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Research Article

Varietal Trials and Physiological Components Determining Yield Differences among Cowpea Varieties in Semiarid Zone of Nigeria

Nkeki Kamai, Nuhu Adamu Gworgwor, and Joshua Wasinaninda Wabekwa

Department of Crop Production, University of Maiduguri, Maiduguri 600001, Nigeria

Correspondence should be addressed to Nkeki Kamai; nkekikamai@yahoo.com

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Field trials were 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), in Borno State in semiarid 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 semiarid zone of Nigeria. The trial consisted of eight treatments, which included two local varieties, namely, *Kannanado White* and *Borno Brown* and six improved varieties, namely, IT90K-277-2, IT97K-568-18, IT89KD-288, IT97K-499-35, IT98K-131-2, and IT89KD-391. The treatments were laid out in a randomized complete block design replicated three times. The gross plot size was 5.0 m × 4.0 m (20 m^2) while the net plot size was 3.6 m × 3.0 m (10.8 m^2). The results showed that the improved varieties, namely, IT90K-277-2, IT97K-499-35, IT98K-131-2, and IT89KD-288, had significantly higher grain yield per hectare and matured earlier to escape drought in this agroecological zone. The local varieties also had significantly heavier grains, took more days to reach first and 50% flowering, and matured later than the improved varieties. Cowpea grain yield per hectare was highly positively correlated with harvest index, shell weight, soil moisture suction measurements, shelling percentage, and grain yield per plant and also 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. The results also indicated that fodder yield per hectare was highly positively correlated with photosynthetically active radiation thereby indicating that higher photosynthetically active radiation produced higher yield of fodder.

1. Introduction

Cowpea, *Vigna unguiculata* (L.) Walp, also popularly called "beans" in Nigeria is a legume of vital importance to the livelihood of millions of people in West and Central Africa. It provides nutritious grain and less expensive source of protein for both rural and urban consumers [1]. It is estimated that cowpea supplies 40% of the daily protein requirements to most people in Nigeria [2]. 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 [3]. Some 8 million ha of cowpea are in West and Central Africa, especially in Nigeria, Burkina Faso, Mali, and Senegal. Nigeria is the largest cowpea producer in the world and also has the highest level of consumption [4, 5]. In Nigeria cowpea is largely grown in the northern part of the country which has savanna type of vegetation and light rainfall [6] and the production trend of cowpea shows a significant improvement with an increase of some 440% in planted area and increase of some 410% in yield over the period of 1961–1995 [7]. Despite the potential for further yield increase, cowpea production faces numerous problems including pest attack, diseases, and drought. As the population continues to increase, new productive cowpea varieties are needed that will overcome these problems [8]. Due to several constraints the average cowpea grain production in West Africa was reported to be as low as 358 kg/ha [4] whereas Singh et al. [9] estimated 240 kg/ha cowpea grain yield as an average for northern Nigeria. In most parts of Borno State, rainfall is unreliable, frequently less and poorly distributed for a good cowpea crop. In semiarid zone, early season and terminal drought conditions are almost an annual event. Improving the yield of cowpea in the state requires the use of drought-tolerant and drought-avoidance varieties [10].

The objectives of the study were to evaluate the agronomic performances and to identify physiological traits associated with high grain yieldof some improved cowpea varieties in semiarid 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 rain ends early [11]. The improved varieties have acceptable seed quality for various regions and are resistant to major diseases and parasitic weeds. They also have synchronous flowering and maturity [12]. 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 dry ecologies of Borno State. Therefore, the need to try these promising cowpea varieties for their adaptability in the semiarid 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 semiarid zone of Nigeria.

2. Materials and Methods

The study was conducted at the Teaching and Research Farm, Faculty of Agriculture, University of Maiduguri, (11°47.840′N; 13°12.021′E; elevation 319 m asl) in Borno State in the semiarid zone, Nigeria, during the 2010 and 2011 rainy seasons, August to November each year. The gross plot size was 5.0 m × 4.0 m (20 m^2) and the net plot size was 3.6 m × 3.0 m (10.8 m^2). Each plot contained 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, namely, *Kannanado White* and *Borno Brown*, and 6 improved varieties, namely, 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 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 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 [13]. Linear correlation coefficient (r) among combined means of two years of cowpea variety and physiological parameters was calculated at 5%.

Table 1: Physicochemical characteristics of the soil at the experimental site.

S/No.*	Soil characteristics	Physicochemical properties
	Chemical analysis	
1	pH in H_2O	6.71
2	Organic carbon (g/kg)	4.40
3	Organic matter (g/kg)	7.59
4	Total N (g/kg)	0.05
5	Available potassium (me/100 g)	0.29
6	Available phosphorus (g/kg)	5.30
	Mechanical analysis (0–15 cm depth)	
1	Clay (%)	15.0
2	Sand (%)	70.0
3	Silt (%)	15.0
4	Field texture	Sandy loam

*S/No.: serial number.

3. Results and Discussion

The soil was sandy loam having organic matter content of 7.59 g/kg. The pH of the soil was almost neutral while available phosphorus was 5.30 g/kg (Table 1). Based on the soil properties of the site it was ideal for cowpea growth. Cowpea variety had no significant effect on seedling establishment (%) at 2 WAS (Table 2). The nonsignificance 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. Data on number of days to first and 50% flowering as influenced by cowpea variety as presented in Table 2 showed that *Kannanado White* and *Borno Brown* varieties had significantly the longest number of days to first and 50% flowering compared with the rest of the varieties. 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 IT89K-391 and IT97K-499-35 (Table 2). The study shows that the local varieties and IT89KD-288 significantly 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 [14]. It is noteworthy that these varieties had the highest grain yields compared to the other varieties. This is so because according to Campos et al. [15] and Ogbonnaya et al. [16] cowpea is known to have high stomatal control leading to a rapid closure of stomata under water stress conditions. Table 2 shows the significant effect of cowpea variety on the amount of solar radiation (SR), especially photosynthetically active radiation (PAR), intercepted by the crop where *Kannanado White*, *Borno Brown*, IT97K-499-35, and IT89KD-288 intercepted significantly the highest PAR compared with the rest of the varieties. Also *Borno Brown*, *Kannanado White*, and IT89K-391 varieties significantly took the longest number of days for the individual pods to mature from authesis

TABLE 2: Effect of cowpea variety on physiological parameters at Maiduguri 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 percentage (%)	Harvest index	Grain yield per plant (g)	Grain yield ($kg\,ha^{-1}$)	Shell weight ($kg\,ha^{-1}$)	Fodder yield ($kg\,ha^{-1}$)
IT90K-277-2	88.50	43.00^{d}	52.67^{d}	12.83^{b}	76.23^{bc}	13.64^{c}	82.50^{c}	15.50^{b}	78.04	34.35^{a}	15.92^{a}	998.2^{a}	291.68^{b}	3387.6^{cd}
Kannanado White	90.17	64.33^{a}	80.00^{a}	8.83^{c}	92.08^{a}	18.08^{a}	97.17^{a}	19.80^{a}	63.13	15.18^{e}	7.37^{c}	378.3^{c}	140.87^{d}	4016.1^{b}
IT97K-499-35	93.50	39.17^{e}	52.17^{d}	13.00^{ab}	88.53^{ab}	17.03^{ab}	80.67^{cd}	15.17^{b}	69.14	34.27^{a}	12.27^{ab}	990.8^{a}	451.37^{a}	2720.7^{c}
Borno Brown	89.83	64.17^{a}	78.33^{a}	6.50^{cd}	90.75^{a}	18.38^{a}	98.50^{a}	20.42^{a}	63.81	14.37^{e}	5.59^{c}	373.9^{c}	167.10^{cd}	4902.8^{a}
IT89KD-391	96.17	45.17^{cd}	55.83^{cd}	13.67^{ab}	68.68^{c}	17.67^{a}	78.83^{d}	16.07^{b}	72.92	27.48^{bc}	12.72^{ab}	745.6^{b}	296.85^{b}	3373.0^{bc}
IT97K-568-18	87.17	47.67^{c}	60.67^{bc}	12.50^{b}	64.32^{c}	16.53^{ab}	82.17^{c}	14.86^{b}	71.15	25.87^{c}	$9.46b^{c}$	750.4^{b}	290.03^{b}	3699.1^{b}
IT98K-131-2	89.83	44.83^{cd}	54.00^{cd}	16.00^{a}	71.27^{c}	15.14^{bc}	76.33^{e}	15.15^{b}	69.63	31.00^{ab}	12.46^{ab}	938.0^{ab}	419.17^{a}	3425.6^{bc}
IT89KD-288	91.17	56.00^{b}	65.33^{b}	5.17^{d}	94.87^{a}	15.13^{bc}	91.67^{b}	15.97^{b}	77.21	20.73^{d}	9.47^{bc}	784.8^{ab}	235.13^{bc}	5365.1^{a}
SE (±)	2.887	1.201	1.025	1.089	4.891	0.685	0.675	0.419	2.571	1.614	1.586	75.18	32.232	261.46

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).

compared with the other varieties, except varieties IT89KD-391 and IT97K-568-18 (Table 2). The significantly longest number of days to physiological maturity was recorded by the local varieties *Kannanado White* and *Borno Brown* in the combined data (Table 2). Similar results were reported by Elemo [17]. This is probably because they produced most of their flowers and pods at the end of the rain unlike the elite varieties. The results indicated that *Kannanado White* and *Borno Brown* local varieties had significantly the heaviest grains but significantly the lowest grain yields compared with the rest of the varieties (Table 2). Ellis-Jones and Amaza [18] 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 [19].

The data in Table 2 show the differences among the cowpea varieties on shelling percentage and the results indicated that cowpea variety had no significant effect on this parameter. Table 2 also presents that the varieties IT90K-277-2, IT97K-499-35, and IT98K-131-2 had significantly higher harvest index compared with the rest of the varieties. This means that these varieties with higher harvest index have higher ability to partition current assimilates to the grain and the reallocation of stored structural assimilates to the seed [20]. Table 2 further shows the variety IT90K-277-2 had significantly the highest mean yield per plant among the 8 cowpea varieties tested, but only comparable with IT97K-499-35, IT89KD-391, and IT98K-131-2. The highest mean grain yields ($kg\,ha^{-1}$) were produced by the varieties IT90K-277-2 and IT97K-499-35 compared with the other varieties, except for IT98K-131-2 and IT89-288. Despite the high yield potential of these varieties, their adoption by farmers may be of some concern. Kamara et al. [8] 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. Also earlier reports showed that seed size is a primary determinant of yield in cowpea [21, 22]; this was not the case in the present study and that of Nakawuka and Adipala [23]. This discrepancy may have been due to the different genotypes used.

The cowpea varieties IT97K-499-35 and IT98K-131-2 had significantly the highest mean shell weight (pod wall) per hectare compared to the rest of the varieties. Data in Table 2 presents the differences among the cowpea varieties on the mean fodder yield ($kg\,ha^{-1}$) where the highest fodder yield ($5361.1\,kg\,ha^{-1}$) was obtained by the semideterminate improved variety (IT89KD-288) but only at par with that of the local variety *Borno Brown* ($4902.8\,kg\,ha^{-1}$) (Table 2). This observation did not agree with the findings of Kamara et al. [19] who reported that the variety IT97K-499-35 (semierect, determinate) produced 42% more biomass than *Borno Brown* since this variety was more heavily infested with *Striga*. A similar observation was reported by Muli and Saha [24] 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 [25]. 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 ($kg\,ha^{-1}$) and 100-grain (g) weight compared to the other varieties. This is in agreement with the findings of Ntare and Williams [26] who reported that the early maturing cultivars (TVX 3236 and B111-2) produced the smallest grains and fodder yield.

4. Interrelationships among Physiomorphological Parameters

The summary of the correlation coefficients between grain yield per hectare and other physiological parameters average across the two years is presented in Table 3. The correlation among the variables showed many significant values. Cowpea grain yield per hectare was highly positively correlated with harvest index, shell weight, soil moisture suction measurements, shelling percentage, and grain yield per plant. However, the results show 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. 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 Turk et al. [27] and Ombakho and Tyagi [28] in cowpea. The results also indicated that number of days to 50% flowering, fodder yield per hectare, 100-grain weight, number of days to physiological maturity, and pod development period were significantly positively correlated with number of days to first flowering, while plant stand at harvest (%), harvest index, shell weight, soil moisture suction measurements, and grain yield per plant were significantly negatively correlated with it (Table 3).

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, shell weight, soil moisture suction measurements, shelling percentage, and grain yield per plant (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, shell weight, and soil moisture suction measurements. The positive correlation of fodder yield per hectare with the percentage transmitted photosynthetically active radiation is in tune with the findings of Gallagher and Biscoe [29] who reported that under nonstressed 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 dry environments like the semiarid

TABLE 3: Correlation coefficients between cowpea varieties, grain yield, and other parameters tested in 2010 and 2011 at Maiduguri.

	GY	DFF	SE2W	DFPF	FY	HGW	HI	DPM	PAR	PDP	SW	MSHG	SMSM	SP	YPP
GY	1.00														
DFF	−0.66**	1.00													
SE2W	−0.10	−0.24	1.00												
DFPP	−0.78**	0.83**	−0.01	1.00											
FY	−0.25	0.50**	0.04	0.49**	1.00										
HGW	−0.55**	0.76**	−0.08	0.74**	0.32*	1.00									
HI	0.74**	−0.66**	−0.21	−0.79**	−0.61**	0.50**	1.00								
DPM	−0.49**	0.84**	−0.25	0.76**	0.46**	0.81**	−0.46**	1.00							
PAR	−0.10	0.25	0.22	0.30*	0.41**	0.28	−0.40**	0.29*	1.00						
PDP	−0.38**	0.32*	0.18	0.38**	0.05	0.48**	−0.21	0.33*	0.07	1.00					
SW	0.64**	−0.63**	0.25	−0.64**	−0.29*	−0.54**	0.34*	−0.69**	0.14	−0.29*	1.00				
MSHG	0.12	0.09	−0.20	−0.05	−0.17	0.11	0.18	0.30*	0.09	0.07	−0.12	1.00			
SMSM	0.40**	−0.45**	−0.26*	−0.53**	−0.74**	−0.34*	0.68**	−0.43**	−0.58**	−0.12	0.23	0.02	1.00		
SP	0.51**	−0.09	−0.42**	−0.40**	−0.06	−0.15	0.62**	0.08	−0.36*	−0.08	−0.16	0.20	0.33*	1.00	
YPP	0.63**	−0.44**	−0.01	−0.61**	−0.24	−0.38**	0.70**	−0.38**	−0.16	−0.19	0.28	−0.01	0.33*	0.52**	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, and *significant at 5% probability level.

zone of Nigeria, where sunshine is abundant. 100-grain weights had a significant positive correlation with harvest index, number of days to physiological maturity, and pod development period and a significant negative correlation with shell weight, soil moisture suction measurement, and grain yield per plant (Table 3). Harvest index had a significant positive correlation with shell weight, soil moisture suction measurements, shelling percentage, and grain yield per plant, and a significant negative correlation with number of days to physiological maturity and PAR. Number of days to physiological maturity had a significant positive correlation with PAR and pod development period and a significant negative correlation with shell weight, soil moisture suction measurements, and grain yield per plant. The pod development period had a significant negative correlation with shell weight (Table 3).

5. Conclusions

In the semiarid zone of Nigeria the highest mean grain yields (kg ha^{-1}) were produced by the varieties IT90K-277-2, IT97K-499-35 compared with the other varieties, except for IT98K-131-2 and IT89-288. Despite the high yield potential of these varieties, their adoption by farmers may be of some concern. Kamara et al. [8] 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. Correlation studies indicate that cowpea grain yield per hectare was highly positively correlated with harvest index, shell weight, soil moisture suction measurements, shelling percentage, and grain yield per plant and negatively correlated with cowpea grain yield per hectare, number of days to first and 50% flowering, 100-grain weight, number of days to physiological maturity, and pod development period. 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.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

[1] I. Inaizumi, B. B. Singh, P. C. Sanginga, V. M. Manyong, A. A. Adesina, and S. Tarawali, *Adoption and Impact of Dry-Season Dual-Purpose Cowpea in the Semiarid Zone of Nigeria*, Impact (International Institute of Tropical Agriculture), IITA, Ibadan, Nigeria, 1999.

[2] N. C. Muleba, J. B. S. Dabire, I. Drabo, and J. T. Ouedraogo, "Technologies for cowpea production based on genetic and environmental manipulations in the semi-arid tropics," in *Technologies Options for Sustainable Agriculture in Sub-Saharan Africa*, T. Bezuneh, A. M. Emechebe, J. Sedgo, and M. Oeudrago, Eds., pp. 192–206, Semi-Arid Food Grain Research and Development Agency (SAFGRAD) of the Scientific, Technical and Research Commission of OAU, Ouagadougou, Burkina Faso, 1997.

[3] S. A. Tarawali, B. B. Singh, M. Peters, and S. F. Blade, "Cowpea haulms as fodder," in *Advances in Cowpea Research*, B. B. Singh, D. R. M. Raj, K. E. Dashiel, and L. E. N. Jackai, Eds., pp. 313–325, Copublication of International Institute of Tropical Agriculture (IITA) and Japan International Research Centre for Agricultural Sciences (JIRCAS), Ibadan, Nigeria, 1997.

[4] FAO, 2000, http://www.fao.org/statistics/en/.

[5] B. B. Singh, "Potential and constraints of improved cowpea varieties in increasing the productivity of cowpea-cereal systems in the dry Savannas of West Africa," in *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*, P. Majiwa, M. Odera, N. Muchiri, G. Omanya, and P. Werehire, Eds., pp. 14–26, African Agricultural Technology Foundation, Nairobi, Kenya, 2007.

[6] Anonymous, "Cowpea: Abuja Securities and Commodity Exchange PLC," 2008, http://www.abujacomex.com/.

[7] R. Ortiz, "Cowpeas from Nigeria: a silent food revolution," *Outlook on Agriculture*, vol. 27, no. 2, pp. 125–128, 1998.

[8] A. Y. Kamara, J. Ellis-Jones, F. Ekeleme et al., "A participatory evaluation of improved cowpea cultivars in the Guinea and sudan savanna zones of north east Nigeria," *Archives of Agronomy and Soil Science*, vol. 56, no. 3, pp. 355–370, 2010.

[9] B. B. Singh, O. L. Chamblis, and B. Sharma, "Recent advances in cowpea breeding," in *Advances in Cowpea Research*, B. B. Singh, D. R. M. Raj, K. E. Dashiel, and L. E. N. Jackai, Eds., pp. 30–49, Copublication of International Institute of Tropical Agriculture (IITA) and Japan International Research Centre for Agricultural Sciences (JIRCAS), Ibadan, Nigeria, 1997.

[10] J. E. Onyibe, A. Y. Kamara, and L. O. Omoigui, *Guide to Cowpea Production in Borno State, Nigeria*, Promoting Sustainable Agriculture in Borno State (PROSAB), Ibadan, Nigeria, 2006.

[11] A. K. Raheja, "Problems and prospects of cowpea production in the Nigerian Savannas," in *Proceedings of the 1st World Cowpea Research Conference*, Tropical Grain Legume Bulletin, no. 32, pp. 78–87, IITA, November 1986.

[12] B. B. Singh, "Breeding suitable cowpea varieties for West and Central African Savanna," in *Progress in Food Grains Research and Production in Semi-Africa*, J. M. Menyonga, J. B. Bezuneh, J. Y. Yayock, and I. Soumana, Eds., pp. 77–85, OAU/STRC-SAFGRAD, Ouagadougou, Burkina Faso, 1994.

[13] D. B. Duncan, "Multiple range and multiple *F* tests," *Biometrics*, vol. 11, no. 1, pp. 1–42, 1955.

[14] Soil Moisture Equipment Corp., "Quick draw soil moisture probe," Operating Instructions Model 2900F1, Soil Moisture Equipment Corp., Santa Barbara, Calif, USA, 1989.

[15] P. S. Campos, J. C. Ramalho, J. A. Lauriano, M. J. Silva, and M. D. C. Matos, "Effects of drought on photosynthetic performance and water relations of four *Vigna genotypes*," *Photosynthetica*, vol. 36, no. 1-2, pp. 79–87, 1999.

[16] C. I. Ogbonnaya, B. Sarr, C. Brou, O. Diouf, N. N. Diop, and H. Roy-Macauley, "Selection of cowpea genotypes in hydroponics, pots, and field for drought tolerance," *Crop Science*, vol. 43, no. 3, pp. 1114–1120, 2003.

[17] K. A. Elemo, "Farmer participating in technology testing: a case of agronomic evaluation of cowpea genotypes in the Nigerian Northern Guinea Savanna," *Agricultural Systems in Africa*, vol. 3, no. 1, pp. 39–49, 1993.

[18] J. Ellis-Jones and P. S. Amaza, "PROSAB: promoting sustainable agriculture in Borno State: an adoption and impact assessment of PROSAB's activities over three cropping seasons (2004–2006)," PROSAB Internal Report, 2007.

[19] A. Y. Kamara, D. Chikoye, F. Ekeleme, L. O. Omoigui, and I. Y. Dugje, "Field performance of improved cowpea varieties under conditions of natural infestation by the parasitic weed *Striga gesnerioides*," *International Journal of Pest Management*, vol. 54, no. 3, pp. 189–195, 2008.

[20] N. C. Turner, G. C. Wright, and K. H. M. Siddique, "Adaptation of grain legumes (pulses) to water-limited environments," *Advances in Agronomy*, vol. 71, pp. 193–231, 2001.

[21] B. C. Imrie and R. A. Bray, "Estimates of combining ability and variance components of grain yield and associated characters of cowpea," in *Proceeding of the Australian Plant Breeding Conference*, pp. 202–204, February 1983.

[22] I. O. Obesesan, "Association among grain yield components in cowpea (*Vigna unguiculata* L. Walp.)," *Genetical Agriculture*, vol. 39, no. 4, pp. 377–386, 1985.

[23] C. K. Nakawuka and E. Adipala, "A path coefficient analysis of some yield components interactions in cowpea," *African Crop Science Journal*, vol. 7, no. 4, pp. 327–331, 1999.

[24] M. B. Muli and H. M. Saha, *Participatory Evaluation of Cowpea Cultivars for Adaptation and Yield Performance in Coastal Kenya*, Kenya Agricultural Research Institute, Regional Research Centre, Mtwapa, Kenya, 2008.

[25] N. A. Gworgwor and H. C. Weber, "Studies on biology and control of *Striga*: II. Varietal response of cowpea (*Vigna unguiculata* (L.) Walp.) to *Striga gesnerioides*," *Journal of Agronomy and Crop Science*, vol. 166, no. 2, pp. 136–140, 1991.

[26] B. R. Ntare and J. H. Williams, "Response of cowpea cultivars to planting pattern and date of sowing in intercrops with pearl millet in Niger," *Experimental Agriculture*, vol. 28, no. 1, pp. 41–48, 1992.

[27] K. J. Turk, A. E. Hall, and C. W. Asbell, "Drought adaptation of cowpea. I. Influence of drought on seed yield," *Agronomy Journal*, vol. 72, no. 3, pp. 413–420, 1980.

[28] G. A. Ombakho and A. P. Tyagi, "Correlation and path coefficient analysis for yield and its components in cowpea (*Vigna unguiculata* (L.) Walp.)," *East African Agriculture and Forestry Journal*, vol. 53, no. 1, pp. 23–27, 1987.

[29] J. L. Gallagher and P. V. Biscoe, "Radiation absorption, growth and yield of cereals," *The Journal of Agricultural Science*, vol. 91, no. 1, pp. 47–60, 1978.