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Effect of Plant density and Cultivar on Growth and Yield of Cowpea (*Vigna unguiculata* L.Walp)

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Abstract: A field experiment was conducted for two successive rainy seasons (2007/08-2008/09) in Kazgail area, in North Kordofan State, Sudan, to examine the effect of plant density and cultivar on growth and yield of cowpea. The three cultivars of cowpea (Buff, Haydoob and Eien Elgazal) were sown in four plant densities of 30,000, 60,000, 90,000 and 120,000 plants ha^{-1}. The experiment was laid out in a randomized complete block design (RCBD) in three replications. The results showed that, plant density had a significant effect on most of the growth attributes measured. Increasing plant population increased plant height and decreased number of leaves per plant and leaf area index (LAI). Increased plant density significantly increased seed yield per unit area, however the number of pods per plant, 100-seed weight, seed yield per plant and harvest index reduced with increased plant density. The local cultivar (buff) had a significantly taller, greater number of leaves per plant, leaf area index, heavier 100-seed weight, greater seed yield per plant, greater final seed yield (t/ha) and late in maturity. The improved cultivar (Ein Elgazal) scored the highest values of harvest index.

Key words: Population density, Leaf area index, seed yield, Cowpea.

INTRODUCTION

Cowpea *(Vigna unguiculata* L.Walp.) is an ancient leguminous crop, which has been grown throughout the tropics and sub tropics. The cultivated species have been classified under the species unguiculata (Davis, D.W., 1991). Conservative estimates suggest that greater than 12.5 million hectares are planted annually with cowpea around the world. The total world production is estimated about 3.3 million tons of dry grain (Singh, B.B., 1997). The main producing countries of the cowpea crop are in West Africa. Basically, cowpea is a crop of the warm-season of the tropics and subtropics. It is adapted to high temperatures (20^0 – 30^0 C). The crop can be grown quite successfully under condition that are totally unsuitable for the common bean, it grows well in a wide range of soil texture, from heavy clays, if well drained, to sand (Hector, V. and S. Jody, 2002). The optimum plant population of cowpea depends on many factors such as: rainfall, moisture and type of cultivars, available nutrient and management (Eric, B., 1981). Ndiaga (2000) concluded that cowpea cultivars with different plant morphology would require different optimum densities to express their full seed yield potential.

In Sudan, cowpea is mainly grown under rain-fed conditions in Kordofan and Darfour state, which the rainfall ranged between 350 – 500 mm, only very small scattered batches had been grown under irrigation in the northern Sudan. Also it's grown extensively in the "Jubraka" system around the nuba mountains. The crop can give excellent yields of grain and fodder under irrigation and moderate stable yield under rain-fed condition. Cowpea can be grown as a sole crop in annual rotation with pearl millet, sorghum and even peanut or sesame. It can also grow successfully as a relay inter-crop with cereal or cash crops in mid August, if maturing varieties were used (Elawad, H.O., 2000). Cowpea can be used as a feed (grazed, or harvested for fodder), or its pods can be harvested before maturity stage and eaten as a vegetable. The beans are nutritious and provide complementary proteins to cereals. Some people eat both fresh pods and leaves and the dried seeds are popular ingredients in various dishes (Hector, V. and S. Jody, 2002). Cowpea seed contains (20 - 24%) protein, 63.3% carbohydrates and 1.9% fat (Davis, D.W., 1991).

The uses of Cowpea in Sudan are diversified. The seeds can be boiled in Sudan with water and eaten as "Ballila". They can also be cooked with meat, tomatoes and onions into a thick soup, eaten with pancake and /or bread. The paste form soaked seeds can be fried with oil as small doughnuts (Ta ammia) which can be

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eaten alone or with bread. Cowpea hay is a rich feed for livestock in the dry season. Also as a legume, cowpea improves soil fertility and can be used as a trap crop in areas where Striga is a problem (Elawad, H.O., 2000).

Cowpea grain and fodder yields are very low in West Africa and Sudan, the main problems limiting production and expansion of cowpea as pointed out by Singh and Tarawili (1995) and Elawad (2000) are: Low yield potential of existing cultivars, low density of cowpea and Limited use of certified seeds by the cowpea growers, due to deficient marketing and failure to convince the farmers about the advantages of planting certified seeds versus their own seeds The current study carried out investigate the effect of different crop population and cultivars on growth and yield of cowpea.

MATERIALS AND METHODS

A field experiment was conducted for two successive rainy seasons (2007/08 – 2008/09) in Kazgail area (50 km south Elobeid), in North Kordofan state (latitude 11˚ 15' – 16˚ 30' N; longitude 27˚ – 32˚ E). The climate of the area is arid and semi arid zone. The mean annual rainfall ranges between 350 – 500 mm. The soil is sandy with low fertility. Average maximum daily temperature varied between 30˚ and 35˚ C throughout the year (Gebauer, J., 2005).

The experiment was laid out in a randomized complete block design with three replications. The experimental plot was 4×4meters. Treatments consisted of four levels of plant density 30,000, 60,000, 90,000 and 120,000 plants ha^{-1}, designated as P_1, P_2, P_3 and P_4 respectively. Three cultivars of cowpea: Buff (local), Hydoob and Ein Elgaza (improved) were used and designated as V_1, V_2 and V_3 respectively. Sowing was on 25th of July, 2007 and 2008. Seeds were sown in holes at spacing of 60×30 cm, seven seeds were placed in each hole, which were thinned, two weeks later, to 1, 2, 3 and 4 plants per hole, according to plant density need. Manual weeding was practiced twice during both seasons. The Meteorological data (temperature, relative humidity and rainfall) were recorded from planting date to harvest of each treatment in Table 1.

Table 1: Monthly mean temperatures, relative humidity and rainfall during the growing season for cowpea (July -October) in 2008 and 2009 in Kazegal of Sudan.

Month	Mean Temperature ˚C		Mean Relative humidity %		Rainfall (mm)	
	2008	2009	2008	2009	2008	2009
July	32.2	33.2	50.3	43.7	219.2	111.7
August	30.1	31.3	58.1	50.4	243,0	120.3
September	31.0	32.2	43.2	39.6	141.8	91.7
October	34.0	33.8	35.5	40.5	N R	84.0

*N R: No Rainfall

A sample of four plants was taken randomly from two central rows in each experimental unit at 30 days after sowing (DAS), and then continued at an interval of 15 days to measure the following growth attributes: plant height, number of leaves per plant and leaf area index. Leaf area index (L.A.I) is a dimensionless quantity. It is the leaf area (upper side only) per unit area of land below. It is expressed as m^2 leaf area per m^2 ground area. Leaf area was determined using the punch method (Watson, D.L. and M.L. Watson, 1953), by taking 50 discs and was calculated using the following relationship:-

$$\text{Leaf area} = \frac{\text{Total area of leaf discs x total dry weight of leaves}}{\text{Dry weight of leaf discs}}$$

The leaf area index (L.A.I), was determined as follows:-

$$\text{Leaf area index} = \frac{\text{leaf area per plant}}{\text{Plant ground area}}$$

Yield attributes includes: number of pods per plant, number of seeds per pods, 100-seed weight and final seed yield (t/ha). Harvest index was determined by using the following formula:-

$$\text{Harvest index} = \frac{\text{Economical Yield (seed yield/plant)}}{\text{Biological yield (shoot dry weight)}} \text{ X } 100$$

Data were analyzed statistically using analysis of variance according to Gomez and Gomez (Gomez, K.A. and A.A. Gomez, 1984) procedure for a randomized complete block design. The differences of means were identified by Duncan's Multiple Range Test (DMRT) at $P \geq 0.05$.

RESULTS AND DISCUSSION

Increasing plant density decreased plant height at all sampling occasions (Table 2). Similar results were obtained by (Weber, C.R., 1966) who found plants produced at highest densities were taller and more sparsely branches. On the contrary, Mohamed (2002) reported that plant population had no significant effect on plant height. The local cultivar (Buff) had significantly taller plants in the two seasons compared to others. Differences among cultivars in plant height were reported by Miller (1988) and Mohammed (1984). Increasing plant density decreased number of leaves per plant (Table 3). These results are in agreement with the previous findings reported by many workers (Alege, G.O. and O.T. Mustapha, 2007; Weber, C.R., 1966; Mohammed, A.S.E., 1984). They showed that increased plant densities reduced the number of branches per plant. The local cultivar (Buff) had the greatest number of branches per plant than others. The leaf area index decreased with the increasing plant population (Table 4). Similar results were obtained by Lazim (1973) who found that leaf area index tends to decrease with increasing plant densities. The local cultivar (Buff) had the greater leaf area index than others.

Generally, increasing the plant population increased competition among plants for soil moisture, nutrient, light and carbon dioxide. Moreover, the low population plants grew as isolated units for most of their early life and interfered less with each other than at higher densities. This might explain the significant effect of plant population on most of the parameters measured in the present study. Difference in growth attributes observed among cultivars may be to the growth habit and to the genetically potential of each genotype.

Plant population had a significant effect on most yield components measured in this study. Generally increasing plant population decreased the number of pods per plant in both seasons (Table. 5). This reduction may be attributed to the interference among branches. These findings are in accord with the previous results reported by Weber *et al,* (1966) and Hamad (2004)They indicated that plants produced at the highest densities set fewer pods than those at the lowest densities. The plant population had no significant effect on number of seeds per pod in both seasons (Table 6). This is in agreement with the finding of Salih (1992) and Mohammed (2002). They found that plant population had a little or no effect on the number of seeds per pod. However the cultivar (Hydoob) had the greatest seed number per pod. The variation in number of seeds per pod among cultivars might be referred to genotype.

Plant population had a significant effect on mean 100-seed weight in both seasons (Table 7). Decreased plant population resulted in increased 100-seed weight. This may be due to better availability of nutrients and better translocation of photosynthates from source to sink and may be due higher accumulation of photosynthates in the seeds. Contrasting results were reported by Taha (1988) and Mohamed (2002). They found that 100-seed weight was not affected by plant population. The local cultivar (Buffa) had heavier seed weight than the introduced cultivars. This may be due to better translocation and partitioning of assimilates from source to sink (seeds).

Generally, increasing plant population decreased seed yield per plant. This was primarily because of reduced number of pods per plant and number of seeds per pod at the higher plant population. Similar results were obtained by many workers (Ball, R.A., 2001; Hamad, M.S., 2004; Salih, F. and M.J. Bahrani, 2000). The local cultivar (Buff) had significantly higher seed yield per plant than the improved one. This is because of heavier seed weight of the local cultivar.

The final seed yield per unit area was greatly affected by plant population (Table 8). Thus, increasing plant population increased seed yield per unit area. This may be attributed to the highest number of plants per unit area. Similar result was obtained by Herbert and Baggerman (1982) who found that the highest seed yield was obtained with the higher plant density. The local cultivar (Buff) gave the highest seed yield per unit area compared to the other two cultivars during the two seasons. The seed yield in the first season is relatively higher than the second season. This is because, it receive a highest amount of rainfall (Table 1).

Table 2: Effect of plant population and cultivars on plant height (cm) of cowpea.

Treatments	2007/2008				2008/2009			
	30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS
P_1	13.64[a]	37.12[a]	49.63[c]	60.83[d]	14.06[a]	26.79[b]	50.55[c]	57.93[c]
P_2	14.03[a]	26.94[b]	53.36[a]	62.79[c]	13.86[a]	27.06[b]	52.92[b]	63.96[b]
P_3	14.05[a]	28.67[b]	53.35[a]	64.3[b]	4.37[a]	29.07[a]	53.87[b]	64.69[b]
P_4	15.33[a]	30.60[b]	55.34[a]	69.69[a]	15.17[a]	30.79[a]	55.55[a]	70.94[a]
SE±	0.48	0.56	0.52	1.05	0.42	0.39	0.59	0.46
V_1	18.35[a]	35.42[a]	75.27[a]	109.01[a]	18.73[a]	35.99[a]	75.70[a]	109.49[a]
V_2	12.37[b]	24.18[bc]	39.28[b]	39.97[b]	12.02[b]	23.64[b]	39.33[b]	38.88[b]
V_3	12.06[cb]	25.42[c]	44.21[c]	44.23[c]	12.35[cb]	25.66[c]	44.65[c]	44.78[c]
SE±	0.42	0.48	0.45	0.91	0.36	0.34	0.52	0.39
CV %	6.2	16.6	9.4	9.4	7.2	8.2	5.1	3.1

Similar letters are not significantly different at the 0.05 level of probability according to Duncan multiple range test.

Table 3: Effect of plant population and cultivars on number of leaves per plant of cowpea.

Treatments	2007/2008				2008/2009			
	30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS
P_1	12.22[a]	15.56[a]	43.0[a]	40.67[a]	12.0[a]	15.56[a]	38.67[a]	42.33[a]
P_2	10.67[ac]	13.33[ac]	30.11[b]	34.0[bc]	10.44[ab]	15.33[a]	32.89[b]	35.56[bd]
P_3	9.33[cd]	11.11[cd]	24.67[c]	33.67[c]	8.89[bc]	12.0[bd]	23.89[cd]	32.56[c]
P_4	7.78[d]	10.78[d]	27.33[d]	37.22[d]	8.0[c]	11.44[d]	27.56[d]	34.44[d]
SE±	0.64	0.61	0.59	0.79	0.47	0.27	0.98	0.39
V_1	13.08[a]	16.25[a]	53.17[a]	72.50[a]	12.25[a]	16.33[a]	53.17[a]	68.17[a]
V_2	8.42[bc]	11.0[bc]	22.83[b]	22.25[b]	8.33[bc]	11.92[bc]	22.92[b]	24.58[b]
V_3	8.50[c]	10.83[c]	17.33[c]	14.42[c]	8.92[c]	12.50[c]	16.17[c]	15.92[c]
SE±	0.55	0.53	0.30	0.68	0.41	0.46	0.84	0.33
CV %	52.6	2.6	8.9	3.7	6.0	13.3	5.0	3.6

Similar letters are not significantly different at the 0.05 level of probability according to Duncan multiple range test.

Table 4: Effect of plant population and cultivars on leaf area index(L.A.I) of cowpea.

Treatments	2007/2008			2008/2009				
	30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS
P_1	0.69[a]	0.77[a]	0.93[a]	0,89	0.70[a]	0.82[a]	0.87[a]	0.80
P_2	0.58[bcd]	0.72[a]	0.86[b]	0.81	0.58[bd]	0.71[b]	0.89[a]	0.87
P_3	0.62[cd]	0.72[a]	0.90[ab]	0.89	0.63[c]	0.71[bc]	0.91	0.88
P_4	0.62[d]	0.76[a]	0.90[ab]	1.02	0.59[cd]	0.67[bd]	0.93[a]	1.01
SE±	0.01	0.01	0.02	0.02	0.01	0.01	0.02	0.02
V_1	0.72[a]	0.84[a]	1.01[a]	1.16	0.70[a]	0.79[a]	1.01[a]	1.03
V_2	0.57[bc]	0.71[bc]	0.82[bc]	0.80	0.58[b]	0.67[b]	0.83[b]	0.82
V_3	0.59[c]	0.69[c]	0.86[c]	0.75	0.60[bc]	0.72[c]	0.86[c]	0.84
SE±	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.02
CV %	4.5	6.4	2.4	6.8	4.7	5.3	6.7	7.9

Similar letters are not significantly different at the 0.05 level of probability according to Duncan multiple range test.

Table 5: Effect of plant population and cultivars on number of pods per plant of cowpea.

Treatments	Season 2007/2008				Season 2008/2009			
	V1	V2	V3	Mean	V1	V2	V3	Mean
P1	11.66[b]	19.00[a]	15.33[b]	15.33[a]	11.67[b]	15.67[a]	14.00[a]	13.78[a]
P2	9.33[c]	8.67[c]	9.67[c]	9.22[b]	9.33[c]	7.00[c]	8.00[c]	8.11[b]
P3	7.67[d]	7.33[d]	8.00[c]	7.67[c]	8.00[c]	6.33[d]	7.00[c]	7.11[c]
P4	6.67[d]	7.00[d]	7.33[d]	7.00[c]	7.00[c]	6.00[d]	5.67[d]	6.22[d]
Mean	8.83[b]	10.50[a]	10.09[a]	9.00[a]	8.75[b]	8.67[b]		
SE ±(P)	0.29			0.39				
SE ±(V)	0.25			0.34				
SE ±(PXV)	15.99			6.47				
C V %	24.5			12.6				

Similar letters are not significantly different at the 0.05 level of probability according to Duncan multiple range test

Plant density had significant effect on harvest index (Table 9). Higher plant population decreased harvest index due to greater dry matter of the shoot. Similar results were obtained by Weber *et al*, (1966) who reported that lower plant population tended to increase harvest index. The introduced cultivars had a greater harvest index compared with the local cultivar. The may be due to higher seed yield of introduced cultivars. Similar results were reported by Suliman (2000) who found that the introduced cultivars had greater harvest index than the local cultivar.

Table 6: Effect of plant population and cultivars on number of seeds per pod of cowpea.

Treatments	Season 2007/2008				Season 2008/2009			
	V1	V2	V3	Mean	V1	V2	V3	Mean
P1	9.00[b]	11.67[a]	9.00[b]	9.89	9.00[b]	10.67[a]	9.00[b]	9.56
P2	7.67[d]	9.67[b]	8.67[c]	8.67	7.33[d]	10.13[a]	8.33[c]	8.60
P3	7.67[d]	10.11[a]	7.65[d]	8.59	7.67[d]	10.01[a]	8.00[c]	8.56
P4	7.00[d]	10.33[a]	8.67[c]	8.66	6.66[d]	10.57[a]	8.00[c]	8.51
Mean	7.83[c]	10.51[a]	8.51[b]	7.74[c]	10.35[a]	8.33[b]		
SE ±(P)	0.30			0.33				
SE ±(V)	0.26			0.29				
SE ±(PX V)	2.57			2.14				
C V %	10.9			15.00				

Similar letters are not significantly different at the 0.05 level of probability according to Duncan multiple range test.

Table 7: Effect of plant population and cultivars on 100 seeds weight of cowpea grown.

Treatments	Season 2007/2008				Season 2008/2009			
	V1	V2	V3	Mean	V1	V2	V3	Mean
P1	25.32	15.16	18.41	19.63[a]	25.51	15.92	17.58	18.67[a]
P2	24.11	13.59	16.83	18.18[b]	25.23	12.78	17.46	18.49[b]
P3	23.79	13.90	17.75	18.48[b]	24.67	13.69	17.42	18.59[b]
P4	21.92	13.86	17.50	17.76[b]	23.86	13.28	17.36	19.17[a]
Mean	23.79[a]	14.13[c]	17.62[b]	24.82[a]	13.92[c]	17.45[b]		
SE ±(P)	0.34		0.14					
SE ±(V)	0.29		0.12					
SE ±(PX V)	2.79		3.08					
C V %	5.0		8.0					

Similar letters are not significantly different at the 0.05 level of probability according to Duncan multiple range test.

Table 8: Effect of plant population and cultivars on seed yield (t/ha) of cowpea grown.

Treatments	Season 2007/2008				Season 2008/2009			
	V1	V2	V3	Mean	V1	V2	V3	Mean
P1	1.13[c]	0.50[d]	0.80[d]	0.81[c]	1.03[c]	0.52[d]	0.71[d]	0.75[c]
P2	2.53[b]	0.70[d]	1.15[c]	1.46[b]	2.34[b]	0.74[d]	0.64[d]	1.24[b]
P3	3.06[a]	1.50[c]	1.22[c]	1.93[b]	2.75[b]	1.47[c]	1.09[c]	1.77[b]
P4	3.85[a]	1.15[c]	2.71[b]	2.57[a]	3.52[a]	1.28[c]	2.44[b]	2.41[a]
Mean	2.64[a]	0.96[c]	1.47[b]	2.41[a]	1.00[b]	1.22[b]		
SE ±(P)	0.09			0.04				
SE ±(V)	0.08			0.04				
SE ±(PX V)	0.81			0.71				
C V %	17.7			10.0				

Similar letters are not significantly different at the 0.05 level of probability according to Duncan multiple range test.

Table 9: Effect of plant population and cultivars on harvest index (%) of cowpea.

Treatments	Season 2007/2008				Season 2008/2009			
	V1	V2	V3	Mean	V1	V2	V3	Mean
P1	7.33[e]	18.21[d]	31.67[a]	19.07[c]	7.67[e]	19.00[c]	31.67[a]	19.45[b]
P2	7.00[e]	17.41[d]	21.00[c]	15.14[d]	6.33[e]	16.41[d]	21.00[c]	14.58[c]
P3	7.00[e]	34.57[a]	28.00[b]	23.19[a]	6.84[e]	28.33[b]	27.19[b]	20.79[a]
P4	7.00[e]	21.64[c]	32.43[a]	19.41[b]	6.00[e]	21.39[c]	31.00[a]	19.46[b]
Mean	7.08[c]	22.96[b]	28.27[a]	6.71[c]	21.28[b]	27.71[a]		
SE±(P)	0.006			0.004				
SE±(V)	0.005			0.003				
SE±(PX V)	0.008			0.004				
CV%	30.0			20.0				

Similar letters are not significantly different at the 0.05 level of probability according to Duncan multiple range test.

Conclusion:

Increased plant population increased seed yield (t/ha). The local cultivar (Buff) gave the highest seed yield per unit area, but it seems to be a fodder type than grain type because it is late maturing with dense growth habit and it gave the lowest harvest index. From the results obtained, it can be concluded that, if the crop is grown for seed yield, high plant population (12 plants m^{-2}) is recommended in North Kordofan State, Sudan. The explanation is that semi prostrate growth habit of cowpea has a compensate ability at dense planting within the row and thus increased yield per unit area.

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