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Varietal Trials and Physiological Basis for Yield Differences among Cowpea Varieties in Sudan Savanna of Nigeria

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***Abstract* – Field trials were conducted at Damboa (11o10.736'N; 12 o47.100'E; elevation 398 m asl) on the trial site of the International Institute of Tropical Agriculture (IITA) in Borno State 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. 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 IT90K-277-2, IT97K-499-35 and IT98K-131-2 had significantly higher grain yield per hectare, harvest index and matured earlier to escape drought in this agro-ecological zone. The results also show that cowpea grain yield was positively correlated with harvest index, shell weight 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.**

***Keywords* – Physiological, Cowpea, Varieties, Sudan Savanna, Damboa, Nigeria.**

I. Introduction

Cowpea, *Vigna unguiculata* (L.) Walp, also popularly called 'beans' in Nigeria is an important food legume and versatile crop, primarily cultivated in the dry savannas of tropical Africa, Asia and South America covering over 12 million ha with annual production exceeding 3 million tones [1]. About 64% of the area under cowpea production is in West and Central Africa where the crop is normally grown in mixture with millet, maize and sorghum in the Sudan savanna and Sahelian region. 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 ([2], [3]. In Nigeria cowpea is largely grown in the northern part of the country which has Savanna type of vegetation and light rainfall [4] with Borno State being the major producer [5]. Cowpea provides cash income for people as well as a protein supplement in the daily diets. Cowpea leaves, green pods and green peas are consumed as food and the green as well as the dry haulms are fed to livestock. Due to several constraints the average cowpea grain production in West Africa was reported to be as low as 358 kg/ha [2] whereas [6] 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 [7] Improving the yield of cowpea in the State requires the use of drought-tolerant and drought-avoidance varieties. The objectives of the study are to evaluate the agronomic performances and to identify physiological traits associated with high grain yield of some improved cowpea varieties in Sudan savanna zone of Nigeria. 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 [8]. 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 [9]. The improved varieties are therefore early maturing, photoinsensitive 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 Sudan savanna 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 this region since scanty 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 region of Nigeria.

II. Materials and Methods

The study was conducted at Damboa (11o10.736′N; 12 o47.100′E; elevation 398 m asl) on the trial site of the

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International Institute of Tropical Agriculture (IITA) in Borno State in Sudan savanna of North East 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 6 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. Physiological parameters measured are seedling establishment (%) at two weeks after sowing (2 WAS), number of days to first and 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) and per ha (kg ha-1), shell weight (kg ha-1) and fodder yields.

All data were subjected to analysis of variance (ANOVA) using Statistix 8.0 version. Treatment means were compared where F-values were significant using Duncan's Multiple Range Test (DMRT) at 5% level of probability [10]. Linear correlation coefficient (r) among combined means of two years of cowpea variety and physiological traits were calculated at 5%.

III. Results and Discussion

Details of the physico-chemical analysis of the soils at the experimental site presented in Table 1shows that the soil was loam and having organic matter of 13.54 g/kg. The pH of the soil was almost neutral while available phosphorus was 1.80 g/kg (Table 1). Based on the soil properties of the site it was ideal for cowpea growth. The effects of cowpea variety on physiological parameters averaged over two years are summarized in Table 2. Cowpea variety had no significant effect on seedling establishment (%) at 2 WAS. 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. *Kannanado White* and *Borno Brown* varieties had significantly the longest mean number of days to first shown flower appearance compared with the rest of the varieties. The results also show that the local varieties (*Kannanado White* and *Borno Brown*) had significantly the longest number of days to 50% flowering compared with the rest of the except IT89KD-288. There were no significant differences in soil moisture suction readings and the amount of solar radiation, especially photosynthetically active radiation (PAR), intercepted by the crop among the varieties averaged across years (Table 2). The *Borno Brown* variety recorded significantly the longest time from anthesis to maturity of individual pods (about 18 days) than IT90K-277-2, IT97K-499-35, IT97K-568-18 and IT89KD-288. However, the cowpea variety *Borno Brown* had similar pod development period when compared with *Kannanado White*, IT89KD-391 and IT98K-131-2 (Table 2). The significantly longest number of days to physiological maturity was recorded by the local varieties *Kannanado White* and *Borno Brown* while the improved variety IT89KD-288 is at par with these varieties (Table 2). Similar results were reported by [11]. This is probably because they produced most of their flowers and pods at the end of the rains, though [12] reported that cowpea is far more drought tolerant than some other legumes such as soybeans. Also the improved variety IT98K-131-2 matured in about 23 days earlier than the local variety *Kannanado White*. Earliness in maturity is important in the Sudan Savanna agro-ecology because early cultivars can escape drought and some insect infestations providing the first food and marketable product available from the current growing season and can be grown in a diverse array of cropping systems [13]. Data on 100-grain weight as affected by cowpea varieties as presented in Table 2 indicated that *Kannanado White* and *Borno Brown* varieties had significantly the heaviest grains and the lowest grain yield (kg ha-1) compared with the rest of the other varieties (Table 2). Reference [14] 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 [15]. Also earlier reports showed that seed size is a primary determinant of yield in cowpea ([16], [17], this was not the case in the present study and that of [18]. This discrepancy may have been due to the different varieties used. The differences among the cowpea varieties on shelling percentage shows that cowpea variety had no significant effect on shelling percentage (Table 2). The result also shows that IT90K-277-2 and IT97K-499-35 had significantly the highest HI but comparable with IT98K-131-2 variety (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 [19].

The effect of cowpea variety on grain yield per plant for the combined analysis did not show significant difference in mean yield per plant among the eight cowpea varieties tested. The highest grain yields were produced by the varieties IT90K-277-2, IT97K-499-35 and IT98K-131-2 in the combined data compared with the other varieties. The same varieties also had the highest harvest index. This is consistent with the findings of [20] who stated that selecting for high harvest index could produce cowpea cultivars with the potential for high grain yields.

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 [21] 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. The effect of cowpea variety on shell weight (pod wall) per hectare was significant where the variety IT97K-499-35 produced significantly highest mean shell weight per hectare compared to the rest of the varieties except for IT98K-131-2 and IT97K-568-18 (Table 2). Borno Brown variety had significantly the highest fodder yield (4950.1 kg ha-1) in the combined mean compared to all the other varieties, except IT89KD-288, *Kannanado White,* IT97K-568-18, IT98K-131-2 and IT89KD-288 are statistically similar compared to the rest of the varieties. In the present study *Borno Brown* and *Kannanado White,* produced about 63% higher fodder yield than IT97K-499-35 (semi-erect, determinate). This observation did not agree with the findings of [15] who reported that the variety IT97K-499-35 (semi-erect, determinate) produced 42% more biomass than *Borno Brown* since this variety was more heavily infested with *Striga*. A similar observation with this study was reported by [22] 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 [23]. In this study, it is shown that the early maturing cowpea varieties (IT90K-277-2 and IT97K-499-35) produced significantly lower fodder and 100- grain weight compared to the other varieties. This is in agreement with the findings of [24] who reported that the early maturing cultivars (TVX 3236 and B111-2) produced the smallest grains and fodder yield. Reference [14]) reported lower adoption of IT97K-499-35 in a study area in North East Nigeria because farmers preferred large-seeded brown varieties. Efforts should therefore be made to develop *Striga*resistant cowpea varieties that meet end-user preferences [15]. The importance of seed size has been on record for centuries ago. This can be seen from the words of Virgil, the Roman poet, “no matter what treatment was given to seed grain it was in vain except when they also with great care picked out the largest grain’’ and that he had seen them degenerate unless the industrious hand did yearly cull the largest’’. Virgil was probably writing about wheat and whatever inspired the words would have been based more on observation than on research [25].

IV. Interrelationships among Physiological Parameters

Correlation coefficient (r) among the various parameters taken combined for years are presented in Table 3. The correlation coefficient between cowpea grain yield per hectare with harvest index, shell weight and grain yield per plant were significantly positively correlated (Table 3). In contrast there were significant negative correlation between cowpea grain yield per hectare and number of days to first and 50% flowering, 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. A similar observation was made by [26], [27] in cowpea. Number of days to first flower appearance had a 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, and a significant negative correlation with harvest index and shell weight. The significant positive correlation between number of days to physiological maturity and days to first flowering indicates that flowering date can be used as a reliable measure of maturity in cowpea. A similar observation was made by [26], [27] in cowpea. The 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 significant negative correlation with harvest index and shell weight (Table 3). Fodder yield per hectare had a significant positive correlation with 100-grain weight, number of days to physiological maturity and PAR, and a significant negative correlation with harvest index and soil moisture suction measurements (Table 3). The positive correlation of fodder yield per hectare with the percentage transmitted photosynthetically active radiation are in tune with the findings of [28] 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 and pod development period, and a significant negative correlation with harvest index and shell weight. The significant positive correlation was observed between number of days to physiological maturity and 100-seed weight suggests that selecting for large seed size would lead to long duration of reproductive phase. A similar observation was reported by [26], [27] in cowpea. The correlation coefficient between harvest index with shell weight, shelling percentage and grain yield per plant were significantly positively correlated. In contrast, there were significant negative correlation between harvest index and number of days to physiological maturity, PAR and pod development period. Also the results show that PAR had a significant negative correlation with soil moisture suction measurements and shelling percentage (Table 3).

V. Conclusions

In our work the highest HI and grain yields were produced by the varieties IT90K-277-2, IT97K-499-35 and IT98K-131-2 in the combined data compared with the other varieties. This is in agreement with the findings of [20] who stated that selecting for high harvest index could produce cowpea cultivars with the potential for high grain yields. Also the correlation coefficient between cowpea grain yield per hectare with harvest index, shell weight and grain yield per plant were significantly positively correlated and there were significant negative correlation between cowpea grain yield per hectare and number of days to first and 50% flowering, 100-grain weight, number of days to physiological maturity and pod development period.

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Table 1: Physico-chemical characteristics of the soil at the experimental site

S/No	Soil Characteristics	Physico-Chemical Properties
	Chemical Analysis	
1	pH in H2O	6.40
2	Organic carbon (g/kg)	7.80
3	Organic matter (g/kg)	13.45
4	Total N (g/kg)	0.84
5	Available potassium (me/100g)	0.28
6	Available phosphorus (g/kg)	1.80
	Mechanical Analysis (0-15 cm depth)	
1	Clay (%)	26.1
2	Sand (%)	44.8
3	Silt (%)	29.1
4	Field Texture	Loam

Table 2: Effect of cowpea variety on physiological parameters at Damboa in 2010 and 2011 combined analysis

Treatment/ Cowpea variety	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-graqin weight (g)	Shelling Percent-tage (%)	Harvest index	Grain yield Per plant (g)	Grain yield (kg ha^{2})	Shell weight (kg ha^{2})	Fodder yield (kg ha^{2})
IT90K-277-2	93.33	42.67^{d}	50.50^{c}	11.50	82.00	14.50^{de}	70.83^{b}	15.35^{bc}	75.04	31.80^{a}	13.88	1071.6^{ab}	356.05^{b-d}	3401.2^{c}
Kannanado White	92.50	52.50^{a}	64.50^{a}	13.33	95.13	17.45^{ab}	84.67^{a}	19.63^{a}	68.07	13.52^{e}	12.58	524.5^{d}	242.48^{d}	4977.7^{a}
IT97K-499-35	93.50	40.17^{d}	48.17^{c}	13.00	82.98	15.47^{c-e}	67.83^{bc}	14.80^{bc}	71.74	32.10^{a}	14.18	1326.0^{a}	516.93^{a}	3044.8^{c}
Borno Brown	94.00	53.17^{a}	64.00^{a}	11.50	90.05	17.75^{a}	82.67^{a}	19.87^{a}	74.05	17.30^{e}	15.88	594.0^{d}	240.30^{d}	4950.1^{a}
IT89KD-391	93.83	42.67^{cd}	50.33^{c}	12.67	79.47	16.86^{ab}	70.33^{b}	16.35^{b}	74.89	30.53^{b}	14.34	982.3^{bc}	323.52^{cd}	3633.3^{bc}
IT97K-568-18	96.50	44.17^{c}	54.50^{b}	13.17	78.42	14.08^{e}	71.50^{b}	14.42^{c}	69.79	24.67^{bc}	14.42	938.7^{bc}	400.27^{a-c}	4735.4^{a}
IT98K-131-2	90.67	43.17^{c}	49.17^{c}	11.67	79.12	16.13^{a-d}	61.83^{c}	15.70^{b}	70.64	27.20^{ab}	15.32	1100.3^{ab}	452.77^{ab}	4303.8^{ab}
IT89KD-288	93.50	47.50^{b}	62.17^{a}	12.50	89.47	15.72^{cd}	83.83^{a}	15.23^{bc}	70.10	19.53^{cd}	12.95	712.9^{cd}	278.73^{d}	4778.2^{a}
SE(+)	2.716	0.991	0.973	0.998	4.992	0.606	2.937	0.556		1.959	2.588	97.06	40.949	310.26

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

Table 4: Correlation coefficients between cowpea varieties, grain yield and other parameters tested Table 3: in 2006 and 2007 at Damboa

	GY	DFF	SE2W	DFPF	FY	HGW	HI	DPM	PAR	PDP	SW	SMSM	SP	YPP
GY	1.00													
DFF	-0.64**	1.00												
SE2W	0.00	-0.11	1.00											
DFPF	-0.71**	0.78**	-0.03	1.00										
FY	-0.28	0.39**	0.26	0.50**	1.00									
HGW	-0.48**	0.63**	-0.25	0.52**	0.31*	1.00								
HI	0.75**	-0.61**	-0.14	-0.80**	-0.45**	-0.45**	1.00							
DPM	-0.44**	0.51**	0.27	0.65**	0.35*	0.29*	-0.58**	1.00						
PAR	-0.21	0.21	0.05	0.43**	0.34*	0.23	-0.46**	0.27	1.00					
PDP	-0.30**	0.43**	-0.33*	0.32*	0.09	0.56**	-0.29*	0.16	0.10	1.00				
SW	0.72**	-0.58**	0.15	-0.50**	-0.10	-0.50**	0.37**	-0.32*	0.08	-0.27	1.00			
SMSM	0.09	0.17	-0.38**	-0.10	-0.34*	0.16	0.22	-0.10	-0.48**	0.13	-0.36*	1.00		
SP	0.24	0.04	-0.27	-0.14	-0.26	0.20	0.42**	-0.19	-0.38**	0.01	-0.43**	0.67**	1.00	
YPP	0.30*	0.13	-0.11	-0.08	0.08	0.15	0.31*	-0.22	-0.08	-0.07	-0.10	0.41**	0.60**	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 2 WAS, YPP= Yield per plant, SW=Shell weight, FY= Fodder yield, **= Highly significant at 1% probability level, *= Significant at 5% probability level.