C
Variety				
SAMPEA 19	6.8[abc]	5.4[c]	5.6[bc]	5.3[c]
SAMPEA 21	6.8[abc]	6.6[bc]	8.7[a]	7.5[ab]
SE±		0.68		

Means in the same column followed by the same letter(s) are not significantly different at 5% level of probability using Student-Newman Keuls Test, 1M:1C= 1 row of maize to1 row of cowpea, 1M:2C= 1 row of maize to 2 rows of cowpea, 2M:1C= 2 rows of maize to 1 row of cowpea, 2M:2C= 2 rows of maize to 2 rows of cowpea

Effect of Cowpea varieties and Row Arrangement on the yield and yield related components of cowpea in Maize-Cowpea intercrop

Table 6 presents the effect of cowpea varieties and row arrangement (RA) on the vegetative yield and yield components of cowpea in a maize-cowpea intercrop at BUK and Minjibir during the 2023 wet season. Results show that number of pods per plant, pod weight, and grain yield were significantly influenced by cowpea varieties, where SAMPEA 21 produced the highest values for these parameters compared to SAMPEA 19 at both locations.

This superiority of SAMPEA 21 may be attributed not only to its breeding as a high-yielding variety but also to its specific genetic traits, such as an erect growth habit and compact canopy structure, which reduce self-shading and competition with maize. These traits improve light interception and resource efficiency in intercropping systems, particularly under limited moisture and nutrient conditions. By contrast, SAMPEA 19 has a more spreading growth habit, which may increase shading and competition with maize rows, thereby reducing its overall productivity in the intercrop**.** This suggests that SAMPEA 21 has a genetic advantage in yield potential, likely due to its breeding for high-yield traits.

Pod yield, kernel yield, and stover yield were also significantly influenced by row arrangement (RA) at BUK ($P < 0.001$), while at Minjibir, higher pod and kernel yields were obtained. This location-based difference in yield performance may be due to variations in rainfall distribution and soil characteristics. Minjibir, characterized by relatively higher rainfall and slightly sandier soils compared to BUK, may have offered better drainage and moisture availability, thus enhancing pod and kernel formation, especially in wider row arrangements like 1M:1C. However, nutrient limitations or acidic soil pH could also have affected stover yield and nutrient uptake more severely in Minjibir than BUK.

This implies that both varietal selection and agronomic practices, such as row spacing, interact with environmental conditions to shape crop performance. In intercropping systems, productivity is strongly influenced by variety choice, as short-duration or erect cowpea varieties reduce shading and competition, while maize varieties with upright leaves and moderate height help minimize light competition and boost overall yield, as reported by Joda et al. (2021) and Nyambose et al. (2021).

In terms of pod yield across both locations, the 1M:1C row arrangement produced the highest yield (2.0 t ha^{-1}), followed closely by 2M:2C (1.8 t ha^{-1}). Conversely, the 1M:2C and 2M:1C arrangements resulted in significantly lower pod yields (1.6 t ha^{-1}). Similarly, kernel yield was highest under the 1M:1C RA and was statistically comparable to yields recorded under 2M:2C and 2M:1C. The 1M:2C arrangement produced the lowest kernel yield. At the Minjibir location, the 1M:1C RA again produced the highest kernel yield, followed by 1M:2C and 2M:2C,

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whereas the 2M:1C RA recorded the least yield. Across locations, sole cropping consistently resulted in the lowest kernel yield.

Regarding stover yield, the highest values were obtained under the 2M:2C RA, followed by 1M:2C and 2M:1C. The 1M:2C arrangement resulted in the lowest stover yield at Minjibir. These findings suggest that a balanced maize–cowpea intercropping system, particularly the 1M:1C configuration, optimizes pod and kernel yields. In contrast, denser planting systems like 2M:2C enhance biomass accumulation in the form of stover yield. This reflects improved resource partitioning and reduced intra-species competition typical of well-managed intercropping systems. These results align with those of Singh et al. (2023), who reported that improved yield performance in intercropping systems is often attributed to enhanced resource use efficiency, especially in semi-arid ecologies. Similarly, Idoko et al. (2018) found that a 1:1 maize–cowpea intercropping system significantly improved grain yields of both crops by minimizing interspecific competition and maximizing light and nutrient use efficiency. Additionally, Tetteh et al. (2021) observed that the 2M:2C configuration could maintain competitive grain yields while enhancing stover biomass production, corroborating the current study's findings.

Table 6: Effect of Cowpea Varieties and Row arrangements on Yield and yield related components of Cowpea in Maize-Cowpea Intercrop during the 2023 Rainy Season at BUK and Minjibir

Treatment	BUK				Minjibir			
	Pod count plant^{-1}	Pod yield (t ha^{-1})	Kernel yield (t ha-^{1})	Stover yield (t ha-^{1})	Pod countpl ant^{-1}	Pod yield (t ha-^{1})	kernel yield (t ha-^{1})	Stover yield (t ha-^{1})
Variety (V)								
SAMPEA 19	31.7^{b}	1.7^{b}	1.4^{b}	5.0	35.3^{b}	1.5^{b}	1.3^{b}	3.4
SAMPEA 21	41.1^{a}	1.8^{a}	1.6^{a}	4.7	39.8^{a}	1.6^{a}	1.4^{a}	3.3
P value	0.03	0.003	0.004	0.24	0.01	0.03	0.03	0.83
SE±	1.38	29.07	35.55	203.65	0.82	26.49	33.04	313.04
Row Arrangement (RA)								
1M:1C	38.4	2.0^{a}	1.7^{a}	5.1^{ab}	33.7	1.8^{a}	1.6^{a}	3.5
1M:2C	35.6	1.6^{c}	1.3^{c}	4.1^{b}	33.0	1.5^{c}	1.3^{b}	3.1
2M:1C	38.0	1.6^{c}	1.4^{b}	4.8^{ab}	32.9	1.3^{c}	1.1^{c}	3.7
2M:2C	37.9	1.8^{b}	1.5^{ab}	5.4^{a}	30.4	1.6^{b}	1.4^{b}	3.1
P value	0.75	0.0002	0.0017	0.04	0.27	0.0001	0.0004	0.38
SE±	2.76	58.76	71.10	407.30	2.04	32.79	35.01	193.64
Interaction								
V x RA	0.323	0.643	0.672	0.472	0.940	0.561	0.004	0.32

Means in the same column followed by the same letter(s) are not significantly different at 5% level of probability using Student-Newman Keuls Test, 1M:1C= 1 row of maize to1 row of cowpea, 1M:2C= 1 row of maize to 2 rows of cowpea, 2M:1C= 2 rows of maize to 1 row of cowpea, 2M:2C= 2 rows of maize to 2 rows of cowpea

The interaction between variety and row arrangement significantly influenced cowpea kernel yield. As shown in Table 7, the SAMPEA 21 × 1M:1C combination recorded the highest kernel yield, while the SAMPEA 19 × 2M:1C interaction produced the lowest. This suggests that both genotype and spatial configuration significantly affect yield outcomes. The superior performance of SAMPEA 21 under the 1M:1C RA may be attributed to its upright growth habit, early maturity, and nitrogen-fixing ability, which enhance its compatibility in intercropping systems (Singh et al., 2023). Idoko et al. (2018) further support this by demonstrating that the 1M:1C system facilitates better cowpea yield performance through reduced competition and improved resource allocation. Conversely, wider maize-dominant configurations such as 2M:1C tend to suppress cowpea growth, particularly in less competitive varieties like SAMPEA 19, due to increased shading and belowground competition as earlier reported by Tetteh et al. (2021).
Table 7: Interaction between Cowpea Varieties and Row Arrangement on kernel yield of Cowpea in a Maize-Cowpea intercrop in Minjibir during 2023 Rainy season

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Treatment	Row Arrangement			
	1M:1C	1M:2C	2M:1C	2M:2C
Variety				
SAMPEA 19	1432.3b	1259.3bc	1044.3d	1331.3b
SAMPEA 21	1667.3a	1256.7bc	1119.7cd	1397.7b
SE±		62.53		

Means in the same column followed by the same letter(s) are not significantly different at 5% level of probability using Student-Newman Keuls Test, 1M:1C= 1 row of maize to1 row of cowpea, 1M:2C= 1 row of maize to 2 row of cowpea, 2M:1C= 2 rows of maize to 1 row of cowpea, 2M:2C= 2 rows of maize to 2 rows of cowpea

Conclusion

This study confirms that row arrangement and cowpea variety significantly influence the growth and yield performance of maize in a maize–cowpea intercropping system. The 1:1 row configuration, particularly when combined with the SAMPEA 21 variety, enhanced maize vegetative growth and grain yield, indicating more efficient resource utilization. Although the effects on most maize yield components were not statistically significant, the 1:1 arrangement demonstrated superior overall productivity and land use efficiency, making it especially suitable for resource-limited smallholder farmers in northern Nigeria. To improve grain yield and land productivity in the Sudano-Sahelian region, the 1:1 maize–cowpea intercropping system using SAMPEA 21 is strongly recommended. This variety's compatibility with maize supports better crop performance and reduces interspecific competition. Extension services and agricultural policies should actively promote such balanced intercropping practices to enhance resource use efficiency and build resilience under rainfed farming conditions.

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