FUDMA Journal of Agriculture and Agricultural Technology
ISSN: 2504-9496
Vol. 12 No. 1, March 2026: Pp144-154

https://doi.org/10.33003/jaat.2026.1201.17

YIELD PERFORMANCE OF COWPEA VARIETIES (*Vigna unguiculata* (L.) Walp) UNDER VARYING PLANT POPULATIONS AND PHOSPHORUS FERTILIZER RATES IN NIGERIAN SAVANNA ZONE

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ABSTRACT

Two field trials were conducted during the 2023 rainy season in Dutsin-Ma and Funtua to assess the yield performance of cowpea varieties (*Vigna unguiculata (L.) Walp*) as influenced by plant population and phosphorus fertilizer rates in the savanna zone of Nigeria. The treatments consisted of a factorial combination of three varieties (SAMPEA 20T, SAMPEA 19 and ZAFA), three plant populations (22,267, 26,667 and 33,333 plants ha^{-1}) and three phosphorus rates (30, 60 and 90 P_2O_5 kg ha^{-1}). A Randomized Complete Block Design (RCBD) was used with three replications. The varietal effect significantly ($P<0.05$) increased cowpea yield and yield components. SAMPEA 19 demonstrated superior grain yield ha^{-1} performance (1766kg) compared to ZAFA (1671kg) and SAMPEA (1514kg) in Dutsin-Ma, while ZAFA yielded superior (1915kg) to SAMPEA 19(1856kg) and SAMPEA 20T(1782kg) in Funtua. The plant population of 33,333 cowpea plants ha^{-1} produced significantly higher grain yield ha^{-1} (1747kg) than that of plant population 26,667(1603kg) and 22,267(1600kg) in Dutsin-Ma, while plant population of 26,667 gave significantly higher grain yield ha^{-1} (2016kg) than 33,333(1782kg) and 22,267(1755kg) in Funtua. Applying phosphorus fertilizer significantly ($P<0.05$) increased cowpea yield and yield components. Applying 30 P_2O_5 kg ha^{-1} produced significantly higher grain yield (1880 kg ha^{-1}) than 1547 and 1524 kg ha^{-1} for 60 and 90kg P_2O_5 ha^{-1} in Dutsin-Ma, respectively, and higher grain yield (2051 kg ha^{-1}) than 1802 and 1700 kg ha^{-1} for 60 and 90kg P_2O_5 ha^{-1} in Funtua, respectively. Applying 30 kg P_2O_5 ha-^{1} is the most suitable rate for cowpea production in both locations.

Keywords: plant population, phosphorus, variety, cowpea, savanna zone, grain yield.

INTRODUCTION:

Cowpea (*Vigna unguiculata* (L.) *Walp*) is a widely grown leguminous crop in Nigeria, known for its high protein content and nitrogen-fixing ability. It is a critical source of food and income for millions of smallholder farmers, particularly in Nigeria, the world's largest producer and consumer of cowpeas (FAO, 2021). Cowpea is a staple food and a vital source of protein for millions of people, particularly in Sub-Saharan Africa, Asia, and certain regions of the Americas (Mateva et al., 2023). It is cultivated across various agro-ecological zones. The crop's significance in sustainable agricultural systems stems from its adaptability to different soil types and its ability to fix atmospheric nitrogen (Phiri et al., 2023). Cowpea production faces challenges, including variable yields, susceptibility to pests and diseases, and the impact of climate change on production conditions (Jiménez et al., 2023). With increasing global demand for nutrient-dense foods and growing pressure on agricultural systems to ensure food security, there is a clear need to boost cowpea production. Among the numerous factors influencing cowpea productivity, genotype, plant population density, and phosphorus nutrition are among the most important determinants of growth, development, and grain yield (Traore et al., 2014).

Despite its importance, cowpea production is significantly constrained by several factors, including low-yielding local varieties, susceptibility to pests and diseases, and environmental stresses such as drought and erratic rainfall (Singh et al., 2020). A major challenge is the lack of location-specific data on the performance of different cowpea varieties. Although improved varieties have been developed through breeding programs, their performance varies widely across agro-ecological conditions, including soil type, rainfall distribution, and temperature (Kamai et al., 2022). Studies have shown considerable variation in yield, maturity period, and resistance to biotic and abiotic stresses among cowpea varieties (Sabo et al., 2022; Aliyu et al., 2021). One key agronomic factor influencing cowpea yield is plant population, which determines the intensity of intra-specific competition for resources such as light, nutrients, water, and space. Optimizing plant population is essential for achieving maximum yield and efficient resource use. However, there is no universally recommended plant population for cowpea cultivation, as the ideal density often varies with environmental conditions, soil fertility, variety, and management practices (Singh et al., 2019). Several studies have shown that both low and high plant densities can adversely affect cowpea performance. Low densities may lead to underutilization of land resources and increased weed competition, while excessively high densities can intensify competition for light and nutrients, reducing pod formation and seed weight (Abayomi et al., 2008).

Phosphorus plays a critical role in plant growth and development, influencing root development, energy transfer, and nodulation in legumes. However, in many tropical and subtropical soils, phosphorus availability is limited by fixation with iron and aluminum oxides (Roy et al., 2006). This results in suboptimal growth, poor nodulation, and reduced cowpea yield. Studies have shown that phosphorus deficiency not only hampers biomass accumulation but also limits the efficiency of biological nitrogen fixation, thereby compromising both productivity and sustainability (Carsky et al., 2001). Although research has established the need for phosphorus supplementation in legumes, optimal phosphorus application rates for cowpea vary across soil types, climatic zones, and genotypes (Adu-Gyamfi et al., 2007). Inappropriate phosphorus application, either too low or excessive, can lead to nutrient imbalance, increased production costs, and environmental degradation (FAO, 2019). This study was designed to assess the yield performance of cowpea varieties as influenced by plant population and phosphorus fertilizer rates in the savanna zone of Nigeria

MATERIALS AND METHODS

The two-location trials were conducted during the 2023 rainy season at the Faculty of Agriculture Teaching and Research Farm, Federal University Dutsin-Ma (Lat. 12°17′N, Long. 07°27′E, 605 m above sea level), in the Sudan savanna ecological zone, and at the Katsina State Agricultural and Rural Development Authority (KTARDA), Zone II Funtua (Lat. 11°04′N, Long. 07°30′E, 858 m above sea level), in the Northern Guinea savanna ecological zone of Nigeria. The treatments consisted of 3 × 3 × 3 factorial combinations of three cowpea varieties comprising two improved varieties (SAMPEA-20T and SAMPEA-19) and one local variety (ZAFA), three plant populations: 33,333 (40×75 cm), 26,667 (50×75 cm) and 22,267 (60×75 cm) plants ha-1, and three rates of single superphosphate fertilizer: 30, 60 and 90 kg P_2O_5 ha^{-1}. The treatments were laid out in a Randomized Complete Block Design (RCBD) and replicated three times. Each gross plot consisted of 4 ridges, measuring 12 m² (4 m × 3 m), and a net plot (two inner ridges) measuring 6 m² (4 m × 1.5 m). The distance between plots was 0.5 m, and the distance between replications was 0.75 m.

The experimental field was ploughed and harrowed, then ridged, with 75 cm inter-row spacing. Prior to land preparation, soil samples were collected from different points in the field during the 2023 rainy season at a depth of 0–30 cm using a handheld auger. The analyses were carried out at the Institute for Agricultural Research (I.A.R.) in the agronomy department laboratory, Ahmadu Bello University, Zaria. The cowpea seeds were sown after dressing with Seed-care (metalaxyl, carboxin, furathiocarb) at a rate of 10g per 2.5kg seed to protect the seed against soil-borne pathogens, at intra-row spacing of 40 cm, 50 cm, and 60 cm on ridges according to treatment. Seedlings were thinned to two per stand, and gap filling was done one week after sowing. Single Super Phosphate (SSP, 20%) fertilizer was applied at rates of 30, 60, and 90 kg P_2O_5 ha^{-1}. Phosphorus fertilizer rates were applied at sowing. Weeds were controlled through pre-emergence herbicide application immediately after sowing while the second weeding was done 6 weeks after sowing by hand hoeing and hand pulling. In both locations, Pests and Diseases were controlled by application of Cypermethrin from 6 to 9 WAS at weekly intervals at a dose of 200 ml per in 20 litres of water using a knapsack sprayer, beginning from the time of flower initiation in cowpea. The crops were harvested from the net plots for grain yield determination by manual hand picking, and the yield was recorded per plot. Harvesting was done immediately when the leaves turned yellow, and the pods were sufficiently dry.

Data and observations on cowpea yield parameters were collected. The number of pods per plant and the number of seeds per pod were recorded for the five tagged plants in each net plot. 100-seed weight, pod yield per hectare, grain yield per hectare, harvest index and biomass yield per hectare were computed from the entire net plot. The data collected were analyzed using analysis of variance (ANOVA) in a randomized complete block design (RCBD), with SAS version 9.0 (SAS, 2002). The differences among treatment means were separated using Duncan's Multiple Range Test (DMRT) (Duncan, 1955), at 5% level of probability.

RESULTS

Physical and Chemical Properties of Soils of the Experimental sites

The general physical and chemical properties of the surface soil (0-30cm) used for the field experiment at each location during the 2023 rainy season are presented in Table 1. The analysis shows that the soil texture in the Dutsin-Ma experimental site was essentially sandy loam and the soil pH (H_2O) was slightly alkaline (7.45). The organic carbon (OC) (12.61) and available P (15.60) in the soil were high, while the total N (1.65) was low, and the exchangeable cation exchange capacity was moderate (4.06). At the Funtua site, the soil texture was predominantly loam, and the soil pH (H_2O) was moderately acidic (6.25). The organic carbon (OC) (15.60) and available P (15.60) in the soil were high, while total N (2.50) was low, and the exchangeable cation exchange capacity was moderate (4.78) Table 1.

Number of Pods per Plant

The effects of variety, plant population, and phosphorus rates on the number of pods per plant of cowpea in the Dutsin-Ma and Funtua experimental sites during the 2023 rainy season are presented in Table 2. The variety at both experimental sites had a significant effect on the number of pods per plant ($P < 0.05$). In Dutsin-Ma, ZAFA produced significantly ($P<0.05$) higher numbers of pods per plant than SAMPEA-20T and SAMPEA-19 varieties, but in Funtua, SAMPEA-19 produced significantly ($P<0.05$) higher numbers of pods per plant than SAMPEA-20T and ZAFA varieties (Table 2). The plant population at both experimental sites had a significant ($P<0.05$) effect on the number of pods per plant (Table 2). In Dutsin-Ma, plant population of 33,333 and 22,267 plant ha^{-1} produced significantly ($P<0.05$) higher number of pods per plant than 26,667 plant ha^{-1} (Table 2), but in Funtua, plant population of 33,333 plant ha^{-1} produced significantly ($P<0.05$) higher number of pods per plant than the other 26,667 and 22,267 plant ha^{-1} (Table 2). The phosphorus rates at both experimental sites had significant ($P<0.05$) effect on the number of pods per plant, where the plot supplied with 30 and 90 kg P_2O_5 ha^{-1} produced significantly ($P<0.05$) higher pods per plant than 60 kg P_2O_5 ha^{-1} in Dutsin-Ma and in Funtua, plot supplied with 60 kg P_2O_5 ha^{-1} produced significantly

($P<0.05$) higher pods per plant than 30 and 90 kg P_2O_5 ha^{-1} (Table 2). The interactions among all factors had no significant effect ($P>0.05$) on the number of pods per plant at both the Dutsin-Ma and Funtua experimental sites.

Number of Seeds per Pod

The effects of variety, plant population, and phosphorus rates on the number of seeds per pod of cowpea at the Dutsin-Ma and Funtua experimental sites during the 2023 rainy season are presented in Table 2. The variety at both experimental sites had a significant ($P<0.05$) effect on the number of seeds per pod only in Dutsin-Ma. SAMPEA 19 produced significantly ($P<0.05$) higher numbers of seeds per pod than SAMPEA-20T and ZAFA varieties in Dutsin-Ma, but in Funtua, ZAFA produced a non-significant ($P>0.05$) higher number of seeds per pod than SAMPEA-20T and SAMPEA 19 varieties (Table 2). The plant population at both experimental sites had a significant ($P<0.05$) effect on the number of seeds per pod (Table 2). In Dutsin-Ma, a plant population of 22,267 plant ha^{-1} produced significantly ($P<0.05$) higher number of seeds per pod than 33,333 and 26,667 plant ha^{-1} (Table 2), but in Funtua, a plant population of 33,333 plant ha^{-1} produced significantly ($P<0.05$) higher number of seeds per pod than 26,667 and 22,2267 plant ha^{-1} (Table 2). The phosphorus rates at both experimental sites had a significant ($P<0.05$) effect on the number of seeds per pod, with plots supplied

Table 1: Physical and chemical characteristics of soils in Dutsin-Ma and Funtua experimental sites during the 2023 rainy season

Soil Characteristics	Soil depth (0-30cm)	
Particle Size Distribution (g kg^{-1})	Dutsin-Ma	Funtua
Sand	800	580
Silt	120	280
Clay	80	140
Textural Class	Sandy loam	Loam
Chemical Composition		
pH in H_2O (1:2.5)	7.45	6.50
pH in 0.01M $CaCl_2$ (1:2.5)	6.55	5.40
Organic Carbon (g kg^{-1})	12.61	15.60
Total Nitrogen (g kg^{-1})	1.65	2.50
Available Phosphorus (g kg^{-1})	13.70	15.60
Exchangeable Bases (Cmol kg^{-1})		
Calcium (Ca)	2.98	3.28
Magnesium (Mg)	0.54	1.10
Potassium (K)	0.20	0.25
Sodium (Na)	0.14	0.30
Aluminium and Hydrogen (A^{3+}+ H^+)	0.20	0.30
CEC (Cmol kg^{-1})	4.06	5.10

Analysed at the Department of Agronomy, Ahmadu Bello University, Zaria, (2023).

Table 2: Effect of variety, plant population and phosphorus rates on number of pods per plant, number of seeds per pod and 100 seeds weight of cowpea in Dutsin-Ma and Funtua during 2023 rainy season

	Dutsin-Ma			Funtua		
Treatment	No. of pods per plant	No. of seeds per pod	100 seeds weight (g)	No. of pods per plant	No. of seeds per pod	100 seeds weight (g)
VARIETY (V)						
SAMPEA 20T	71.62^b	8.26^b	14.18^b	92.11^c	13.48	21.13^b
SAMPEA 19	70.61^b	10.15^a	13.77^c	116.74^a	13.52	20.15^c
ZAFA	86.57^a	9.67^b	16.57^a	99.00^b	13.74	24.90^a
SE$\underline{+}$	0.924	0.178	0.107	1.419	0.176	0.151
Plant population (S) (plants ha^{-1})						
22,267	77.02^a	10.30^a	14.45^b	97.52^c	13.52^b	22.02
26,667	72.44^b	9.33^b	15.12^a	102.56^b	13.07^b	22.25
33,333	79.34^a	8.44^c	14.95^a	107.78^a	14.15^a	21.91
SE±	0.924	0.178	0.107	1.419	0.176	0.151
Phosphorus rate (P_2O_5 kg ha^{-1})						
30	82.94^a	9.37^b	14.77	83.52^c	13.74	21.89
60	64.74^b	8.81^c	15.00	117.00^a	13.63	22.15
90	81.12^a	9.89^a	14.75	107.33^b	13.37	22.14
SE±	0.924	0.178	0.107	1.419	0.176	0.151

Interaction						
V*S	NS	NS	NS	NS	NS	NS
V*P	NS	NS	NS	NS	NS	NS
S*P	NS	NS	NS	NS	NS	NS
V*S*P	NS	NS	NS	NS	NS	NS

Means followed by the same superscript(s) within same column in each treatment group are not significantly different at 5% probability level according to Duncan Multiple Range Test (DMRT). NS= Not Significant at 5% level of probability

with 90 kg P_2O_5 ha^{-1} producing a significantly (P<0.05) higher number of seeds per pod than 30 and 60 kg P_2O_5 ha^{-1} in Dutsin-Ma. In the Funtua plot supplied with 30 kg P_2O_5 ha^{-1}, the number of seeds per pod was not significantly higher (P>0.05) than at 60 and 90 kg P_2O_5 ha^{-1} (Table 2). The interactions among all factors had no significant effect (P>0.05) on the number of seeds per pod at both the Dutsin-Ma and Funtua experimental sites.

100-Seeds Weight (g)

The effects of varieties, plant population, and phosphorus rates on the 100-seed weight of cowpea at the Dutsin-Ma and Funtua experimental sites during the 2023 rainy season are presented in Table 2. The variety at both experimental sites had a significant (P<0.05) effect on 100-seed weight. ZAFA produced significantly (P < 0.05) higher 100-seed weight than SAMPEA-20T and SAMPEA 19 in both locations (Table 2). The plant population had a significant (P<0.05) effect on 100-seed weight in Dutsin-Ma only (Table 2), where plant populations of 33,333 and 26,667 plant ha^{-1} produced significantly (P<0.05) higher 100-seed weight than 22,267 plant ha^{-1} in Dutsin-Ma (Table 2), but plant population was not significant (P>0.05) in Funtua (Table 2). The phosphorus rates at both experimental sites had no significant (P>0.05) effect on 100 seed weight in both locations, where plots supplied with 60 kg P_2O_5 ha^{-1} produced a non-significant (P>0.05) higher number of 100 seed weight than 30 and 90 kg P_2O_5 ha^{-1} in both locations (Table 2). The interactions among all the factors had no significant (P>0.05) on the 100-seed weight in both the Dutsin-Ma and Funtua experimental sites.

Pod Yield per Hectare (kg)

The effects of varieties, plant population, and phosphorus rates on cowpea pod and grain yields per hectare in Dutsin-Ma and Funtua during the 2023 rainy season are presented in Table 3. The variety effect had a significant (P<0.05) effect on pod yield per hectare only in Dutsin-Ma. In Dutsin-Ma, SAMPEA-20T produced significantly (P<0.05) higher pod yield per hectare than SAMPEA 19 and ZAFA, but in Funtua, SAMPEA-20T produced a non-significant higher pod yield (P>0.05) per hectare than SAMPEA 19 and ZAFA (Table 3). The plant population at both experimental sites had a significant (P<0.05) effect on pod yield per hectare (Table 3). At both locations, the densities of 33,333 and 26,667 plant ha^{-1} produced significantly (P<0.05) higher numbers of pods per plant than 22,267 plant ha^{-1}. The phosphorus rates had a significant (P<0.05) effect on pod yield per hectare in both locations, with plots supplied with 90 kg P_2O_5 ha^{-1} producing significantly (P<0.05) higher pod yield per hectare than those supplied with 30 or 60 kg P_2O_5 ha^{-1} in Dutsin-Ma. In the Funtua plot supplied with 30 and 60 kg P_2O_5 ha^{-1} gave significantly (P<0.05) higher pod yield per hectare than 90 kg P_2O_5 ha^{-1} (Table 3). The interactions among all the factors had no significant (P>0.05) effect on pod yield per hectare in both the Dutsin-Ma and Funtua experimental sites.

Grain Yield per Hectare (kg)

The variety at both experimental sites had a significant (P<0.05) effect on grain yield per hectare (Table 3). In Dutsin-Ma, SAMPEA 19 produced significantly (P<0.05) higher grain yield per hectare than other varieties. However, in Funtua, ZAFA, though statistically similar to SAMPEA 19, produced significantly (P<0.05) higher grain yield per hectare than SAMPEA-20T (Table 3). The plant population of 33,333 plant ha^{-1} produced significantly (P<0.05) higher grain yield per hectare than 26,667 and 22,267 plant ha^{-1} in Dutsin-Ma, but in Funtua, the plant population of 26,667 plant ha^{-1} produced significantly (P<0.05) higher grain yield per hectare than 22,267 and 33,333 plant ha^{-1} (Table 3). The phosphorus rates had a significant (P<0.05) effect on grain yield per hectare in both locations, with plots receiving 30 kg P_2O_5 ha^{-1} producing significantly (P<0.05) higher grain yield per hectare than plots receiving 60 or 90 kg P_2O_5 ha^{-1}. The interaction between variety and phosphorus rates was significant (P<0.05) in Dutsin-Ma, where ZAFA with 30 kg P_2O_5 ha^{-1} produced the highest grain yield, whereas ZAFA with 60 kg P_2O_5 ha^{-1} produced the lowest grain yield (Table 4).

Table 3: Effect of varieties, plant density and phosphorus rates on pod and grain yield per hectare of cowpea in Dutsin-Ma and Funtua during 2023 rainy season

Treatment	Dutsin-Ma		Funtua	
	Pod yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Pod yield (kg ha^{-1})	Grain yield (kg ha^{-1})
Variety (V)				
SAMPEA 20T	2379.2^{a}	1514^{c}	2620.8	1782^{b}
SAMPEA 19	2269.1^{b}	1766^{a}	2528.6	1856^{ab}
ZAFA	2108.6^{c}	1671^{b}	2582.1	1915^{a}
SE±	33.15	25.6	49.92	33.6
Plant population (S) (plants ha^{-1})				
22,267	2123.8^{b}	1600^{b}	2367.3^{b}	1755^{b}
26,667	2333.6^{a}	1603^{b}	2745.6^{a}	2016^{a}
33,333	2299.5^{a}	1747^{a}	2618.6^{a}	1782^{b}
SE±	33.15	25.6	49.92	33.6
Phosphorus rate (P_2O_5) (kg ha^{-1})				
30	2188.9^{b}	1880^{a}	2641.2^{a}	2051^{a}
60	2244.2^{ab}	1547^{b}	2643.1^{a}	1802^{b}
90	2323.8^{a}	1524^{b}	2447.2^{b}	1700^{c}
SE±	33.15	25.6	49.92	33.6
Interaction				
V*S	NS	NS	NS	NS
V*P	NS	**	NS	*
S*P	NS	**	NS	**
V*S*P	NS	NS	NS	NS

Means followed by the same superscript(s) within same column in each treatment group are not significantly different at 5% probability level according to Duncan Multiple Range Test (DMRT)
NS= Not Significant at 5% level of probability

Table 4: Interaction between varieties and phosphorus rates on grain yield of cowpea in Dutsin-ma during 2023 rainy season

	Phosphorus rates (P_2O_5 kg ha^{-1})		
Variety	30	60	90
SAMPEA-20T	1528.9^{cd}	1396.9^{d}	1615.2^{bcd}
SAMPEA 19	2003.5^{ab}	1905.0^{abc}	1392.3^{d}
ZAFA	2108.8^{a}	1340.4^{d}	1564.6^{cd}
SE±		44.34	

Means followed by the same superscript(s) are not significantly different at 5% probability level according to Duncan Multiple Range Test (DMRT)

Table 5: Interaction between varieties and phosphorus rates on grain yield of cowpea in Funtua during 2023 rainy season

	Phosphorus rates (P_2O_5 kg ha^{-1})		
Variety	30	60	90
SAMPEA-20T	2117.7^{a}	1615.6^{b}	1612.3^{b}
SAMPEA 19	2008.0^{ab}	1745.3^{ab}	1815.9^{ab}
ZAFA	2028.0^{ab}	2044.7^{ab}	1672.7^{ab}
SE±		58.25	

Means followed by the same superscript(s) are not significantly different at 5% probability level according to Duncan Multiple Range Test (DMRT)

Table 6: Interaction between plant population and phosphorus rates on grain yield of cowpea in Dutsin-ma during 2023 rainy season

	Phosphorus rate (P_2O_5 kg ha^{-1})		
Plant population	30	60	90
22,267	1799.4^{abcd}	1580.1^{bcd}	1508.5^{bcd}
26,667	1863.8^{ab}	1683.0^{abcd}	1264.3^{d}
33,333	2063.6^{a}	1379.1^{cd}	1799.4^{abc}
SE±		44.34	

Means followed by the same letters are not significantly different at 5% probability level according to Duncan Multiple Range Test (DMRT)

Table 7: Interaction between plant population and phosphorus rates on total grain yield of cowpea at Funtua during 2023 raining season

	Phosphorus rate (P_2O_5 kg ha^{-1})		
Plant population	30	60	90
22,267	1909.0^{abc}	1598.9^{bc}	1757.2^{abc}
26,667	2198.2^{a}	2024.9^{ab}	1826.1^{abc}
33,333	2046.4^{ab}	1781.9^{abc}	1517.6^{c}
SE±		58.25	

Means followed by the same superscript(s) are not significantly different at 5% probability level according to Duncan Multiple Range Test (DMRT)

The interaction between variety and phosphorus rates was significant ($P<0.05$) on grain yield per hectare in Funtua, where SAMPEA 20T plus 30 kg P_2O_5 ha^{-1} produced the highest grain yield, whereas SAMPEA 20T with 90 kg P_2O_5 ha^{-1} produced the lowest grain yield (Table 5). The interaction between plant population and phosphorus rates was significant ($P<0.05$) on grain yield in Dutsin-Ma, where 33,333 plant ha^{-1} with 30 kg P_2O_5 ha^{-1} produced the highest grain yield per hectare, while 26,667 plant ha^{-1} with 90 kg P_2O_5 ha^{-1} produced the lowest grain yield per hectare (Table 6) The interaction between plant population and phosphorus rates was significant on grain yield per hectare of cowpea in Funtua, where 26,667 plant ha^{-1} with 30 kg P_2O_5 ha^{-1} produced the highest grain yield per hectare, while 33,333 plant ha^{-1} with 90 kg P_2O_5 ha^{-1} produced the lowest grain yield per hectare (Table 7).

Biomass Yield per Hectare (kg)

The effects of variety, plant population, and phosphorus rates on cowpea biomass yield per hectare in Dutsin-Ma and Funtua in Table 8. The variety at both locations had a significant ($P<0.05$) effect on biomass yield per hectare, with the plot planted with ZAFA yielding significantly higher biomass per hectare than SAMPEA-20T and SAMPEA 19, which were at par in both locations. The plant population at both locations had a significant ($P<0.05$) effect on biomass yield per hectare, where the plot with a plant population of 33,333 plants ha^{-1} yielded significantly higher biomass yield per hectare than 22,267 and 26,667 plant ha^{-1} in Dutsin-Ma, while in Funtua, plots with a plant population of 26,667 plants ha^{-1} yielded significantly ($P<0.05$) higher biomass per hectare than 22,267 and 33,333 plant ha^{-1} but plant population 33,333 plant ha^{-1} produced significantly ($P<0.05$) higher biomass yield per hectare than 22,267 plant ha^{-1} (Table 8). Phosphorus rates in both locations had a significant effect on biomass yield per hectare, with plots supplied with 30 kg P2O5 ha^{-1} yielding significantly more biomass than those supplied with 60 or 90 kg P_2O_5 ha^{-1} (Table 8). The interactions among all the factors had no significant effect ($P > 0.05$) on biomass yield per hectare in Dutsin-Ma and Funtua.

Harvest Index (HI)

The effects of varieties, plant population, and phosphorus rates on the harvest index (H.I.) of cowpea at Dutsin-Ma and Funtua are presented in Table 8. The variety at both locations had a significant ($P<0.05$) effect on harvest index, where SAMPEA 19 produced significantly ($P<0.05$) higher HI than other varieties in Dutsin-Ma, while in Funtua, SAMPEA 19, though statistically similar with SAMPEA 20T, produced significantly ($P<0.05$) higher HI than SAFA. The plant population in both locations had a significant ($P<0.05$) effect on HI, where 22,267 plants ha^{-1} produced significantly higher HI than 26,667 and 33,333 plants ha^{-1} in both locations. The phosphorus rates in both locations had a significant ($P<0.05$) effect on HI, where plots that received 30 and 90 kg P_2O_5 ha^{-1} produced significantly ($P<0.05$) higher HI than other phosphorus rates in Dutsin-Ma, while in Funtua, applying 30 kg P_2O_5 ha^{-1} gave significantly ($P<0.05$) higher HI than 60 and 90 kg P_2O_5 ha^{-1} (Table 9). The interaction among all factors had no significant effect on HI in either location.

Table 8: Effect of varieties, plant density and phosphorus rates on biomass yield per hectare and harvest index of cowpea in Dutsin-Ma and Funtua during 2023 rainy season

Treatment	Dutsin-Ma		Funtua	
	Biomass yield/ha (kg)	Harvest index (%)	Biomass yield/ha (kg)	Harvest index (%)
Variety (V)				
SAMPEA 20T	3834.8^{c}	41.12^{b}	4671.7^{b}	39.28^{ab}
SAMPEA 19	4149.3^{b}	44.28^{a}	4718.1^{b}	39.46^{a}
ZAFA	4369.1^{a}	39.01^{c}	5036.7^{a}	38.32^{b}
SE±	48.22	0.545	70.42	0.351
Plant population (S) (plants ha^{-1})				
22,267	3648.3^{b}	44.89^{a}	4151.6^{c}	42.64^{a}
26,667	4060.1^{b}	41.93^{b}	5277.1^{a}	38.79^{b}
33,333	4644.8^{a}	37.59^{c}	4997.7^{b}	35.64^{c}
SE±	48.22	0.545	70.42	0.351
Phosphorus rate (P_2O_5) (kg ha^{-1})				
30	4481.5^{a}	43.93^{a}	4988.5^{a}	42.58^{a}
60	4169.0^{b}	37.97^{b}	4786.9^{b}	37.90^{b}
90	3702.7^{c}	42.51^{a}	4651.1^{b}	36.59^{c}
SE±	48.22	0.545	70.42	0.351
Interaction				
V*S	NS	NS	NS	NS
V*P	NS	NS	NS	NS
S*P	NS	NS	NS	NS
V*S*P	NS	NS	NS	NS

Means followed by the same superscript(s) within same column in each treatment group are not significantly different at 5% probability level according to Duncan Multiple Range Test (DMRT). NS= Not Significant at 5% level of probability.

DISCUSSION:

Varietal Effect on Yield and Yield Components of Cowpea

Significant differences exhibited by the cowpea varieties on yield and yield components, including number of pods per plant, number of seeds per pod, 100-seed weight, pod yield per hectare, grain yield per hectare, biomass yield, and harvest index, could be attributed to genetic differences among the varieties, their adaptability to environmental conditions, and prevailing weather parameters. ZAFA, a local variety, demonstrated superiority in some instances, possibly because it is more ecologically adaptable and more resilient to harsh environmental stresses common in the Nigerian savanna. The observed varietal differences align with findings reported by Singh and Tarawali (1997), who found significant differences in grain and fodder yields among promising medium-maturing cowpea varieties. It also agrees with Masenya (2016), who recorded significant varietal responses in the number of pods per plant and per hectare in the evaluation of introduced cowpea lines. Works by Shambharkar *et al.* (2006), Onat *et al.* (2016), Dapaah *et al.* (2014) and Sharma *et al.* (2013) have also corroborated this finding, reporting a varietal response on the number of pods per plant in groundnut and cowpea. However, the SAMPEA 19 in Dutsin-Ma and ZAFA in Funtua yielded significantly higher cowpea grain yield than other varieties. The superiority of SAMPEA 19 in Dutsin-Ma and ZAFA in Funtua, compared to other varieties, may be due to genetic factors, adaptability, soil, and climatic conditions. This agrees with Singh and Tarawali *et al.* (1997), Singh *et al.* (2002), Adjei-Nsiah *et al.* (2008) and Timko *et al.* (2007), who all reported significant varietal influence on cowpea grain yield.

Effect of Plant Population on Yield and Yield Components of Cowpea

The marked increase in grain yield and associated yield components observed under optimum plant population may be attributed to efficient utilization of available resources, such as light, moisture, nutrients, and growing space, due to the increased plant population. This agrees with the results of Ismail and Hall (2000), who stated that higher density planting resulted in increased yield per unit area and Ball et al. (2001), who reported that increasing plant population reduced yield per plant but increased yield per unit area. This disagrees with Purcell *et al.* (2002), who reported that as plant population density decreased, the number of pods per stem and the number of seeds per pod increased. This is because the resources needed for pod formation are less in demand at low densities. Also, it disagrees with Kamara *et al.* (2014), who reported that yield increased with the number of plants per stand, although individual plant yield was reduced because the lower half of the stem produced fewer pods. The plant population at both locations significantly enhanced cowpea yield and yield parameters. The plant populations of 33,333 plants ha^{-1} in Dutsin-Ma and 26,667 plants ha^{-1} in Funtua produced significantly higher grain yields than the other densities at both locations. This superiority of 33,333 and 26,667 plants ha^{-1}, compared to other plant populations, could be due to increases in yield parameters, which cumulatively led to better cowpea grain yield. This is consistent with the results reported by Kamara et al. (2003), who found that an increase in the number of plants per hectare was associated with increased plant height. It also agrees with the results of Coulibaly et al. (2024), who reported that a positive relationship between increasing plant population per hectare and grain and fodder yields.

Effect of Phosphorus Fertilizer on Yield and Yield Components of Cowpea

Application of phosphorus increased grain yield and yield components, as evidenced by significant increases in the number of pods per plant, the number of seeds per pod, 100-seed weight, pod yield per hectare, grain yield per hectare, biomass yield per hectare, and harvest index. This could be attributed to the vital role of phosphorus as a macronutrient for legume crops, supporting root development, nodule formation, energy transfer (ATP), and ultimately grain production (Dakora & Keya, 1997). This aligns with the findings of other workers (Okeleye & Okelana, 2000; Haruna & Usman, 2013; Odundo et al., 2001; Ntare & Bationo, 2002; Nyoki et al., 2013; Singh et al., 2011; and Ndor et al., 2012), who also reported significant increases in cowpea yield in response to phosphorus application. Application of 30 kg P_2O_5 ha^{-1} resulted in a significantly higher cowpea grain yield than other phosphorus rates at both locations. This agrees with Mohammed et al. (2019), who found that applying phosphorus at rates between 30 and 45 kg P_2O_5 ha^{-1} optimized grain yields, while further increases led to diminishing returns, suggesting that excessive P application offers no additional yield benefit. It also agrees with Ibrahim et al. (2020), who noted that phosphorus use efficiency in cowpea was highest at moderate P rates of 30 kg P_2O_5 ha^{-1}, beyond which fixation losses occurred due to low soil pH and high iron/aluminum content.

Interactions

The interaction between variety and phosphorus rate had a highly significant effect on grain yield per hectare in Dutsin-Ma, whereas in Funtua it was significant. This agrees with Khan et al. (2021), who also found significant variety × phosphorus interaction effects, where phosphorus fertilization increased grain yield more substantially in improved varieties than in local cultivars. The improved varieties exhibited enhanced pod formation and seed filling, suggesting higher phosphorus uptake efficiency. The interaction between plant population and phosphorus rates had a highly significant effect on grain yield per hectare in both locations. This is in line with Ene-Obong *et al.* (2021), who found that moderate spacing (30 × 50 cm) combined with 40 kg P_2O_5 ha^{-1} resulted in maximum pod number and grain yield. Similarly, Ajeigbe *et al.* (2016) reported that semi-erect varieties exhibited greater responsiveness to increasing phosphorus levels than the spreading types.

CONCLUSION

The study demonstrated that cowpea grain yield and yield components were significantly influenced by varietal differences, plant population density and phosphorus fertilizer application. SAMPEA 19 proved most suitable for Dutsin-Ma, while both SAMPEA 19 and ZAFA performed best in Funtua. Plant populations of 33,333 plants ha^{-1} in Dutsin-Ma and 26,667 plants ha^{-1} in Funtua produced superior grain yields. Application of 30 kg P_2O_5 ha^{-1} consistently resulted in the highest grain yield and is therefore recommended for cowpea production in both locations.

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