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Effect of Plant Population on Cowpea (*Vigna unguiculata* L. Walp.) Growth Characters, Grain and Fodder Yield in Soudanian and Soudano-Sahelian Zones of Burkina Faso

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ABSTRACT: Cowpea varieties respond differently to plant population per hectare due to their intrinsic morphological differences and the influence of the weather and soil condition in growing environment. The objective of this study was to investigate the effect of plant population on growth and yield characters of erected and semi-erected cowpea varieties in two agroecological zones of Burkina Faso. A split-plot experiment with three replications conducted in two consecutive rainy seasons, 2019 and 2020, at Kamboinse and Farako-Ba research stations was used to determine the effect of three plant population, 62,500 (control), 95,258 and 111,111 on four improved cowpea varieties, KVx745-11P, Komcalle, Tiligre, Neerwaya. The results showed a significant variation of fodder and grain yield in both locations. At Farako-Ba the combined years data recorded the values of 3740.50, 5240.94 and 5164.02 kilogram per hectare for fodder yield and 1124.14, 1242.93 and 1372.93 kilogram per hectare for grain yield at the plant population of 62,500, 95,238 and 111,111, respectively. The same trend was Observed in Kamboinse with slightly higher average means of fodder and grain yield which were 4300.75, 6446.06, 6699.06 kilogram per hectare and 1285.82, 1481.06 and 1650.03 kilogram per hectare, respectively. From the study it is also noticed that grain and fodder yield were impacted by genotypes and environment. The positive relationship between plant population, fodder and grain yield suggest that improved cowpea varieties yield can be substantially increased with the plant population of 111,111 per hectare.

KEYWORDS: Cowpea Varieties, Plant per Hectare, Yield, Agroecological Zones, Burkina Faso.

1 INTRODUCTION

Cowpea (*Vigna unguiculata* (L.) Walp.) is the second important grain legume in Africa and the most widely planted native legume crop in Sub-Saharan region [1]. It is a major source of dietary protein that staple crops, cereals and tuber cannot provide [2]. The consumption of cowpea supplies most of macro and micronutrients of the diet. Cowpea is also recognized as one of richest foods in nutraceuticals compounds. Due to its nutrients and functional benefits, cowpea is gaining industrial importance for being used as a potential ingredient in food formulations [3], [4]. Beyond cowpea consumption by humans, it is an excellent fodder for livestock. According to [5] in semi-arid regions of tropics, cowpea fodder with its high nutritional quality is an important component which increase productivity and profitability of mixed crop-livestock system. As well as it is known for its qualities in humans and animals feeding, in Sub Saharan Africa (SSA), cowpea occupy a prominent place in the legume trade. According to [2], it is a cash generating commodity for smalls and medium size entrepreneurs' farmers. Trade of fresh cowpea leaves, grains and processed food provides both rural and urban communities, opportunities for earning some money [6]. In the past 30 years, an increasing trend was observed in cowpea production and utilization in SSA. However, under conditions of subsistence agriculture, the average cowpea yield in farmer's fields range from 100-300 $kgha^{-1}$ although the ecological conditions are suitable for the growth and development of the crop [1]. Cowpea production is faced to major constraints and challenges that can be classified into three types: socio-economic, biotic and abiotic constraints. In previous years, to reverse the trend of low yields, in Burkina Faso, plant breeders have released resistant varieties to parasitic weeds, bacterial and fungal diseases and most of these varieties are erect and semi-erect type with early and medium maturity cycle. The recommended plant population corresponding to 62,500 plant ha^{-1} (80 x 40 cm with 2 plants per stand) used in cowpea production may not be appropriate for news release cowpea varieties. According to [7], among the agronomic practices that have direct relationship with cowpea grain production, plant population is one of the most important, especially influencing morpho-physiology, production components and productivity. [8], stated that adjusting of population is an important tool to optimize crop growth and the time required for canopy closure, and to achieve maximum biomass and grain yield. [9], reported that increasing plant population reduced yield of individual plants but increased yield per unit area.

In this context, investigate to determine the effect of plant population in improved cowpea varieties which are gaining importance in term of planting area, will surely help cowpea growers to increase grain and fodder yield.

2 Materials And Methods

2.1 Experimental Sites

The experiments were carried out in rainy season 2019 and 2020 at Farako-Ba and Kamboinse Research Station which belong to Institut de l'Environnement et de Recherches Agricoles (INERA). Farako-Ba (11°5'N, 4°18'W; altitude 439 m) is located in Soudanian Agroecological zone (AEZ) while Kamboinse (12°.46'N, 1°.54'W; Altitude: 293 m) is located in soudano-sahelian AEZ.

2.2 Treatments And Experimental Design

The experiments were conducted in split plot design with three replications. Four cowpea varieties were subjected to the effect of three plant population. The cowpea varieties used as plants material possess farmers desired traits and have been realised by cowpea breeding program of INERA. Their maturity cycle varies from 60 to 70 days. Komcalle (KVx442-3-25) is an erected variety, Neerwaya (KVx780-6) and Tiligre (KVx775-33-2G) are semi-erected. The variety KVx745-11P is a dual-purpose one, its stay green at maturity stage. The plant population used were 62,500 (80 x 40 cm), 92,238 (70 x 30 cm) and 111,111 (60 x 30 cm); 62,500 plants/ha is used as control, it is the recommended plant population for cowpea production in Burkina Faso.

Two factors constituted with cowpea varieties (four) and plant population (three) were randomised in plots. Cowpea variety is maintained as whole plot treatment and plant population is considered as sub plot treatment. The area of each whole plot was 30 m^2 whereas the area of each sub plot was equal to 9.6 m^{2,} 8.4 m^2 and 7.2 m^2 for the respective plant population of 62,500, 92,238 and 111,111 per hectare. The sub plots were separated by 1 m length, a distance of 1.5 m is left between whole plots and replications. The total area of the experiment plot per location was 555.9 m^2.

2.3 Cultural Practices

Chemical NPK (14-23-14) fertilizer at a rate of 100 kg/ha combined with poultry manure at 1,5 t/ha were used in experiments of both sites at 2019 and 2020 rainy season. The land was cleared, ploughed and poultry manure was incorporated before harrowing and levelling. Before sowing, seeds were treated with *Chlorpyrifos-ethyl* and *thiram* (*Calsio*) at a rate of 20 g per kg of seeds. These chemicals have advantage of having insecticidal and fungicidal properties. Weed control was done manually two times, at 3 and 6 weeks after sowing. Insecticides were sprayed at flowering and pod-filling stage corresponding to 5 and 7 WAS respectively, to control pests, insects and diseases. For this purpose, *Deltamethrin* was used at the dose of 1litre per hectare.

2.4 Data Collection

Growth data were collected on six randomly selected and tagged plants from net plots. The average number of leaves, leaves chlorophyll content and plants dry weight were calculated from measurements taken on tagged at 6 WAS. Crop growth rate (CGR) is the increase in plant dry weight per unit time. Dry weight of sampled plants at 3 and 6 WAS were used for it calculation according to the formula suggested by [10]. Plants height were measured from the ground base to the top of the main branch and the average was recorded; measurements were taken at 9 WAS using a graduated meter stick. The total number of branches borne on the main stem of the tagged plants was counted and their mean computed as a number of branches per plant, these measurements were done at 9 WAS.

Data on reproductive traits, fodder and grain yield components were collected on each net plot. Day to 50% flowering and day 95% maturity were estimated by considering plants of each net plot. The average Pods length were obtained from 10 randomly selected mature pods collected on tagged plants. The average number of seeds per pods was determined by threshing manually the ten pods used previously and the mean was recorded as average number of seeds per pod. From threshed seeds, 100 seeds were picked and weighed and the values were recorded as 100 seeds weight. Shelling percentage was obtained by dividing the shelled grain weight of the net plot over the unshelled weight multiply by 100. Harvest index was calculated by weighing the total grains obtained per net plot and divided by the total biological yield and multiplied by 100. Fodder yield and grain yield of each net plot were assessed and converted to yield per hectare.

2.5 Laboratory Analysis Of Soil

Poultry manure was incorporated in top sol before sowing. Prior and sowing, soil samples were collected from experimental plots at 0-30 cm depth using an auger, in a W-shape in order to have a representative and composite sample. Then, samples physico-chemical properties were determined by using standard procedures. Poultry manure elemental composition was also determined.

2.6 Statistical Analysis

Data on cowpea growth and yields characters were subjected to analysis of variance (ANOVA) by using JMP Pro 2017 statistical package. Student Newman's Keuls (SNK) test was used to sort out significant difference among treatments ($P \leq 0.05$). Cowpea variety x plant population interaction effect on fodder and grain yield in both locations was done by using combined year data of each location.

3 Results And Discussions

3.1 Results

3.1.1 Edaphic And Climatic Conditions Of The Experimental Sites

The initial soil physical and chemical properties of the experimental sites and poultry manure used as background manure presented in Table 1, were determined using standard procedure. The soil texture at Farako-Ba site was sandy-loam, with pH = 5.70, the available phosphorus was 3.06 mg/kg, the percent of Organic Carbon and Total Nitrogen was 0.34 and 0.067 respectively. The Cation Exchange Capacity (CEC) value was 2.23. Soil of Kamboinse was loamy textured, its pH=5. 60 and the available phosphorus content was 2.15 mg/kg. The Organic Carbon content was 0.41% and 0.067 % for Total N content. The CEC value was 2.77 cmol$^+$/Kg. The pH of poultry manure was acidic (5.61) with a richest in Organic C (13.27%), Total N (0.66%), Available P (4.75) and CEC (3.11 cmol$^+$/kg) when compared to soils composition of Farako-Ba and Kamboinse.

Table 1. Physical and Chemical Property of Soils at Farako-Ba and Kamboinse and Poultry Manure chemical

Soil Physical Properties	Farako-Ba	Kamboinse	Chemical Properties	Farako-Ba	Kamboinse	Poultry Manure
Sand	63.37	46.75	pH	6.59	6.13	5.61
Silt	21.18	40.54	Organic C (%)	0.50	0.64	13.27
Clay	15.45	12.71	Total N (%)	0.047	0.051	0.66
Texture Class	Sandy-Loam	Loamy	Available P (mg/Kg)	4.89	3.45	4.75
			Ex.cations (cmol$^+$/Kg)			
			K	0.15	0.13	1.13
			Na	0.10	0.06	0.12
			Ca	1.40	1.55	2.05
			Mg	0.43	0.60	0.81
			EA (cmol$^+$/Kg)	0.02	0.09	0.16
			CEC (cmol$^+$/Kg)	2.09	2.43	3.11

Source: Soil Lab, Centre for Dryland Agriculture, Bayero University, Kano

The weather data during the experimentation period (July-October), collected from the National Meteorology Agency (ANAM), indicated variations in rainfall, minimum and maximum temperatures at Farako-Ba and Kamboinse. At Farako-Ba, the average variation of temperatures was 22.03 to 31.16˚C and 21.86 to 30.96˚C for 2019 and 2020, respectively. The total rainfall amount recorded was 1037.50 and 818.70 mm for 2019 and 2020, respectively. For Kamboinse site, average temperatures varied from 23.73 to 33.04˚C and from 23.46 to 32.96 ˚C for 2019 and 2020, respectively. The total rainfall recorded was 800.90 and 812.70 mm for 2019 and 2020, respectively.

3.1.2 Growth And Yield Components Results

The plants growth characters such average leaves number, leaves chlorophyll content and plants dry weight did not reveal significant variation according to cropping season and plant population per hectare (Table 2). But, cowpea variety showed significant differences for these characters.

Table 2. Cropping Year, Plants/ha and Varietal Effect on Number of Leaves, Leaves Chlorophyll Content and Plants Dry Weight at Farako-Ba and Kamboinse

	Leaves number 6WAS		Leaves chlorophyll 6WAS		Plants dry weight (g) 6WAS	
Cropping Season	Farako-Ba	Kamboinse	Farako-Ba	Kamboinse	Farako-Ba	Kamboinse
2019	30.68	39.64	53.42	54.90	31.87	34.58
2020	32.27	37.72	54.03	53.49	32.25	35.96
SE±	0.827	0.965	0.628	0.624	1.994	1.655
Prob.	0.1865	0.1592	0.4954	0.1251	0.8979	0.5654
Plants/ha						
62,500	32.30	40.56	53.58	54.59	31.32	34.49
95,238	32.03	37.79	53.59	54.45	32.27	37.06
111,111	30.09	37.69	53.99	53.54	32.59	34.26
SE±	1.013	1.182	0.770	0.764	2.442	2.026
Prob.	0.2630	0.1507	0.9103	0.5939	0.9353	0.5695
Varieties						
KVx745-11P	30.79ab	37.94b	52.94	54.69a	31.09	34.96b
Komcalle	28.18b	31.72c	53.57	51.64b	28.78	26.32c
Neerwaya	33.49a	43.47a	54.12	55.51a	31.15	43.61a
Tiligre	33.45a	41.58ab	54.26	54.93a	37.21	36.20b
SE±	1.170	1.365	0.889	0.883	2.819	2.340
Prob.	0.0069	<.0001	0.7034	0.0189	0.2240	<.0001

Means followed by the same letter (s) within a treatment group are not significantly different at 5% level of probability using Student Newman Keuls (SNK) test

The results presented in Table 3 showed that crop growth rate (CGR), the average plants height and average number of branches were also statistically similar according to cropping season and plant population per hectare. However, their differences are pronounced at variety scale.

Table 3. Cropping Year, Plants/ha and Varietal Effect on Crop Growth Rate, Plants Height and Branches Number at Farako-Ba and Kamboinse

	Crop Growth Rate (3-6WAS)		Plant height (cm) 9WAS		Branches number 9WAS	
Cropping Season	Farako-Ba	Kamboinse	Farako-Ba	Kamboinse	Farako-Ba	Kamboinse
2019	9.60	10.71	51.81	53.19	4.31	4.19
2020	9.80	10.18	52.45	56.30	4.10	4.09
SE±	0.615	0.514	1.573	1.613	0.100	0.068
Prob.	0.8142	0.4721	0.7361	0.1577	0.1556	0.3662
Plants/ha						
62,500	9.33	9.96	53.15	53.73	4.46a	4.25
95,238	10.03	10.75	52.38	56.55	4.16ab	4.13
111,111	9.74	10.63	50.88	53.95	3.99b	4.05
SE±	0.753	0.629	1.927	1.975	0.122	0.083
Prob.	0.8030	0.6438	0.6086	0.5022	0.0306	0.2723
Varieties						
KVx745-11P	9.68	10.39a	54.22b	48.27	3.75b	3.64b
Komcalle	8.87	8.02b	16.82c	16.79	4.25a	4.17a
Neerwaya	9.64	12.14a	67.80a	77.48	4.56a	4.42a
Tiligre	10.62	11.25a	69.69a	76.43	4.25a	4.33a
SE±	0.870	0.726	2.225	2.281	0.141	0.96
Prob.	0.5677	0.0019	<.0001	<.0001	0.0023	<.0001

Means followed by the same letter (s) within a treatment group are not significantly different at 5% level of probability using Student Newman Keuls (SNK) test

The results presented in Table 4 showed significant variation of 50% flowering and 95% maturity as the cropping season and variety. The effect on plant population on these characters was not significant. The average pods length was statistically similar across growing season and plant population. However, significant variations of pods length were observed between cowpea.

Table 4. Cropping Year, Plants/ha and Varietal Effect on 50% Flowering, 95% Maturity and Pods length (cm) at Farako-Ba and Kamboinse

	50% Flowering		95% Maturity		Pods length (cm)	
Cropping Season	Farako-Ba	Kamboinse	Farako-Ba	Kamboinse	Farako-Ba	Kamboinse
2019	39.36a	39.11a	65.43a	64.74a	15.98	16.04
2020	38.64b	37.97b	63.31b	62.50b	16.30	16.43
SE±	0.140	0.128	0.287	0.194	0.195	0.187
Prob.	0.0004	<.0001	<.0001	<.0001	0.2403	0.1159
Plants/ha						
62,500	39.21	38.54	64.32	63.88	16.07	16.35
95,238	38.75	38.71	64.29	63.55	15.86	15.94
111,111	39.04	38.38	64.50	63.43	16.48	16.41
SE±	0.171	0.157	0.352	0.237	0.238	0.231
Prob.	0.1494	0.3188	0.8643	0.3501	0.1695	0.2547
Varieties						
KVx745-11P	39.11a	38.67a	66.15a	66.50a	14.26b	14.96b
Komcalle	37.78b	37.39b	61.17c	60.52d	14.13b	14.76b
Neerwaya	39.50b	39.06a	64.44b	63.17c	17.85a	17.43a
Tiligre	39.61b	39.06a	65.72a	64.29b	18.32a	17.79a
SE±	0.198	0.181	0.406	0.274	0.275	0.267
Prob.	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

Means followed by the same letter (s) within a treatment group are not significantly different at 5% level of probability using Student Newman Keuls (SNK) test

Shelling percentage and 100 seeds weight (Table 5) significantly vary according to cropping season and variety. The effect of plant population was not significant on these characters.

The harvest index values were statistically the same for the two consecutive cropping years and for locations. Plant population and varieties had significant influence on harvest index (HI). However, the HI values were statistically same for the two consecutive years and for locations. Plant population and varieties had significant effect on HI. The results indicated that high plant population decreased HI, the dual-purpose variety KVx745-11P recorded the lowest HI due to the favouring high expression of fodder trait at the disadvantage of grain yield. In opposite, the erect variety Komcalle with small spray recorded the highest HI. Tiligre and Neerwaya which are similar regarding to their growth habit, scored statistically similar values of HI.

Table 5. Cropping Year, Plants/ha and Varietal Effect on Shelling percentage, 100 Seeds weight and Harvest Index at Farako-Ba and Kamboinse

	Shelling percentage (%)		100 Seeds weight (g)		Harvest Index (%)	
Cropping Season	Farako-Ba	Kamboinse	Farako-Ba	Kamboinse	Farako-Ba	Kamboinse
2019	69.64a	76.66a	14.59	18.17a	0.19	0.18
2020	65.84b	74.98b	15.95	16.24b	0.19	0.19
SE±	0.658	0.470	0.190	0.194	0.004	0.004
Prob.	0.0002	0.0061	<.0001	<.0001	0.2686	0.4809
Plants/ha						
62,500	68.56	76.35	15.40	17.26	0.20a	0.20a
95,238	67.22	75.47	15.20	16.90	0.18b	0.18b
111,111	67.46	75.64	15.21	17.46	0.20a	0.18b
SE±	0.806	0.576	0.232	0.237	0.005	0.005
Prob.	0.4647	0.4368	0.7745	0.1623	0.0010	0.0028
Varieties						
KVx745-11P	68.18	76.08b	10.77c	11.50c	0.17c	0.15c
Komcalle	69.28	78.65a	15.36b	16.76b	0.21a	0.21a
Neerwaya	66.98	73.78c	17.52a	20.10a	0.20ab	0.19b
Tiligre	66.54	74.77bc	17.44a	20.46a	0.19b	0.20ab
SE±	0.931	0.665	0.268	0.274	0.005	0.006
Prob.	0.1689	<.0001	<.0001	<.0001	<.0001	<.0001

Means followed by the same letter (s) within a treatment group are not significantly different at 5% level of probability using Student Newman Keuls (SNK) test

The influence of cropping season on fodder yield was not significant at Farako-Ba and Kamboinse (Table 6). However, a positive relationship was found between increasing of plants density and fodder yield. The results showed that fodder yield depend also on variety type. KVx745-11P, Neerwaya and Tiligre recorded statistically similar fodder yield in both locations and the variety Komcalle which is erected and early maturing recorded the lowest fodder yield. There was no significant difference of fodder yield if compare 95,238 and 111,111 plants/ha. The average fodder yield recorded at Farako-Ba was lower than the average recorded at Kamboinse regarding the effect of plant population and cowpea variety.

The average grain yield was lower at Farako-Ba than Kamboinse for 2019 and 2020 experiments (Table 6). In both locations, it is an increasing trend of grain yield with plant population per hectare. The means separation through SNK test showed that the three plant population give statistically different grain yield. The fact that grain is positively correlated to plant population suggest that the optimum plant population was not achieved in this study.

Table 6. Cropping Year, Plants/ha and Varietal Effect on Fodder and Grain Yield at Farako-Ba and Kamboinse

	Fodder Yield (kg/ha)		Grains Yield (kg/ha)	
Cropping Season	Farako-Ba	Kamboinse	Farako-Ba	Kamboinse
2019	4509.56	5657.05	1238.62	1439.72b
2020	4920.74	5973.53	1254.71	1504.89a
SE±	178.739	173.915	10.762	12.460
Prob.	0.1031	0.2026	0.2509	0.0003
Plants/ha				
62,500	3740.50b	4300.75b	1124.14c	1285.82c
95,238	5240.94a	6446.06a	1242.93b	1481.06b
111,111	5164.01a	6699.06a	1372.93a	1650.03a
SE±	218.909	213.001	13.181	15.661
Prob.	<.0001	<.0001	<.0001	<.0001
Varieties				
KVx745-11P	4868.75a	6036.60a	1027.14c	1108.54c
Komcalle	4054.68b	4702.41b	1293.14b	1545.30b
Neerwaya	4909.20a	6521.77a	1339.75a	1644.37a
Tiligre	5027.98a	6000.38a	1326.64ab	1591.00b
SE±	252.775	245.952	15.220	17.622
Prob.	0.0301	<.0001	<.0001	<.0001

Means followed by the same letter (s) within a treatment group are not significantly different at 5% level of probability using Student Newman Keuls (SNK) test

The figure 1 below show the plant population x variety interaction effect on grain yield at Farako-Ba and Kamboinse. The relationship is positive for cowpea variety Komcalle, Neerwaya and Tiligre. However, it is noticed that the dual-purpose variety show statistically similar with slight decreasing trend if plant population increase.

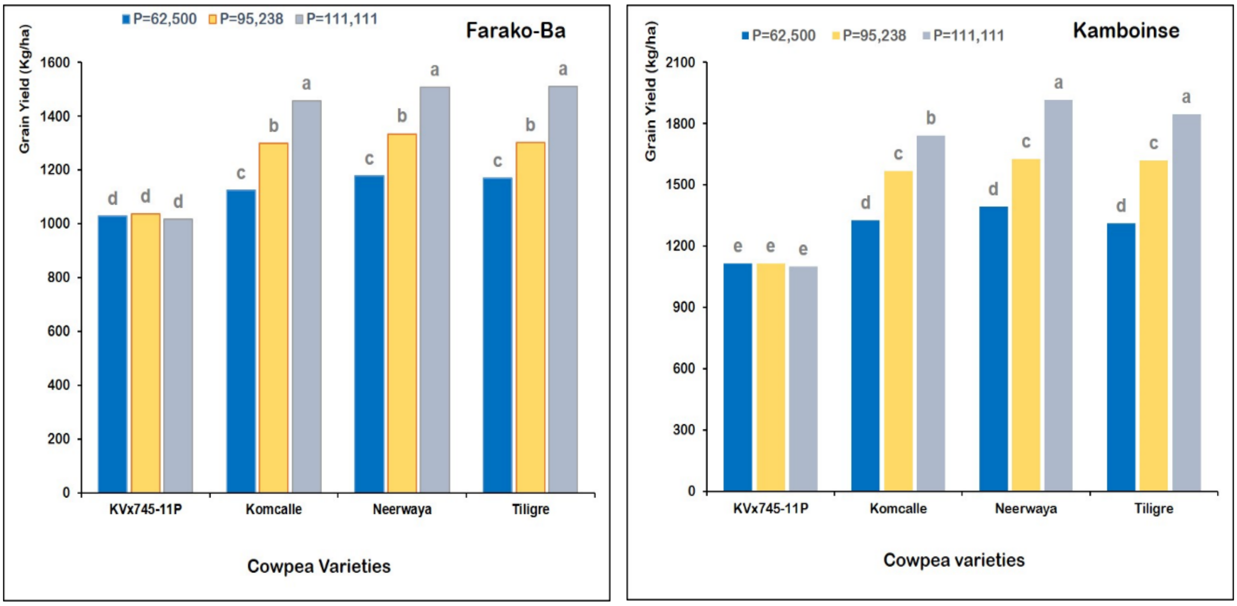

Fig. 1. Plant Population x Variety Interaction Effect on Grain Yield at Farako-Ba and Kamboinse

The results of plant population x variety interaction on fodder and grain yield are presented in Table 7. These results were obtained by using combined years' data for Farako-Ba and Kamboinse site. A positive relationship was observed between fodder yield and plant population per hectare. It is also observed that the cowpea varieties were inherently different in term of grain and fodder yield.

Table 7. Cowpea Varieties x Plants/ha Interaction Effect on Fodder Yield (Kg/ha) and Grain Yield at Farako-Ba and Kamboinse Using Combined Year data

Cowpea Varieties		Fodder Yield (kg/ha)		Grain Yield (kg/ha)	
	Plants/ha	Farako-Ba	Kamboinse	Farako-Ba	Kamboinse
KVx745-11P	62,500	3748.85lm	4667.30j-l	765.77t	1060.89r
	95,238	5274.70g-j	6787.21a-c	966.82s	1173.87pq
	111,111	5684.26d-i	6553.72a-d	1132.47qr	1307.20l-o
Komcalle	62,500	2652.40n	3615.49m	1144.10p-r	1385.33j-l
	95,238	4156.09k-m	5757.56d-h	1307.37m-o	1536.10d-g
	111,111	4676.94j-k	5412.78e-j	1467.74g-k	1674.69bc
Neerwaya	62,500	3780.74m	5161.04g-j	1237.45n-p	1437.66h-k
	95,238	5679.97d-i	6907.57ab	1394.64i-m	1594.51c-f
	111,111	6035.55c-f	6728.05a-c	1505.65e-h	1782.47a
Tiligre	62,500	3700.23m	4838.93i-k	1221.32o-q	1387.30k-m
	95,238	6062.97c-g	6121.95b-e	1327.88l-n	1594.77c-e
	111,111	5129.13h-j	7231.86a	1488.79f-j	1732.83ab
SE±		323.31		35.21	

Means followed by the same letter (s) within a treatment group are not significantly different at 5% level of probability using Student Newman Keuls (SNK) test

3.2 DISCUSSION

The experimental sites have different weather patterns which could have significant influence on cowpea phenology. According to [11], [12] cowpea varieties growth and yield characters are strongly correlated to soil and climatic conditions. [13] observed that abundance of rainfall has negative effect on cowpea yield while a positive relationship was found between higher temperatures and cowpea grain yield. In this study, the average number of leaves per plant was negatively correlated to plant population per hectare, comparable results were found by [14]. Cowpea grown under low density had higher leaves chlorophyll content than those grown at high density [14], which is different from our findings. The result may be explained by the fact that increasing in plant population is not enough to induce competition between plants for nutrients, light and water in which would result decrease of average leaves chlorophyll content. The average plant height was not significantly impacted by cropping season as well as plant population per hectare. [15] and [16] found that cowpea produced at highest density led to taller plants height. In contrary, [17] demonstrated that plant height decrease with increasing of plant density per hectare. Furthermore, [18] and [15] reported that differences in plants height could be explained by genetic variation between the varieties. Significant difference of plant height was noted within the varieties which can be classified into three group according to their height. The average number of branches per plant was significantly different among the cowpea varieties due to their genetic composition. [12] and [19] reported significant difference in average number of branches per plant among different cowpea varieties. The variation of plant population did not significant affect 50% flowering and 95% maturity as well as average pods length. Concerning 50% flowering, similar results were found by [20] who observed that this character gave statistically similar results when cowpea was sown at low or high plant population. This result is contrasted to the earlier results reported by [21] which found that increasing plant density could delay flowering in legume crops. Significant differences of 50% flowering, 95% maturity and average pods length is probably the fact of genotypes differential response. Shelling percentage and 100 seeds weight were significantly affected by cropping season and variety, this is comparable to the findings of [22] and [23]. The fact that 100 seeds weight follow the same trend from one location to another is the proof that this character is more varietal dependent. Our findings are supported by several studies from authors such [22], [24], [25] who noted significant difference between cowpea varieties for this character. However, this is inconsistent with the findings of [26] and [27] where varieties were statistically similar when 100 seeds weight was compared. Harvest index is an important character which contribute to predict grain yield because it has positive and close relationship [28] and [29]. High plant population decrease harvest index due to greater dry matter of shoots in expense of grains. Similar results were reported by [25], [30]. Furthermore, it is observed that harvest index is strongly correlated to the variety growth habit. These results are in line with previous reports which showed that harvest index of local cowpea varieties, generally prostrate or high spray were lower than improved ones [25], [31]. Fodder yield increase with plant population, this is corroborated by earlier findings [32] – [34], [35]. Also, [36] and [35] found that cowpea cultivars respond differently to plant population and the medium maturing varieties produced more fodder yield than the early maturing varieties, these results are consistent with our findings. It is remarked that there is a difference of fodder yield according to location, inherent environmental conditions of each locations may explain these differences [37]. According to [35], [38] and [39] the difference of grain yield across the locations is account for rainfall and soil fertility variations. [38] demonstrated that high density and super high density significantly increase grain yield of cowpea varieties in comparison with normal density. Similar effect of planting density on cowpea grain yield were highlighted by authors such [35], [40] and [41]. In both locations, the combined year data revealed positive relationship between fodder and grain yield with increasing of plant population per hectare. Also, the interaction showed that variety and growing location have significant impact on fodder and grain yield. Comparable results were found by [42], [29] and [17].

4 CONCLUSION

From experiments conducted in two agro-ecological zones, growth characters such average leaves number, leaves chlorophyll content, plants dry weight, crop growth rate and average branches number of erected and semi-erected cowpea varieties did not show any significant variation due to effect of plant population per hectare. Also, character such 50% flowering, 95% maturity, pods length, shelling percentage, 100 seeds weight were not significantly influenced by plants population per hectare within the same location. The variation of these characters cited above account for intra seasonal rainfall, temperature, edaphic factors as well as intrinsic differences between the varieties. Furthermore, the results of this study show positive relationship between increasing of plants/ha with grain and fodder yield. We also suggest that the optimal yield should be determined by gradually increasing the plant population per hectare.

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REFERENCES

[1] N.A.S, Lost crops of Africa Natl. Acaddemic Press, vol. Volume II, pp. 1–351, 2006.
[2] M. P. Timko and B. B. Singh, Cowpea, a Multifunctional Legume *Genomics Trop. Crop.,* pp. 222–258, 2008, doi: 10.1007/s13398-014-0173-7.2.
[3] S. K. Bello, A. A. Yusuf, and M. Cargele, Performance of cowpea as influenced by native strain of rhizobia, lime and phosphorus in Samaru, Nigeria, *Symbiosis* doi: 10.1007/s13199-017-0507-2, 2017.
[4] Da Silva, A. C., Da Costa Santos, D., Junior, D. L. T., Da Silva, P. B., Dos Santos, R. C. and Siviero, A. A. Cowpea: A Strategic Legume Species for Food Security and Health doi: 10.5772/intechopen.79006.pp 1-19, 2018.
[5] E. E. Grings, S. A. Tarawali, M. Blummel, A. Musa, C. Fatokun, and S. Hearne, *Cowpea in evolving livestock systems, Proc. Fith World Cowpea Conf.* pp. 322–333, 2012.
[6] T. Ngalamu, J. Odra, and N. Tongun *Cowpea Production Handbook*. pp. 1-45, 2015. https://www.researchgate.net/publication/284900187
[7] A. A. D. C Bezzera, A. C. D. Neves, M. D. M. Rocha and L. D. C. R. D. Brito, Morpho-physiological and productive biometry in semi-erect cultivars of the cowpea under different plant populations pp. 625–630, 2017, doi: 10.5935/1806-6690.20170072.
[8] X. Liu, J. Jin, G. Wang, and S. J. Herbert, Soybean yield physiology and development of high-yielding practices in Northeast China *F. Crop. Res.,* vol. 105, no. 3, pp. 157–171, 2008, doi: 10.1016/j.fcr.2007.09.003.
[9] R. A. Ball, R. W. McNew, E. D. Vories, T. C. Keisling, and L. C. Purcell, Path analyses of population density effects on short-season soybean yield, *Agron. J.,* vol. 93, no. 1, pp. 187–195, 2001, doi: 10.2134/agronj2001.931187x.
[10] D. Watson, Comparative physiology studies on the growth of fied crop II: The effect of varying nutrient supply on net assimulation rate and leave area, *Ann. Bot.,* vol. 11, pp. 375–407, 1958.
[11] A. E. Hall, N. Cisse, S. Thiaw, H. O. A. Elawad, J. D. Ehlers, A. M. Ismail, R. L. Fery, P. A. Roberts, L. W. KItch, L. L. Murdock, O, Boukar, O. D. Phillips and K. H. McWatters, Development of cowpea cultivars and germplasm by the Bean/Cowpea CRSP, *F. Crop. Re, s.,* vol. 82, no. 2–3, pp. 103–134, 2003, doi: 10.1016/S0378-4290 (03) 00033-9.
[12] K. Agyeman, J. N. Berchie, I. Osei-Bonsu, E. Tetteh Nartey, and J. K. Fordjour, Growth and Yield Performance of Improved Cowpea (*Vigna unguiculata* L.) Varieties in Ghana, *Agric. Sci.,* vol. 2, no. 4, pp. 44–52, 2014, doi: 10.12735/as.v2i4p44.
[13] I. Mohammed, D. A. Alawa, J. S. Mshelia, J. A. Betiang, S. B. Azu, and S. S. Bishie-unung, Effect of climate variation on the yield of cowpea (*Vigna unguiculata*), vol. 17, no. 3, pp. 456–462, 2021, doi: 10.5897/AJAR2020.14960.
[14] J. Bisikwa, R. Kawooya, J. M. Ssebuliba, S. P. Ddungu, M. Biruma, and D. K. Okello, Effects of plant density on the performance of local and elite cowpea [*Vigna unguiculata* L. (Walp)] varieties in Eastern Uganda, *African J. Appl. Agricutural Sci. Technol.,* vol. 1, no. 1, pp. 28–41, 2014.
[15] A. M. El Naim and A. A. Jabereldar, Effect of plant density and cultivar on growth and yield of cowpea (*Vigna unguiculata* L.Walp), *Aust. J. Basic Appl. Sci.,* vol. 4, no. 8, pp. 3148–3153, 2010.
[16] M. N. Tswanya, C. Kyuka, T. E. Bashiru, H.S. Muhammad, F.G. Bello and I. Abubakar, Effect of Spacing on Growth and Grain Yield of Cowpea Varieties (*Vigna unguiculata*) in Guinea Savanna Zone, Nigeria,« *Int. J. Agric.,* vol. 8, no. 1, pp. 1–9, 2023, doi: 10.47604/ija.1909.
[17] A. M. Segun, O. A. Elizabeth, O. K. Kolapo and S. K. Alani, «Productivity of Cowpea (*Vigna unguiculata* (L) Walp) genotypes under Varying Population Densities,» *Niger. J. Pure Appl. Sci.,* vol. 34, no. 2, pp. 4089–4100, 2021, doi: 10.48198/njpas/21.a12.

[18] B. Karikari and E. Arkorful, «Effect of phosphorus fertilizer on dry matter production and distribution in three cowpea (*Vigna unguiculata* L. Walp.) varieties in Ghana,» *J. Plant Sci.,* vol. 10, no. 5, pp. 167–178, 2015, doi: 10.3923/jps.2015.167.178.

[19] A. Miheretu and J. Sarkodie-Addo, «Response of cowpea (*Vigna unguiculata* [L.] Walp) varieties following application of nitrogen fertilizers and inoculation», *Journal of Agriculture and Veterinary Science* Vol.10, Issue 4, PP 32-38, 2017, 10.9790/2380-1004013238.

[20] D. N. Njoku and C. O. Muoneke, « Effect of Cowpea Planting density on Growth Yield and Productivity of Component Crops in Cowpea/Cassava Intercropping System» *Journal of Tropical Agriculture, Food, Environment and Extension* vol. 7 pp. 106–113, 2008.

[21] I. E. Rhoda, «Growth, Yield and Yield Components of Soybean as influenced by Sowing dates and plants population,» Ahmadu Bello University, Zaria. Nigeria, pp 65, 1989.

[22] O. S. Sakariyawo, P. A. S. Soremi, K. A. Okeleye and S. G. Aderibigbe, «Variation in the performance of contrasting maturity class of cowpea cultivars (*Vigna unguiculata* L. Walp) in the derived Savanna,» *Agro-Science,* vol. 15, no. 2, p. 41, 2017, doi: 10.4314/as.v15i2.6.

[23] Y. Momohjimoh and M. U. Tanko, «Effect of Nitrogen Starter Dose and Phosphorus Fertilizer Application on Growth, Yield Characters and Grain Crude Protein Content of Three Varieties of Cowpea in Anyigba, Kogi State, Nigeria,» *J. Innov. Agric.,* vol. 8, no. 1, p. 1, 2021, doi: 10.37446/jinagri/rsa/8.1.2021.1-10.

[24] I. E. Ezeaku, B. N Mbah and K. P. Baiyeri, «Planting date and cultivar effects on growth and yield performance of cowpea (Vigna unguiculata (L.) Walp),» *African J. Plant Sci.,* vol. 9, no. 11, pp. 439–448, 2015, doi: 10.5897/ajps2015.1353.

[25] A. M. El Naim, A. A. Jabereldar, S. E. Ahmed, F. M. Ismaiel and E. A. Ibrahim, «Determination of Suitable Variety and Plants per Stand of Cowpea (*Vigna unguiculata* L. Walp) in the Sandy Soil, Sudan,» *Adv. Life Sci.,* vol. 2, no. 1, pp. 1–5, 2012, doi: 10.5923/j.als.20120201.01.

[26] A. Singh, A. L. Baoule, H. G. Ahmed, A. U. Dikko, U. Aliyu, M. B. Sokoto, J. Alhassan, M. Musa and B. Haliru, «Influence of Phosphorus on the performance of cowpea (*Vigna unguiculata* (L) Walp.) varieties in the Sudan savanna of Nigeria,» vol. 2, no. 3, pp. 313–317, 2011, doi: 10.4236/as.2011.23042.

[27] B. Karikari, E. Arkorful and S. Addy, «Growth, Nodulation and Yield Response of Cowpea to Phosphorus Fertilizer Application in Ghana,» *J. Agron.,* vol. 14, no. 4, pp. 234–240, 2015, doi: 10.3923/ja.2015.234.240.

[28] C. Toker and M. I. Cagirgan, «The use of Phenotypic Correlations and Factor Analysis in Determining Characters for Grain Yield Selection in Chickpea (*Cicer arietinum* L.),» *Hereditas,* vol. 140, no. 3, pp. 226–228, 2004, doi: 10.1111/j.1601-5223.2004.01781.x.

[29] N. Kamai, N. A. Gworgwor and J. W. Wabekwa, «Varietal Trials and Physiological Components Determining Yield Differences among Cowpea Varieties in Semiarid Zone of Nigeria,» *ISRN Agron.,* vol. 2014, pp. 1–7, 2014, doi: 10.1155/2014/925450.

[30] M. Majoddam and A. Nouri, «The effect of Sowing Date and Plant Density on Yield and Yield Components of Cowpea,» *J. Med. Plants Res.,* vol. 6, no. 9, pp. 461–467, 2012, doi: 10.5897/jmpr11.1318.

[31] A. D. S. de Freitas, A. F. Silva and E. V. de Sá Barretto Sampaio, «Yield and Biological Nitrogen Fixation of Cowpea Varieties in the Semi-Arid Region of Brazil,» *Biomass and Bioenergy,* vol. 45, pp. 109–114, 2012, doi: 10.1016/j.biombioe.2012.05.017.

[32] C. S. Patidar, «Effect of Row Spacings on Growth and Seed yield of Forage Cowpea [*Vigna unguiculata* (L.) Walp.] varieties,» Jawaharlal Nehru Krishi Vishwa Vidyalaya Jabalpur, Thesis, pp 83, 2005.

[33] G. E. Nwofia, M. C. Nwanebu and E. U. Mbah, «Yield and Yield Component Responses of Some Cowpea Varieties to Population Density Structures Under Rainfed Conditions in Lowland Tropics of Southeast Nigeria,» *World J. Agric. Sci.,* vol. 10, no. 2, pp. 68–75, 2014, doi: 10.5829/idosi.wjas.2014.10.2.1815.

[34] A. Y. Kamara, L. Omoigui, N. Kamai and Ewansiha S.« *Improving Cultivation of Cowpea in West Africa,* Sivasankar, S. *et al.* (ed.), Achieving sustainable cultivation of grain legumes Vol. 2: Improving Cultivation of Particular Grain Legumes, Burleigh Dodds Science Publishing, Cambridge, UK, 2018, 2018, doi: 10.19103/AS.2017.0023.30.

[35] A. Y. Kamara, A. I. Tofa, S. Kyei-Boahen, R. Solomon, H. A. Ajeigbe, and N. Kamai, «Effects of Plant Density on the Performance of Cowpea in Nigerian Savannas,» *Exp. Agric.,* vol. 54, no. 1, pp. 120–132, 2018, doi: 10.1017/S0014479716000715.

[36] A. T. Jallow and T. U. Ferguson, «Effects of Plant Densities and Cultivar on Seed Yield of Cowpeas (*Vigna unguiculata* (L.)) in Trinidad. *Tropical Agriculture, 62* (2),» 1985.

[37] B. D. Adewale, C. Okonji, A. A. Oyekanmi, D. A. C. Akintobi, and C. O. Aremu, «Genotypic Variability and Stability of Some Grain Yield Components of Cowpea,» *African J. Agric. Res.,* vol. 5, no. 9, pp. 874–880, 2010, doi: 10.5897/AJAR09.481.

[38] H. Ishikawa, B. J. Batieno, C. Fatokun, and O. Boukar, «A High Plant Density and the Split Application of Chemical Fertilizer Increased the Grain and Protein Content of Cowpea (*Vigna unguiculata*) in Burkina Faso, West Africa,» *Agric.,* vol. 12, no. 2, 2022, doi: 10.3390/agriculture12020199.

[39] K. Atakora, M. E. Essilfie, K. Agyarko, H. K. Dapaah, and K. G. Santo, «Evaluation of Yield and Yield Components of Some Cowpea (Vigna unguiculata (L.) Walp) Genotypes in Forest and Transitional Zones of Ghana,» *Agric. Sci.,* vol. 14, no. 07, pp. 878–897, 2023, doi: 10.4236/as.2023.147059.

[40] W. Erskine and T. N. Khan, «Effects of Spacing on Cowpea Genotypes in Papua New Guinea, *Expl Agric.,* pp. 401-410, 1976 doi: 10.1017/S0014479700007420.

[41] B. Ali, A. U. Izge, P. E. Odo, and D. Aminu, «Varietal Performance of Dual Purpose Dry Season Cowpea (*Vigna unguiculata* L. Walp),» *Am. J. Sustain. Agric.,* vol. 3, no. 1, pp. 13–18, 2009.

[42] D. Shanko, M. Andargie, and H. Zelleke, «Genetic Variability and Heritability of Yield and Related Characters in Cowpea (*Vigna unguiculata* L. Walp.),» vol. 4, no. 2, pp. 21–26, 2014.