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DETERMINATION OF PHYSIOLOGICAL YIELD COMPONENTS AMONG COWPEA VARIETIES IN NORTHERN NIGERIA

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ABSTRACT
Field trials were conducted at two locations, namely the teaching and research Farm, faculty of Agriculture, University of Maiduguri, Maiduguri (11°47.840'N; 13 °12.021'E; elevation 319 masl) and Damboa (11°10.736'N; 12 °47.100'E; elevation 398 masl) on the trial site of the International Institute of Tropical Agriculture (IITA) in Borno State both in Sudan Savanna zone of Nigeria during the 2010 and 2011 rainy seasons. The objectives of the study were to evaluate the agronomic performances of some improved cowpea varieties and to identify the physiological traits associated with high grain yield in the Sudan Savanna zone of Nigeria. The trial consisted of eight treatments, which included two local varieties *viz*: Kannanado *White* and *Borno Brown* obtained from farmers in Damboa, Borno State and six improved varieties *viz*: IT90K-277-2, IT97K-568-18, IT89KD-288, IT97K-499-35, IT98K-131-2 and IT89KD-391 obtained from IITA stations in Kano and Maiduguri, Nigeria. The treatments were laid out in a randomized complete block design (RCBD) replicated three times at each site. The gross plot size was 5.0 m x 4.0 m (20 m^2) while the net plot size was 3.6 m x 3.0 m (10.8 m^2). The results showed that the improved varieties produced higher grain yield per hectare, greater harvest index, and matured earlier than their local counterparts. The local varieties also had significantly heavier grains, took more days to reach first and 50% flowering and matured later than the improved varieties. The results also indicated that fodder yield per hectare was highly correlated with photosynthetically active radiation (PAR) thereby indicating that higher PAR produced higher yield of fodder. The improved varieties IT90K-277-2, IT97K-499-35 and IT98K-131-2 had significantly higher grain yield per plant and per hectare, shelling percentage, harvest index and matured earlier to escape drought in this agro-ecological zone. The results showed that cowpea grain yield was positively correlated with harvest index, shell weight, soil moisture suction measurements, shelling percentage (%) and grain yield per plant. Conversely, the results indicated that cowpea grain yield was significantly negatively correlated with number of days to first and 50% flowering, fodder yield, 100-grain weight, number of days to physiological maturity and pod development period.

KEY WORDS: Cowpea, Varieties, Sudan Savanna.

INTRODUCTION

Cowpea, *Vigna unguiculata* (L.) Walp, is a grain crop cultivated in a range of ecologies especially in the Savanna regions and in the tropics and subtropics (Singh *et al*., 1990; Anon., 2008). Cowpea, also popularly called 'beans' is mostly grown in dry areas in mixtures. It is thought that the origin of the cultivated species of cowpea is Africa (Gibbon and Pain, 1988). Cowpea is a legume of significant economic importance worldwide. Of the world's total production area of about 14 million hectares under cowpea, West Africa alone accounts for about 9 million hectares or 64% and 3 million tons of production (FAO, 2000; Singh, 2007). West Africa is the key cowpea producing zone, mainly in the dry Savanna and semi-arid agro-ecological zones. Nigeria is the largest cowpea producer in the world and also has the highest level of consumption (FAO, 2000; Singh, 2007). In Nigeria cowpea is largely grown in the northern part of the country which has Savanna type of vegetation and light rainfall (Anon., 2008). Cowpea is the most important source of nutritious food and fodder in West Africa (Singh, 2007) with 23-35% protein in its grains. Therefore, cowpea has been referred to as ''poor man's meat'' (Nielsen *et al*., 1997). It is estimated that cowpea supplies 40% of the daily protein requirements to most people in Nigeria (Muleba *et al.,* 1997). The use of cowpea haulms as fodder is attractive in mixed crop/livestock systems where both grain and fodder can be obtained from the same crop (Tarawali *et al*., 1997). Due to several constraints the average cowpea grain production in West Africa was reported to be as low as 358 kg/ha (FAO, 2000) whereas Singh *et al*. (1997) estimated 240 kg/ha cowpea grain yield as an average for northern Nigeria. In most parts of Borno State, rainfall is unreliable and frequently less and poorly distributed for a good cowpea crop. In the Sudan savanna, early season and terminal drought conditions are almost an annual event (Onyibe *et al*., 2006). Improving the yield of cowpea in the State requires the use of drought-tolerant and drought-avoidance varieties.

The local cowpea varieties are late maturing, low yielding and photosensitive and very susceptible to drought and heat. Even in the average year, the cowpea cultivars have to rely on moisture stored in the soil after the rains have stopped for grain filling. The crop performs poorly if the rains end early (Raheja, 1986). The improved varieties have acceptable seed quality for various regions, and are resistant to major diseases and the parasitic weed *Striga gesnerioides.* They also have synchronous flowering and maturity (Singh, 1994). The improved varieties are therefore early maturing, photo insensitive and have high yield potential even with less rainfall. In the same vein the improved cowpea varieties have varying degree of yield potentials which could be due to differences in their physiological traits in the dry ecologies of Borno State. Therefore, the need to try these promising cowpea varieties for their adaptability in the Sudan savanna zone of Nigeria is obvious as one of the strategies for improving the productivity of the crop in the zone since no information is available on the performance of these varieties in this zone. Information on physiological differences of the different cowpea varieties will be valuable for future strategies in the development of high yielding cowpeas for the Sudan savanna zone of Nigeria. Therefore, the objectives of the study were to evaluate the agronomic performances and to identify physiological traits associated with high grain yield of some improved cowpea varieties in the Sudan Savanna zone of Nigeria.

MATERIALS & METHODS

The study was conducted at the Teaching and Research Farm, Faculty of Agriculture, University of Maiduguri, Maiduguri (11°47.840′N; 13°12.021′E; elevation 319 m asl) and at Damboa (11°10.736′N; 12 °47.100′E; elevation 398 m asl) on the trial site of the International Institute of Tropical Agriculture (IITA) in Borno State both in Sudan savanna Nigeria during the 2010 and 2011 rainy seasons, August to November each year. The gross plot size was 5.0 m x 4.0 m (20 m^2) and the net plot size was 3.6m x 3.0 m (10.8 m^2). Each plot contained eight (8) rows of 4.0 m long with spacing of 0.75 m between rows and 0.2 m between plants. The trial consisted of 8 treatments (varieties of cowpea). The treatments included two local varieties *viz*: *Kannanado White* and *Borno Brown* and six improved varieties viz: IT90K-277-2, IT97K-568-18, IT89KD-288, IT97K-499-35, IT98K-131-2 and IT89KD-391. The treatments/varieties were laid out in a randomized complete block design (RCBD) replicated 3 times at each site. Physiological parameters measured are seedling establishment (%) at two weeks after sowing (2 WAS), number of days to first flowering, number of days to 50% flowering, soil moisture suction measurement (centibars), transmitted photosynthetically active radiation, pod development period (days), number of days to physiological maturity, 100-grain weight (g), shelling percentage, harvest index (HI), grain yield per plant (g), grain yield (kg ha^{-1}), shell weight (kg ha^{-1}) and fodder yields. All data were subjected to analysis of variance (ANOVA) using Statistics' 8.0 version. Treatment means were compared where F-values were significant using Duncan's Multiple Range Test (DMRT) at 5% level of probability (Duncan, 1955). Linear correlation coefficient (r) among the overall means of cowpea variety and physiological parameters were calculated at 5%.

RESULTS & DISCUSSION

The soil was sandy loam and loam at Maiduguri and Damboa, respectively, and had lower organic matter content at Maiduguri (7.59 g/kg) than at Damboa (13.54 g/kg). The pH of the soils was almost neutral at both sites while available phosphorus was higher at Maiduguri (5.50 g/kg) than at Damboa (1.80 g/kg) (Table 1). Based on the soil properties of the two sites it was ideal for cowpea growth.

TABLE 1: Physico-chemical characteristics of the soil at the experimental sites at Maiduguri and Damboa

S/No	Soil Characteristics	Maiduguri	Damboa
	Chemical Analysis		
1	pH in H_2O	6.71	6.40
2	Organic carbon (g/kg)	4.40	7.80
3	Organic matter (g/kg)	7.59	13.45
4	Total N (g/kg)	0.05	0.84
5	Available potassium (me/100g)	0.29	0.28
6	Available phosphorus (g/kg)	5.30	1.80
	Mechanical Analysis (0-15 cm depth)		
1	Clay (%)	15.0	26.1
2	Sand (%)	70.0	44.8
3	Silt (%)	15.0	29.1
4	Field Texture	Sandy loam	Loam

Seedling establishment at 2 WAS was statistically not different among locations (Table 2). Seedling establishment at 2 WAS was significantly higher in 2006 (95.27%) than in 2007 (89.00%). Averaged across both locations and both years mean seedling establishment at 2 WAS was significantly similar among all the varieties evaluated (Table 2). The non-significance in stand count is a clear indication that there was a good germination of all the varieties, thus seed quality and viability among the varieties were very good. The effect of years show that the number of days to first flower appearance was significantly higher in 2007 (49.79) than in 2006 (46.50) (Table 2). Similarly, the number of days to first flowering was significantly higher in Maiduguri location (50.54) than at Damboa location (45.75) (Table 2).

TABLE 2: Effects of year, location and variety on physiological parameters of cowpea varieties at Maiduguri and Damboa in 2010 and 2011 combined

Treatment	Seedling establishment at 2 weeks after sowing	Number of days to first flowering	Number of days to 50% flowering	Soil moisture suction measurements at (centibars)	Transmitted photosynthetic active radiation	Pod development period (days)	Number of days to physiological maturity	100-grain weight (g)	Shelling percentage (%)	Harvest index	Grain yield per plant (g)	Grain yield (kg ha^{2})	Shell weight (kg ha^{2})	Fodder yield (kg ha^{2})
Year														
2006	95.27^{a}	46.50^{b1}	59.58^{a}	7.35^{b}	90.80^{a}	15.99	78.63^{b}	16.12^{b}	65.08^{b}	21.88^{b}	10.6^{1}	785.31	381.12^{a}	4319.4^{a}
2007	89.00^{b}	49.79^{a}	58.21^{b}	16.13^{a}	74.62^{b}	16.45	81.54^{a}	16.92^{a}	77.46^{a}	28.12^{a}	14.24^{a}	865.99	256.78^{b}	3769.9^{b}
SE(±)	0.976	0.384	0.0349	0.370	1.774	0.247	0.747	0.172	0.767	0.644	0.747	30.635	12.819	101.05
Location														
Maiduguri	90.79	50.54^{a}	62.38^{a}	11.06^{b}	80.84	16.45	85.98^{a}	16.62	70.63	25.41	10.66^{b}	745.02^{b}	286.52^{b}	3861.2b
Damboa	93.48	45.75^{b}	55.42^{b}	12.42^{a}	84.58	16.00	74.19^{b}	16.42	71.92	24.58	14.19^{a}	906.28^{a}	352.38^{a}	4228.1a
SE(±)	0.976	0.384	0.349	0.370	1.774	0.247	0.747	0.172	0.767	0.644	0.747	30.635	12.819	101.05
Variety														
IT90K-277-2	90.92	42.83^{d}	51.58^{de}	12.17^{ab}	79.12^{bc}	14.07^{d1}	76.67^{b}	15.43^{bc}	76.54^{a}	33.78^{a}	14.90	1034.9^{ab}	323.87^{bc}	3394.4^{ef}
Kannanado White	91.33	58.42^{a}	72.25^{a}	11.08b^{c}	93.61^{a}	17.76^{a}	90.92^{a}	19.72^{a}	65.60^{d}	14.35^{e}	9.97	451.4^{d}	191.68^{d}	4496.9^{bc}
IT97K-499-35	93.53	39.67^{e}	50.17^{e}	13.00^{ab}	85.76^{ab}	16.2b^{c}	74.25^{b}	14.98^{c}	70.44^{bc}	33.18^{a}	13.23	1158.4^{a}	484.15^{a}	2882.8^{f}
Borno Brown	91.92	58.67^{a}	71.17^{a}	9.00^{cd}	90.40^{a}	18.06^{a}	90.58^{a}	20.14^{a}	68.93^{cd}	15.83^{e}	10.73	484.0^{d}	203.70^{d}	4926.4^{ab}
IT89KD-391	95.00	43.92^{cd}	53.08^{d}	13.17^{ab}	74.08^{cd}	17.26^{ab}	74.58^{b}	16.21^{b}	73.91^{ab}	29.01^{b}	13.53	864.0^{bc}	310.18^{bc}	3503.2^{e}
IT97K-568-18	91.83	45.92^{c}	57.58^{c}	12.83^{ab}	71.37^{e}	15.31^{cd}	76.83^{b}	14.64^{c}	70.47^{bc}	25.78^{c}	11.94	844.6^{bc}	345.15^{b}	4217.2^{cd}
IT98K-131-2	90.25	44.00^{cd}	51.58^{de}	13.83^{a}	75.19^{c}	15.64^{c}	69.08^{c}	15.43^{bc}	70.13^{bc}	29.10^{b}	13.89	1019.1^{ab}	435.97^{a}	3864.7^{de}
IT89KD-288	92.33	51.75^{b}	63.75^{b}	8.83^{d}	92.17^{a}	15.42^{cd}	87.75^{a}	15.60^{bc}	74.15^{ab}	20.13^{d}	11.21	748.8^{c}	256.93^{cd}	5071.7a
SE(±)	1.952	0.769	0.698	0.739	3.548	0.494	1.494	0.345	1.534	1.228	1.495	61.270	25.639	202.11

1=Means within a column and treatment followed by similar letter(s) are not significantly different ($P \leq 0.05$) according to Duncan's Multiple Range Test (DMRT).

Averaged over both locations and both years (overall mean) cowpea varieties differed from each other significantly in terms of their number of days to first flower appearance. *Kannanado White* and *Borno Brown* varieties had significantly longer number of days to first flowering compared with the rest of the varieties (Table 2). Number of days to 50% flowering was significantly higher in 2006 (59.58) than in 2007 (58.21) (Table 2). Similarly, number of days to 50% flowering was significantly higher in Maiduguri (62.38) than in Damboa (55.42) (Table 2). Averaged across both years and both locations mean number of days to 50% flowering was significantly higher in *Kannanado White* and *Borno Brown* compared with the rest of the varieties (Table 2). The effect of years showed that the average soil moisture suction or attraction reading was significantly higher in 2007 (16.13) than in 2006 (7.35) (Table 2). Similarly, soil moisture suction measurements were significantly higher in Damboa location (12.42) than in Maiduguri location (11.06) (Table 2). The findings of this study showed that averaged across both locations and both years (overall mean) significantly higher soil moisture suction or attraction force readings (centibars) were observed on the improved varieties except IT89KD-288 than their local counterparts (Table 2). This shows that the local varieties conserve more moisture. The soil suction reading is a direct measure of the availability of moisture for plant growth. As the soil becomes drier, these films become thinner and the attraction or suction increases. The plant root has to overcome this soil suction, or attraction force, in order to withdraw moisture from the soil (Soil Moisture Equipment Corp., 1989). The study also revealed that the highest mean soil moisture suction measurements were significantly obtained by IT97K-131-2 compared with the other varieties but only comparable with IT97K-568-18, IT89K-391, IT97K-499-35 and IT90K-277-2 (Table 2). It is noteworthy that these varieties had the highest grain yields compared to the other varieties. This is so because according to Scotti *et al*. (1999) and Ogbonnaya *et al*. (2003) cowpea is known to have high stomatal control leading to a rapid closure of stomata under water stress conditions.

Mean photosynthetically active radiation (PAR) intercepted was statistically different between years, where the average intercepted PAR was higher in 2006 (90.80%) than in 2007 (74.62%) (Table 2). Conversely, PAR was similar between locations without significant differences (Table 2). Averaged across both years and both locations the varieties IT89KD-288, *Borno Brown*, IT97K-499-35 and *Kannanado White* intercepted significantly the highest PAR compared with the rest of the other varieties (Table 2). Average pod development period did not differ between the locations or years, however, pod development period differed significantly among the cowpea varieties (Table 2). Among the varieties, *Kannanado White*, *Borno Brown* and IT89KD-391 took the longest time from anthesis to maturity of individual pods compared to the rest of the varieties (Table 2). Among the years, the number of days to physiological maturity was significantly higher in 2007 (81.54 days) than in 2006 (78.63 days) (Table 2). Similarly, number of days to physiological maturity was significantly longer in Maiduguri (85.98 days) than in Damboa (74.19 days) (Table 2). Averaged across both locations and both years number of days to physiological maturity was significantly longer in *Kannanado White*, *Borno Brown* and IT89KD-288 compared with the rest of the varieties evaluated (Table 2). Similar results were reported by Elemo (1993). This is probably because they produced most of their flowers and pods at the end of the rains unlike the elite varieties, though Ashley (1999) reported that cowpea is far more drought tolerant than some other legumes such as soybeans, being better able to maintain a constant hydration (water potential) of leaves throughout the stress period. Mean 100-grain weight (g) was statistically different between 2006 and 2007 (Table 2). In 2007 the average 100-grain weight was significantly higher (16.92 g) than in 2006 (16.12 g). In contrast, mean 100-grain weight (g) is similar among locations without significant differences (Table 2). Averaged over both locations and both years the varieties *Kannanado White* and *Borno Brown* produced significantly the heaviest cowpea grains compared with the rest of the varieties (Table 2). Ellis-Jones and Amaza (2007) reported lower adoption of IT97K-499-35 (*Striga*-resistant and higher grain yielding) in a study area in North East Nigeria because farmers preferred local varieties that are large-seeded. Efforts should therefore be made to develop cowpea varieties that meet end-user preferences (Kamara *et al.*, 2008).

Averaged across both locations and both years average shelling percentage was significantly different between years. Shelling percentage was statistically higher in 2007 (77.46%) than in 2006 (65.08%), while shelling percent was similar between locations without significant differences (Table 2). Averaged across both locations and both years (overall mean) cowpea varieties differed significantly in terms of their shelling percentages (Table 2). The highest shelling percentage was obtained by IT90K-277-2, which was comparable with IT89KD-391 and IT89KD-288 but significantly higher than the other varieties (Table 2). Mean harvest index was statistically different among years (Table 2), where it was significantly higher in 2007 (28.12%) than in 2006 (21.88%) (Table 2). In contrast, mean harvest index did not differ significantly among locations (Table 2). Averaged across both locations and both years the varieties IT90K-277-2 and IT97K-499-35 recorded significantly the highest harvest index compared with the rest of the varieties (Table 2). This simple ratio varies on the ability of a variety to partition current assimilates to the grain and the reallocation of stored structural assimilates to the seed (Turner *et al.*, 2000). Mean cowpea grain yield per plant statistically differed among both years and both locations (Table 2). Grain yield per plant was significantly higher in 2007 (14.24 g) than in 2006 (10.61 g). Similarly, yield per plant was significantly higher at Damboa (14.19 g) than at Maiduguri (10.66 g) (Table 2). Although with no statistical differences averaged across both years and locations among the cowpea varieties IT90K-277-2 produced the highest grain yield per plant (14.90 g) and the lowest was by *Kannanado White* (9.97 g) (Table 2).

The effects of year, location and variety on cowpea grain yield at Damboa and Maiduguri in 2006 and 2007 are presented in Table 2. The effect of year on the grain yield (kg ha^{-1}) was not significant, while the locations and the varieties across the locations and years had significant effects on cowpea grain yield per hectare (Table 2). At Damboa there were significantly higher grain yields (906.28 kg ha^{-1}) than in Maiduguri (745.02 kg ha^{-1}). This may be because of edaphic factors such as soil properties and inherent (Akande, 2007). The result of this trial is also in agreement with that of Nielsen and Hall (1985) who reported that grain yield of cowpea varies widely when grown at different locations. Among the varieties, IT90K-277-2, IT97K-499-35 and IT98K-131-2 significantly produced the highest grain yields (kg ha^{-1}) than the other varieties (Table 2). The local varieties produced significantly the lowest grain yields (kg ha^{-1}) (Table 2). Despite the high yield potentials of these varieties their adoption by farmers may be of some concern. For Kamara *et al*. (2010) reported that despite the yield benefits of new varieties, farmers have shown preference for local ones, even when introduced varieties give higher grain yields. The reasons, among others, are ability for relay planting with creeping habit and ability to smother weeds. Although earlier reports showed that seed size is a primary determinant of yield in cowpea (Imrie and Bray, 1983; Obisesan, 1985), this was not the case in the present study and that of Nakawuka and Adipala (1999). This discrepancy may have been due to the different genotypes used.

The effects of year, location and variety averaged across the locations and years had significant effect on shell weight (pod wall) (Table 2). In 2006, shell weight was significantly higher (381.12 kg ha^{-1}) than in 2007 (256.78 kg ha^{-1}). Similarly, shell weight per hectare was statistically higher at Damboa (352.38 kg ha^{-1}) than in Maiduguri (286.52 kg ha^{-1}). Among the varieties, IT97K-499-35 and IT98K-131-2 significantly produced the highest shell weight (kg ha^{-1}) than the other varieties (Table 2). Fodder production was significantly higher in 2006 (4319.4 (kg ha^{-1})) than in 2007 (3769.9 (kg ha^{-1})) (Table 2). Similarly, the fodder yield was significantly higher in Damboa (4228.1 kg ha^{-1}) than in Maiduguri (3861.2 kg ha^{-1}) (Table 2). Averaged over both locations and both years the varieties IT89KD-288 and *Borno Brown* produced significantly higher fodder yield per hectare compared with the rest of the varieties (Table 2). In the present study *Borno Brown* and IT89KD-288 (indeterminate) produced 80.2% and 97.2% higher fodder yield respectively than IT97K-499-35 (semi-erect, determinate). This observation did not agree with the findings of Kamara *et al*. (2008) who reported that the variety IT97K-499-35 (semi-erect, determinate) produced 42% more biomass than *Borno Brown* since these two varieties were more heavily infested with *Striga*. A similar observation was reported by Muli and Saha (2008) who found that local cultivars were more productive in terms of leaf yields. This calls for screening efforts to be geared towards high grain yield from indeterminate varieties, while still maintaining a high yield of fodder. The role played by fodder provision from cowpea to animals during the dry season in the drier northern parts of West Africa is very important (Gworgwor and Weber, 1991). In this study, it is shown that the early maturing cowpea varieties (IT90K-277-2, IT97K-499-35, IT97K-568-18 and IT97K-131-2) produced significantly lower fodder and 100- grain weight compared to the other varieties. This is in agreement with the findings of Bonny and Williams (1992) who reported that the early maturing cultivars (TVX 3236 and B111-2) produced the smallest grains and fodder yield.

Interrelationships among Physiological Parameters

The correlation coefficients (r) for all possible comparisons between physiological traits and grain yield averaged over both locations and both years (overall mean) are presented in Table 3.

TABLE 3: Correlation coefficients among grain yield and physiological parameters tested combined in 2010 and 2011 at Maiduguri and Damboa

	GY	DFF	SE2W	DFPF	FY	HGW	HI	DPM	PAR	PDP	SHW	SMSM	SP	YPP
GY	1.00													
DFF	-0.64**	1.00												
SE2W	0.01	-0.24**	1.00											
DFPF	-0.74**	0.83**	-0.07	1.00										
FY	-0.21*	0.36**	0.16	0.39**	1.00									
HGW	-0.50**	0.66**	-0.16	0.61**	0.30**	1.00								
HI	0.71**	-0.58**	-0.19	-0.72**	-0.53**	-0.47**	1.00							
DPM	-0.51**	0.69**	-0.09	0.72**	0.25*	0.47**	-0.42**	1.00						
PAR	-0.12	0.19	0.17	0.28**	0.38**	0.25*	-0.43**	0.18	1.00					
PDP	-0.35**	0.36**	-0.03	0.38**	0.04	0.51**	-0.23*	0.27**	0.07	1.00				
SHW	0.69**	-0.65**	0.24*	-0.60**	-0.15	-0.52**	0.33**	-0.52**	0.14	-0.29**	1.00			
SMSM	0.22*	-0.17	-0.28**	-0.31**	-0.46**	-0.04	0.39**	-0.24*	-0.48**	0.01	-0.08	1.00		
SP	0.39**	-0.08	-0.35**	-0.33**	-0.11	-0.02	0.54**	-0.06	-0.35**	-0.06	-0.23*	0.44**	1.00	
YPP	0.47**	-0.27**	-0.04	-0.43**	-0.01	-0.09	0.45**	-0.39**	-0.08	-0.15	0.12	0.40**	0.51**	1.00

GY= Grain yield, SMSM= Soil moisture suction measurement, DFF= Days to first flowering, DFPF= Days to 50% flowering, PAR=Photosynthetically active radiation, PDP= Pod development period, DPM=Days to physiological maturity, HGW= 100-grain weight, SP= Shelling percentage, HI= Harvest index, SE2W=Seedling establishment at 2 WAS, YPP= Yield per plant , SW=Shell weight, FY= Fodder yield, **= Highly significant at 1% probability level,*= Significant at 5% probability level.

The results showed that cowpea grain yield was positively correlated with harvest index, shell weight, soil moisture suction measurements, shelling percentage and grain yield per plant (Table 3). Conversely, the results indicated that cowpea grain yield was significantly negatively correlated with number of days to first and 50% flowering, fodder yield, 100-grain weight, number of days to physiological maturity and pod development period (Table 3). The significant negative correlation observed between seed yield and duration of reproductive phase in this study implies that an attempt to breed for long duration phase could repress yield, especially in the intermediate cowpea varieties (Ombakho and Tyagi, 1987). Number of days to first flowering had significant positive correlation with number of days to 50% flowering, fodder yield per hectare, 100-grain weight, number of days to physiological maturity and pod development period. This indicates that flowering date can be used as a reliable measure of maturity in cowpea. A similar observation was made by Turk *et al*. (1980) and Ombakho and Tyagi (1987) in cowpea. Number of days to 50% flowering had a significant positive correlation

with fodder yield per hectare, 100-grain weight, number of days to physiological maturity, PAR and pod development period and a highly significant negative correlation with harvest index, shell weight, soil moisture suction measurements, shelling percentage and grain yield per plant (Table 3). Fodder yield per hectare had a highly significant positive correlation with 100-grain weight and PAR, and a significant negative correlation with harvest index, and soil moisture suction measurements (Table 3). The highly positive correlation of fodder yield per hectare with the percentage transmitted photosynthetically active radiation are in tune with the findings of Gallagher and Biscoe (1978) who reported that under non-stressed environmental conditions, the amount of dry matter produced by a crop is linearly related to the amount of solar radiation (SR), especially photosynthetically active radiation (PAR), intercepted by the crop. Also fodder yield per hectare and PAR are highly negatively correlated with soil moisture suction measurements. Therefore, species that intercept a large fraction of PAR are important in the dry environments like the Sudan savanna of North East Nigeria, where sunshine is abundant. 100-grain weights had a significant positive correlation with number of days to physiological maturity, PAR and pod development period, and a significant negative correlation with harvest index and shell weight. This suggests that selecting for large seed size would lead to long duration of reproductive phase (Turk *et al*. (1980) and Ombakho and Tyagi (1987). The results from this study showed that 100-grain weight is highly positively correlated with number of days to physiological maturity. Furthermore the local indeterminate cowpea varieties with long duration of reproductive period had large seed size without a corresponding seed yield increase. The negative correlation obtained between duration of reproductive phase with number of pods per plant suggest that pod dry matter gain is not due to increasing length of the reproductive period, but may rather be the efficiency of translocation of photosynthate and partitioning to sink. This result corroborated an earlier report of Wien and Ackah (1978). Harvest index had a significant positive correlation with shell weight, matured seeds from 100 grains, soil moisture suction measurements, shelling percentage, and grain yield per plant, and a significant negative correlation with number of days to physiological maturity, PAR and pod development period. Number of days to physiological maturity had a highly significant positive correlation with pod development period, and a significant negative correlation with shell weight, soil moisture suction measurements and grain yield per plant (Table 3). PAR had a highly significant positive correlation with soil moisture suction measurements and shelling percentage. Shelling percentage is highly significantly positively correlated with grain yield per plant. The results further indicated that soil moisture suction measurements had a highly significant positive correlation with shelling percentage and grain yield per plant (Table 3).

CONCLUSION

In this study, the improved varieties performed better than the local varieties in the Sudan Savanna zone of Borno State. For the improved varieties had significantly higher grain yield per plant and per hectare, shelling percentage, harvest index and matured earlier to escape drought in this agro-ecological zone. Among the improved varieties, IT90K-277-2, IT97K-499-35 and IT98K-131-2 were outstanding in terms of yield. Though the local varieties had significantly the lowest grain yield they also had significantly the heaviest grains and conserved more soil moisture in the Sudan savanna of Borno State. There is the need for breeding work between the improved and the local varieties to harmonize their outstanding advantages over the other.

RECOMMENDATION

The improved varieties of cowpea were found suitable in the Sudan savanna zone of Nigeria and could be recommended for adaptive farm trials. Among the varieties, IT90K-277-2, IT97K-499-35 and IT98K-131-2 should be tried for further performance evaluation under farmers' environment for high yield and fodder production. Based on the physiological studies of cowpea in the Sudan savanna zone of Borno State, it is recommended that breeding programme be pursued for this ecological zone on the varieties IT90K-277-2, IT97K-499-35 and IT98K-131-2 for higher fodder production, brown and large-seeded grains, and ability to conserve more soil moisture and to intercept higher photosynthetically active radiation. The local varieties are to be bred for higher yield and harvest index.

REFERENCES

Akande, S. R. (2007) Biplot analysis of genotype by environment interaction of cowpea grain yield in forest and southern guinea savanna agro-ecologies of Nigeria. *Journal of Food, Agriculture and Environment* **5**:(3&4),464-467.

Anonymous (2008) Cowpea: Abuja Securities and Commodity Exchange PLC. http://www.abujacomx.com

Ashley, J. (1999) *Food crops and drought*. *The tropical agriculturalist*. Cste, S (series editor). CTA , Macmilan.

Bonny, R. N. and Williams, J. H. (1992) Response of cowpea cultivars to planting date of sowing in intercrops with pearl millet in Niger. *Expl. Agric*. **28**: 41-48.

Duncan, O.B. (1955) Multiple Range and Multiple F-tests. *Biometrics* **11**: 1-42.

Elemo, K. A. (1993) Farmer participating in technology testing: a case of agronomic evaluation of cowpea genotypes in the Nigerian Northern Guinea Savanna. *Agricultural Systems in Africa* **3** (1): 39-49.

Ellis-Jones, J. and Amaza, P. S. (2007) PROSAB: Promoting Sustainable Agriculture in Borno State: An Adoption and Impact Assessement of PROSAB's Activities over Three Cropping Seasons (2004-2006), PROSAB Internal Report, 41p.

FAO, (2000) Site internet : http / www . FAO.org./ statistics.

Gallagher, J. L. and Biscoe, P. V. (1978) Radiation absorption, growth and yield of cereals. *Journal of Agricultural Science, Cambridge* **91**: 47-60.

Gibbon, D. and Pain, A. (1988) *Crops of the drier regions of the tropics*. ELBS / Longman. 157 pp.

Gworgwor, N. A. and Weber, H. C. (1991) Studies in biology and control of *Striga*. 11. Varietal responses of cowpea (*Vigna unguiculata* (L) Walp.) to *Striga gesnerioides*. *Journal of Agronomy and Crop Science* **166**: 136-140.

Imrie, B. C. and Bray, R. A. (1983) Estimates of combining ability and variance components of grain yield and associated characters of cowpea. *Proceeding of Australian Plant Breeding Conference*, 202-204.

Kamara, A. Y., Chikoye, D., Ekeleme, F., Omoigui, L. O. and Dugje, I. Y. (2008) Field performance of improved cowpea varieties under conditions of natural infestation by the parasitic weed *Striga gesneriodes. International Journal of Pest Management*. **54**:3, 189-195.

Kamara, A. Y., Ellis-Jones, J., Ekeleme, F., Omoigui, L. O. Amaza, P. S. Chikoye, D., and Dugje, I. Y. (2010) A participatory evaluation of improved cowpea cultivars in the Guinea and Sudan savanna zones of north east Nigeria. *Achives of Agronomy and Soil Science.* **56** (3): 355-370.

Muleba, N. C., Dabire, J. B. S., Drabo, I. and Ouedraogo, J. T. (1997) Technologies for cowpea production based on genetic and environmental manipulations in the semi-arid tropics. Pages 192-206 in *Technologies options for sustainable agriculture in sub-Saharan Africa*, edited by Bezuneh, T.; Emechebe, A. M.; Sedgo, J. and Oeudrago, M. Publication of the Semi-Arid Food Grain Research and Development Agency (SAFGRAD) of the Scientific, Technical and Research Commission of OAU Ouagadougou, Burkino Faso.

Muli, M. B. and Saha, H. M. (2008) Participatory evaluation of cowpea cultivars for adaptation and yield performance in coastal Kenya. Kenya Agricultural Research Institute, Regional Research Centre, Mtwapa P.O Box 16, Kikambala.

Nakawuka, C. K. and Adipala, E. (1999) A path coefficient analysis of some yield components interactions in cowpea. *African Crop Science Journal* **7**: 4, 327-331.

Nielsen, C. N. and Hall, A. E. (1985) Response of cowpea (*Vigna unguiculata* (L.) Walp.) in the field to high night air temperature during flowering. I. thermal regimes of production regions field experimental system. *Field Crops Research* **10**: 167-179.

Nielsen, S. S., Ohler, T. A. and Mitchell, C. A. (1997) Cowpea leaves for human consumption, utilization, and nutrient composition. Pages 326-332 in *Advances in cowpea research*, edited by Singh, B. B., Mohan Raj, D. R., Dashiel, K. E. and Jackai, L. E. N. Copublication of International Institute of Tropical Agriculture (IITA) and Japan International Research Centre for Agricultural Sciences (JIRCAS). IITA,Ibadan, Nigeria.

Obesesan, I. O. (1985) Association among grain yield components in cowpea (Vigna unguiculata L. Walp.). *Genetical Agriculture* **33**: 377-386.

Ogbonnaya, C. I., Sarr, B., Brou, C. Diodf, O., Diop, N. N. and Roy-M acauley, H. (2003) Selection of cowpea genotypes in hydroponics, pots and field for drought tolerance. *Crop Sci.* **43**: 229-236.

Ombakho, G. A. and Tyagi, A. P. (1987) Correlation and path coefficient analysis for yield and its components in cowpea (*Vigna unguiculata* (L.) Walp.). *East African Agriculture and Forestry Journal* **53**: 23-27.

Onyibe, J. E., Kamara, A. Y. and Omoigui, L. O. (2006) *Guide to cowpea production in Borno State*, *Nigeria*. Promoting Sustainable Agriculture in Borno State (PROSAB). Ibadan, Nigeria. 36pp.

Raheja, A. K. (1986) Problems and prospects of cowpea production in the Nigerian Savannas. Pages.13-15 in *Tropical grain legume bulletin*. World Cowpea Research Confernce, 5-7 November 1986, **32**, IITA, Special Issue.

Scotti, C. P., Ramalho, J, C., Lauriano, J. A., Silva, L. J. and Ceu-Matos, D. M. (1999) Effects of drought on photosynthetic performance and water relations of four *Vigna* genotypes. *Photosynthetica* **37** (1-2): 79-87.

Singh, B. B. (1994) Breeding suitable cowpea varieties for West and Central African Savanna. Pages 77-85 in *Progress in food grains research and production in Semi-Africa*, edited by Menyonga, J. M., Bezuneh, J. B., Yayock, J. Y. and Soumana, I. OAU / STRC-SAFGRAD, Ouagadougou, Burkino Faso.

Singh, B. B. (2007) Potential and constraints of improved cowpea varieties in increasing the productivity of cowpea-cereal systems in the dry Savannas of West Africa. Pages 14-26 in Majiwa, P., Odera, M., Muchiri, N., Omanya, G. and Werehire, P. (eds). A plan to apply technology in the improvement of cowpea productivity and utilisation for the benefit of farmers and consumers in Africa*: Proceedings of cowpea stakeholders workshop*. Nairobi Kenya: African Agricultural Technology Foundation.

Singh, S. R., Jackai, L. E. N., Dos Santos, J. H. R. and Adalla, C.B. (1990) Insect pests of cowpea. Pages 43-89 in *Insect pests of tropical food legumes,* edited by Singh, S.R. John Wiley and Sons Ltd, Chichester, England.

Soil Moisture Equipment Corp (1989) Model 2900F1 operating instructions ''Quick Draw'' soil moisture probe. Soil Moisture Equipment Corp. P.O. Box 30025, Santa Barbara, CA 93105, USA.

Tarawali, S. A., Singh, B. B., Peters, M. and Blade, S. F. (1997) Cowpea haulms as fodder. Pages 313-325 in *Advances in cowpea research*, edited by Singh, B. B., Mohan Raj, D. R., Dashiel, K. E. and Jackai, L. E. N. Copublication of International Institute of Tropical Agriculture (IITA) and Japan International Research Centre for Agricultural Sciences (JIRCAS). IITA,Ibadan,Nigeria.

Turk, K. J., Hall, A. E. and Asbell, C. W. (1980) Drought adaptation of cowpea .I. Influence of drought on seed yield. *Agronomy Journal* **72**:413-420.

Turner, N. C., Wright, G.C. and Siddique, K.H.M. (2000) Adaptation of grain legumes (pulses) to water-limited environments. *Advances in Agronomy* **71**:193-231.

Wien, H. C. and Ackah, E. E. (1978) Pod development period in cowpeas: Varietal differences as related to seed characters and environmental effects. *Crop Science* **18**:791-794.