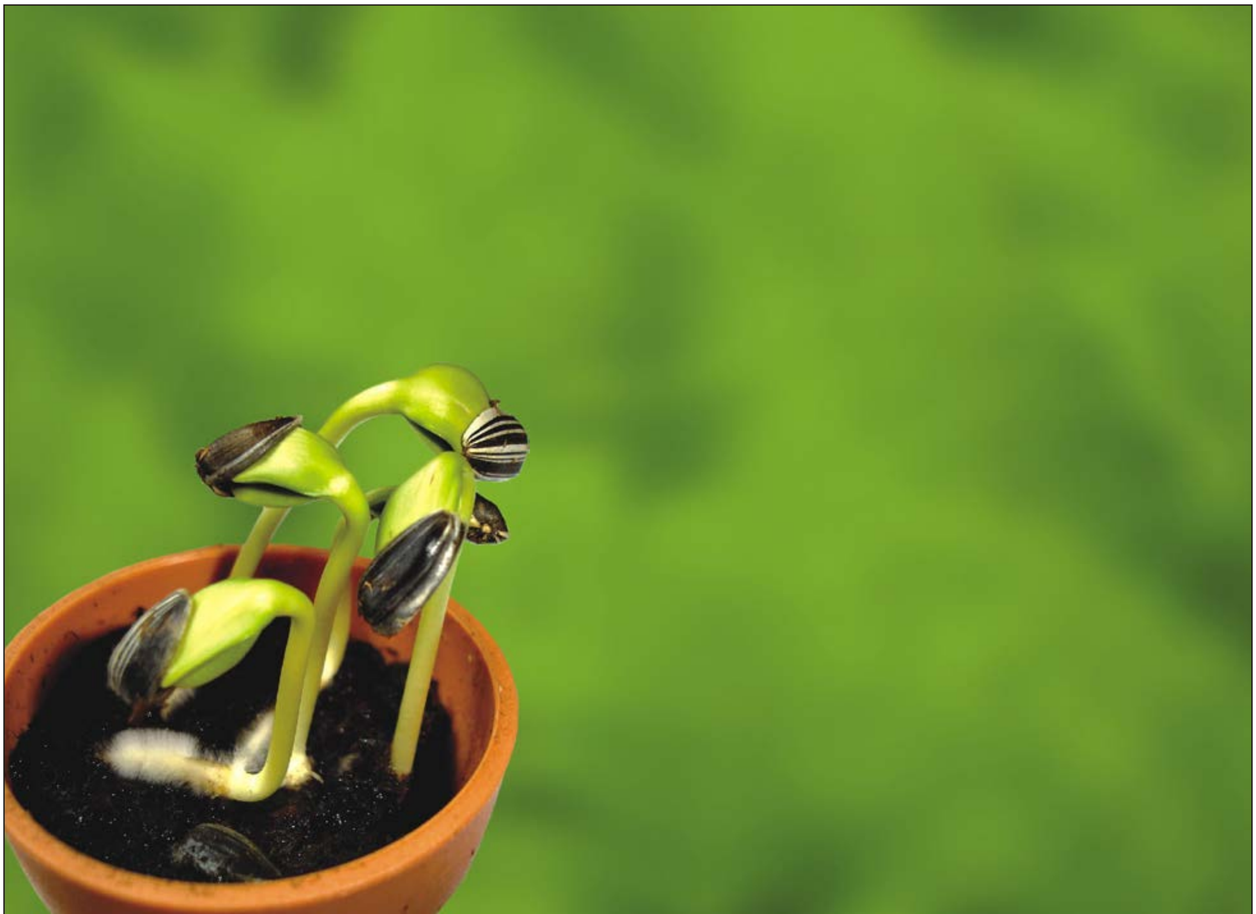

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Field Evaluation of Cowpea Genotypes for Drought Tolerance and *Striga* Resistance in the Dry Savanna of the North-West Nigeria

[1]M.F. Ishiyaku and [2]H. Aliyu
[1]Department of Plant Sciences, Ahmadu Bello University, Zaria, Nigeria
[2]Department of Biological Sciences, Ahmadu Bello University, Zaria, Nigeria

Corresponding Author: H. Aliyu, Department of Biological Sciences, Ahmadu Bello University, Zaria, Nigeria

ABSTRACT
Drought and Striga are some of the key constraints to cowpea production. These are further aggravated by the ever changing global climate and the concomitant effects such as erratic rainfall pattern. This research was conducted to identify lines that are tolerant to drought and resistant to *Striga* in one of the major cowpea belt in West Africa. Twenty two genotypes of cowpea obtained from the Cowpea Breeding Programme of the Institute for Agricultural Research (IAR), Ahmadu Bello University Zaria, Nigeria were evaluated in 2 different dates; beginning of the rainy season representing optimum moisture (7th August) and the end of the rainy season representing drought conditions (7th September) for two years (2008 and 2009). IAR-07-1050 was found to be resistant to *Striga* although susceptible to drought (DRI = -0.32). Others genotypes were infested by *Striga*. Two genotypes, IT98K-412-13 and IT93K-452-1 with DRI = 1.79 and 1.88, respectively were drought tolerant genotypes. IT99K-529-1, Biu Local, Kanannado, IT99K-216-24-2, Sa Babba Sata, IT96D-610 and IT97K-819-118 showed some level of tolerance as indicated by several selection indices including DRI. These indices were very suitable for the identification of drought tolerance in cowpea. DRI and DSI are particularly useful in the classification of genotypes in terms of drought tolerance irrespective of their yield potential. This is highly desirable for the identification of gene sources for further improvement of cowpea for drought tolerance or in combination with other traits.

Key words: Cowpea, drought tolerance, genotypes, selection indices, *Striga* resistance

INTRODUCTION
Cowpea is the primary source of protein to vast majority of the populations in sub-Saharan Africa. It is an important component of the cropping system in most of the drought prone areas where it serves as a vital source of income to farmers and seed traders (Fatokun *et al*., 2000). FAO data of 2010 showed that it is grown on about 10.5 million ha, with an annual grain production of approximately 5.5 million tonnes worldwide an estimated 5300 hg ha^{-1} (http://faostat.fao.org). The grain yield of cowpea is usually low due to a complex of biotic and abiotic stresses (Van Ek *et al*., 1997; Ajeigbe *et al*., 2008). These result in extremely low productivity with a mean yield ranging between 100 to 400 kg ha^{-1} in Africa as compared to above 800 kg ha^{-1} in other areas of the world (Singh, 2002). In sub-Saharan Africa, cowpea is mainly grown under rain fed system with a minimum annual rainfall of about 600 mm (Valenzuela and Smith, 2002). Thus drought is a key abiotic constraint of cowpea yield in this production area (Singh *et al*., 1997). The drought

situation is compounded by the erratic pattern of rainfall in the cowpea belt. Cowpea is mainly exposed to drought at the onset and the end of the rainy season (Singh and Matsui, 2002). Therefore, it is necessary to identify drought tolerant genotypes that can withstand this condition. Farmers in Nigeria, especially in the moist savanna grow cowpea towards the end of raining season in form of relay with cereals like maize and sorghum (Singh and Tarawali, 1997). This system therefore exposes the cowpea even more to drought.

Drought is a condition caused by unavailability of rainfall (Acquaah, 2007). It is said to occur whenever the distribution, amount or duration of precipitation deviates from the normal. In some instances, the amount may be normal but drought may occur when long dry spells occur in the season at critical stages of crop growth and development. According to Acquaah 2007, "The effects of drought depend on the stage of plant growth and development". The most sensitive stages as per yield are pod setting and pod filling (Turk *et al*., 1980).

Crops grown under rainfed agriculture in the dry areas of tropical Africa are subject to dry hot conditions which are synonymous to drought (Hall, 2004). There have been several reports of drought occurrence in the drier part of these areas (Hall, 2004). The most recent history of occurrence of drought in Nigeria however was that of the year 1972 to 1974. The consequences of drought could be dare and painful. According to Derrick (1977), the great drought of 1973 caused devastating economic loss for millions of people especially those whose livelihood depended on crop animal husbandry. These negative effects of drought can be avoided through planting of drought resistant crop varieties, short season crops as well as desert ephemerals (Ayoade, 1977).

Singh and Matsui (2002) listed the methods used to estimate drought tolerances which they noted are expensive and time consuming. These involved measurement of water potential, relative turgidity, diffusion pressure deficit, chlorophyll stability index and carbon isotope discrimination. They reported the identification of several drought tolerant lines using simple, relatively cheap and reliable screening methods. Some of these have been incorporated into improved lines. However, there is the need to identify lines based on their performance in both stressed and non stressed environment so as to enhance productivity across the gradient of moisture stress. There is also need identify simple methods for the classification of these line based on their performance in these environments. Drought also tend to compound other form of stresses in cowpea, for instance, Striga (causes considerable yield reduction in cowpea) infection was reported to be more devastating in areas with sandy soils, low fertility and low rainfall (Sing, 2005).

Therefore, this study was conducted to assess the performance of genotypes under the stresses of drought and *Striga* with a view to identify lines that are tolerant as well as to identify selection criteria for easy identification of drought tolerance under moisture stressed and optimum field conditions.

MATERIALS AND METHODS

Plant material, location and experimental design: Twenty two Cowpea genotypes differing in seed and plant characteristics were used in the studies (Table 1). The genotypes were obtained from the cowpea breeding programme of the Institute for Agricultural Research (IAR), Ahmadu Bello University Zaria, Nigeria and from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. These genotypes were evaluated under 2 different dates of planting, viz., 7th August (optimum moisture condition) and 7th September (moisture stressed condition), for two years (2008 and 2009) at the IAR station, Minjibir (12°10' 52"N 08°39' 22"E), Kano State, Nigeria. The trials were laid in a randomized complete block design with four replications. Each plot

Table 1: Origin and description of the genotypes used

Genotype	Origin	Growth habit	Seed colour	Seed texture
Biu local	Local	Spreading	White	Coarse
IAR-07-1050	IAR	Erect	Brown	Coarse
IT00K-1263	IITA	Semi erect	Brown	Smooth
IT89KD-288	IITA	Semi spreading	White	Coarse
IT93K-452-1	IITA	Erect	White	Coarse
IT96D-610	IITA	Erect	Brown	Coarse
IT97K-1069-6	IITA	Semi erect	Brown	Smooth
IT97K-390-2	IITA	Spreading	Brown	Smooth
IT97K-499-35	IITA	Erect		Coarse
IT97K-819-118	IITA	Semi erect	Brown	Coarse
IT98K-128-3	IITA	Semi erect		Coarse
IT98K-166-4	IITA	Spreading	Brown	Smooth
IT98K-311-8-2	IITA	Semi erect	White	Smooth
IT98K-412-13	IITA	Spreading	White	Coarse
IT98K-491-4	IITA	Erect	White	Coarse
IT98K-628	IITA	Erect	White	Coarse
IT99K-1122	IITA	Semi erect	White	Smooth
IT99K-216-24-2	IITA	Spreading	White	Coarse
IT99K-529-1	IITA	Semi erect	White	Coarse
IT99K-7-21-2-2	IITA	Semi erect	White	Coarse
Kanannado	Local	Spreading	White	Coarse
Sa Babba Sata	Local	Spreading	White	Coarse

consisted of four ridges 4 m long spaced 75 cm between rows and 20 cm within rows with two stands per hill. Recommended management practices for cowpea were observed. Data were taken on days taken for 50% of plants in plots to flower, days to pod maturity as days taken for 90% of the plant in the net plot to reach 90% physiological maturity, seed per plant and grain yield, i.e., the total grain harvested from the net plot which is the two middle rows. *Striga* score was recorded as the number of *Striga* emerged (two middle rows). The record for rainfall for the period between planting and maturity for the entire period of this study was obtained from the Metrological unit, Agricultural Research Station of the IAR, Minjibir Kano State, Nigeria.

Selection indices: Arithmetic Means (AM) and Geometric Means (GM) of seed yield in stress and non stress environments, response of seed yield to drought across stress and non stress environments (RD) and percent reduction in seed yield across stress and non stress environments (PR) were calculated using the method of White and Singh (1991). Drought response index was calculated using the regression model of Bidinger *et al*. (1987a, b) and Drought Susceptibility Index (DSI) was calculated as described by Fischer and Maurer (1978).

Pearson correlation was employed to determine relationship of genotype yields of date 1 and 2 across 2008 and 2009. The analysis was also run to determine the level of association between the genotypes yields and the different selection indices across the two years.

The relationship between yield across dates of planting and rainfall over the two years was determined. For the purpose of the analysis, the corresponding rainfall for any given genotype in a particular planting date was estimated as the total rainfall received from planting to maturity. For example, if a given genotype matured in 60 days from planting, total rainfall from planting to the 60th day is recorded as the rainfall associated with the yield of that genotype.

Data analysis: The data was subjected to statistical analyses to compare performance of the genotypes in the two dates over two years using the general linear model procedure of SAS 9.0 (SAS, 2002). Least Significant Difference (LSD) was computed ($p \leq 0.05$) to compare performance among genotypes.

RESULTS

Result of the field evaluation of the 22 genotypes is presented in Table 2. There was a highly significant difference ($p \leq 0.01$) between dates for days to 50% flowering, maturity, seed per plant, seed yield, *Striga* score and total rainfall. However, there was no significant difference ($p>0.05$) between years for days to 50% flowering, maturity, seed per plant, yield *Striga* score. Rainfall however, differed highly significantly ($p \leq 0.01$) between the two years. There was more rainfall in 2009 with a mean rainfall of 206 mm as compared to 169 mm in 2008. Similarly, the genotypes differed highly significantly ($p \leq 0.01$) in terms of days to 50% flowering, maturity, seed per plant, yield and *Striga* score. The amount of rainfall received by each genotype did not differ. The date by genotype interaction was highly significant ($p \leq 0.01$) for days to 50% flowering, maturity, seed per plant, yield and *Striga* score. Date by genotype interaction was not significant for rainfall.

Means performance of the genotypes for days to 50% flowering, maturity, seed per plant, yield, *Striga* score and rainfall for the drought stressed and optimum conditions are presented in Table 3. The genotypes generally flower earlier under the optimum condition. The mean for days to 50% flowering was 41.05 days and 43.82 days for optimum and stressed conditions, respectively. IT98K-311-8-2 had the earliest flowering with 34.67 days while Biu local had the latest with 47.67 days for the optimum condition. However, the earliest flowering days of 40.17 days was recorded for IT97K-499-35 for the stressed condition. While 48.17 days was the longest recorded in IT97K-1069-6 and IT98K-412-13.

In terms of days taken to maturity, the genotypes mature earlier in the stressed condition with a mean maturity period of 69.48 days. The mean maturity period for the optimum condition was 74.7 days. Biu local had the latest maturity days of 82.67 days for optimum condition whereas the earliest was 70.67 days in IT89KD-288. The earliest period for the stressed condition was 65 days in IT99K-1122 and the latest was 72.67 days in IT98K-128-3 (Table 3).

There were also greater numbers of seeds per plant in the optimum condition. The mean number of seeds per plant was 18.45 for the optimum condition. IT99K-216-24-2 recorded the highest number 45.47 seeds per plant while the lowest number of 7 seeds per plant was recorded in Kanannado. The mean for the stressed condition was 3.5 seeds per plant with IT98K-412-13 recording the highest number of 8.75 seeds per plant and the lowest were 1.07 seeds per plant in IT00K-1263 (Table 3).

Table 2: Mean squares for combine analysis of variance of 22 genotypes of cowpea grown in two dates (early and late sowing) for two years at IAR station Minjibir, Kano State Nigeria

SOV	df	Days to 50% flowering	*Striga* score	Seed/plant	Maturity (days)	Yield (kg ha^{-1})	Rainfall (mm)
Block	2	16.41	115.20	178.90	247.70**	322247*	26.74
Date	1	507.40**	44.18	14736.00**	1792.00**	36329359**	2180600**
Year	1	0.00	0.00	0.00	0.00	0	89818**
Variety	21	52.65**	205.20**	367.90**	26.78*	653939**	1.367
Date×variety	21	47.75**	69.12	197.80**	32.14**	295633**	1.367
Error	217	10.34	41.25	45.79	12.83	82641	81.03
Total	263						

**Significant $p \leq 0.01$, *Significant $p \leq 0.05$

Table 3: Mean performance of some putative drought tolerant cowpea varieties evaluated in field under optimum moisture (date 1) and moisture stressed condition (date 2) over two years in the Sudan Savanna of the North-West Nigeria

	50% flowering (days)		*Striga* score		Seed/plant		Maturity (days)		Yield (kg ha^{-1})		Rainfall (mm)	
Variety	Optimum	Stressed	Optimum	Stressed	Optimum	Stressed	Optimum	Stressed	Optimum	Stressed	Optimum	Stressed
Biu Local	47.7	42.5	14.30	4.50	8.77	2.48	82.7	69.7	396	179.0	280	96.5
IAR-07-1050	40.7	40.8	0.00	0.00	14.30	2.10	73.0	69.3	836	151.0	278	96.5
IT00K-1263	41.3	44.5	0.33	5.67	11.70	1.07	75.3	69.7	536	78.2	279	96.5
IT89KD-288	36.3	44.8	5.33	10.50	10.10	1.58	70.7	68.8	579	87.6	277	96.5
IT93K-452-1	39.0	40.3	7.33	5.00	21.30	5.88	73.0	67.7	992	376.0	278	96.5
IT96D-610	40.7	41.0	11.70	3.00	11.10	4.33	72.3	67.8	668	193.0	277	96.5
IT97K-1069-6	43.7	48.2	13.30	14.30	12.30	1.08	77.3	70.7	647	71.5	279	96.5
IT97K-390-2	41.3	46.2	13.30	3.50	13.90	1.30	74.0	69.8	671	90.6	279	96.5
IT97K-499-35	39.0	40.2	0.00	1.00	22.20	3.23	74.0	67.3	1264	193.0	278	96.5
IT97K-819-118	41.0	45.2	4.00	7.83	20.30	4.10	74.0	70.2	1061	265.0	278	96.5
IT98K-128-3	38.7	47.5	12.00	14.00	17.40	1.17	74.3	72.7	998	76.8	278	96.5
IT98K-166-4	41.0	41.0	9.33	4.83	18.10	1.80	76.0	66.5	818	115.0	280	96.5
IT98K-311-8-2	34.7	45.5	9.33	5.33	15.80	7.77	73.3	70.7	869	188.0	278	96.5
IT98K-412-13	46.3	48.2	1.33	1.17	38.90	8.78	75.0	71.5	1793	527.0	278	96.5
IT98K-491-4	39.7	41.2	10.30	8.33	14.80	2.23	73.3	68.5	891	165.0	278	96.5
IT98K-628	38.3	42.3	0.67	1.50	22.20	1.83	73.3	69.7	1387	118.0	278.	96.5
IT99K-1122	46.7	41.3	0.00	2.00	17.50	2.10	77.3	65.0	1030	143.0	279	96.5
IT99K-216-24-2	43.7	42.8	2.67	4.67	45.50	6.15	76.7	70.0	1578	385.0	279	96.5
IT99K-529-1	41.0	44.2	0.33	7.67	20.50	5.42	75.3	69.2	1075	315.0	278	96.5
IT99K-7-21-2-2	40.3	44.3	0.67	2.67	30.40	6.82	76.0	69.5	1532	279.0	279	96.5
Kanannado	39.3	46.3	9.00	4.50	7.00	2.95	71.3	72.3	457	181.0	277	96.5
Sa Babba Sata	42.7	45.7	14.30	9.67	12.20	3.08	75.0	72.2	602	184.0	278	96.5
Means	41.5	43.8	6.35	5.53	18.50	3.51	74.7	69.5	940	198.0	278	96.5
LSD	2.59	2.59	5.17	5.17	5.45	5.45	2.88	2.88	231	231.0	7.24	7.24

Similarly, the genotype yield was by far greater in the optimum condition. The mean grain yield was 940.04 kg ha^{-1} for the optimum condition as compared to 198.12 kg ha^{-1} for the stressed condition. IT98K-412-13 had the greatest yield for both optimum and stressed conditions with yields of 1792.47 and 526.83 kg ha^{-1} for optimum and stressed conditions respectively. However, the least yield for the optimum condition was 395.5 kg ha^{-1} recorded in Biu local and the least yield for the stressed condition was 71.53 kg ha^{-1} recorded in IT97K-1069-6 (Table 3).

On the other hand, the *Striga* infestation was greater in the optimum moisture than in the stressed condition. The mean *Striga* score was 6.35 and 5.53 for the optimum and stressed conditions respectively. The genotypes, IAR-07-1050, IT97K-499-35 and IT99K-1122 had no *Striga* emergence under the optimum moisture while Sa Babba Sata had the highest score of 14.33 for the optimum condition. In the moisture stressed condition, IAR-07-1050, IT97K-499-35 and IT99K-1122 recorded 0, 1 and 2 *Striga* scores respectively and IT97K-1069-6 had the highest score of 14.33 (Table 3).

Generally, the genotypes received more rainfall under the optimum condition across the two years irrespective of the mean annual rainfall. The mean rainfall received by the genotypes was 278.22 mm and 96.45 mm for the optimum and the stressed condition respectively. The relationship between yield across dates of planting and rainfall over the two years was linear and positive (Fig. 1). The magnitude of the relationship shows a high coefficient of determination ($R^2 = 0.95$).

Mean genotypes grain yield and the corresponding drought selection indices are presented in Table 4. The mean AM across dates for yield was 569.1 kg ha^{-1}. IT98K-412-13 had the highest AM of 1159.69 kg ha^{-1} but the lowest was 287.01 kg ha^{-1} in Biu local. Similarly, the highest GM of 971 kg ha^{-1} was found in IT98K-412-13 but the lowest was 215.1 kg ha^{-1} in IT97K-1069-6. The mean RD was 7.69 with highest and lowest of 2.25 and 13.15 for Biu local and IT98K-628, respectively. Similarly Biu local had the lowest PR of 54.86 whereas the highest was in IT98K-128-3 and the across dates was 78.18. In terms of DRI, only 2 genotypes exceeded the threshold of 1.3, i.e. IT98K-412-13 and IT93K-452-1 with 1.79 and 1.88, respectively. The DRI ranged between -1.88 and 1.88. The mean DSI was .099 and Biu local had the least index of 0.7 whereas the highest was 1.17 in IT98K-412-13.

The correlation coefficients between genotype yields of date 1 and 2 across 2008 and 2009 and between yields and the different selection indices are presented in Table 5. Mean yield of date 1 was highly correlated ($p \leq 0.01$) with yield of date 2 and also with AM, GM and RD but not significant with PR, DRI and DSI. Yield of date 1 has the highest correlation with AM (r = 0.9824**). Yield

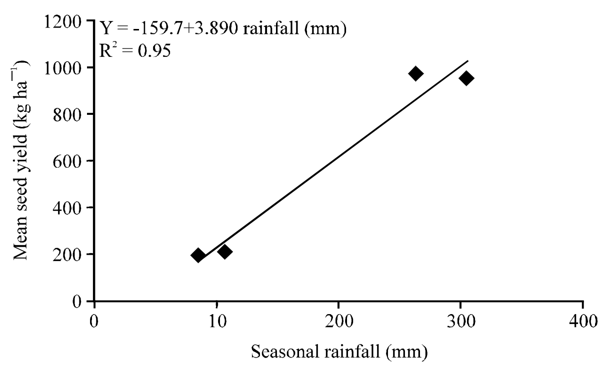

Fig. 1: Relationship between seed yield over genotypes and rainfall

Table 4: Mean performance in grain yield kg ha^{-1} and its corresponding drought selection indices for some cowpea genotypes evaluated in field under optimum moisture (date 1) and moisture stressed condition (date 2) over two years in the Sudan Savanna of the North-West Nigeria

	Yield (kg ha^{-1})							
Genotype	Optimum	Stressed	AM	GM	RD	PR	DRI	DSI
Biu local	396	179.0	287	2664	2.25	54.9	0.916	0.695
IAR-07-1050	837	151.0	493	355	7.10	82.0	-0.323	1.040
IT00K-1263	536	78.2	307	205	4.74	85.4	-0.487	1.080
IT89KD-288	579	87.6	333	225	5.10	84.9	-0.452	1.080
IT93K-452-1	992	376.0	684	611	6.38	62.1	1.880	0.786
IT96D-610	668	193.0	430	359	4.93	71.2	0.511	0.902
IT97K-1069-6	646	71.5	359	215	5.96	88.9	-0.815	1.130
IT97K-390-2	674	90.6	382	247	6.05	86.6	-0.649	1.100
IT97K-499-35	1264	193.0	729	494	11.10	84.8	-0.778	1.070
IT97K-819-118	1063	265.0	664	531	8.28	75.1	0.461	0.952
IT98K-128-3	998	76.8	537	277	9.55	92.3	-1.500	1.170
IT98K-166-4	818	115.0	466	306	7.30	86.0	-0.694	1.090
IT98K-311-8-2	869	188.0	528	404	7.06	78.4	0.049	0.993
IT98K-412-13	1793	527.0	1160	972	13.10	70.6	1.790	0.895
IT98K-491-4	891	165.0	528	383	7.53	81.5	-0.283	1.030
IT98K-628	1387	118.0	753	405	13.20	91.5	-1.880	1.160
IT99K-1122	1030	143.0	586	383	9.20	86.2	-0.867	1.090
IT99K-216-24-2	1576	385.0	980	778	12.40	75.6	0.675	0.958
IT99K-529-1	1075	315.0	695	582	7.88	70.7	0.999	0.896
IT99K-7-21-2-2	1532	279.0	905	654	12.90	81.8	-0.401	1.040
Kanannado	457	181.0	319	288	2.86	60.3	0.852	0.765
Sa Babba Sata	602	184.0	393	333	4.33	69.5	0.550	0.880
Mean	940	198.0	569	421	7.69	78.2	-0.020	0.991

AM: Arithmetic means, GM: Geometric, RD: Response to drought, PR: Percent reduction in seed yield, DRI: Drought response index and DSI: Drought susceptibility index

Table 5: Correlation between grain yield and drought selection indices for 22 cowpea genotypes evaluated in field under optimum moisture (date 1) and moisture stressed condition (date 2) over two years in the Sudan Savanna of the North-West Nigeria

	y1	y2	AM	GM	RD	PR	DRI
y2	0.67**						
AM	0.98**	0.79**					
GM	0.87**	0.95**	0.95**				
RD	0.96**	0.44*	0.89**	0.69**			
PR	0.19	-0.54**	0.02	-0.27	0.43*		
DRI	0.05	0.78**	0.24	0.54**	-0.23	-0.89**	
DSI	0.19	-0.54**	0.02	-0.27	0.43*	1**	-0.89**

AM: Arithmetic means, GM: Geometric, RD: Response to drought, PR: Percent reduction in seed yield, DRI: Drought response index, DSI: Drought susceptibility index, y1: Grain yield under optimum, y2: Grain yield under stressed condition, **Significant at $p \leq 0.01$, *Significant at $p \leq 0.05$

of date 2 was however highly correlated ($p \leq 0.01$) with yield of date 1 and with all the selection indices. AM was also highly correlated ($p \leq 0.01$) with RD and DRI but not with PR and DSI. Significant correlation ($p \leq 0.05$) was obtained between RD, PR and DSI but not DSI. PR was also highly correlated ($p \leq 0.01$) with DRI and DSI. DRI and DSI were also highly correlated.

DISCUSSION

The stressed condition received just about one third of the total rainfall of the optimum planting date. This signifies the extent of drought exposure by the experimental materials. This explains why cowpea farmers do not plant cowpea in these areas in September as such date is considered too off season and also suggests the suitability of the date used in this experiment to illicit response to drought condition.

The highly significant difference of dates for the parameters measured showed that genotype performed better when sown early in August when rainfall is at its peak than in September and this is relatively consistent over the years despite the difference in rainfall pattern in the two years as indicated by the significant differences between the two years in terms of rainfall.

Similarly, the significant difference of genotypes indicates a wide range of drought responses by the genotypes.

The relationship between seed yield across date over the years and rainfall indicated the dependence of seed yield to great extent on the amount of rainfall. The seed yield increases by 3.9 kg ha^{-1} with every mm increase in rainfall. This further stresses the advantage of the earlier sowing date. This result was in agreement with findings of Abebe *et al.* (1998) on relationship between seasonal rainfall and dry bean yield in the Rift Valley.

The significant date by genotype interaction was an indication of lack of consistency in the performance of the genotypes in the two dates since they generally performed better when sown early in August. The mean seed yield for date 1 was 940 kg ha^{-1} and the varieties differ for that date. The highest yield for date 1 was 1792.47 kg ha^{-1} in IT98K-412-13 and the lowest was 395.5 kg ha^{-1} in Biu local. Similarly, the highest seed yield in the date 2 was 526.83 kg ha^{-1} in IT98K-412-13. However, the lowest was 76.82 kg ha^{-1} in IT98K-128-3 not Biu local, whereas the mean yield for this date was 198.12 kg ha^{-1}.

Based on Am, IT98K-412-13, IT99K-216-24-2, IT99K-7-21-2-2 and IT98K-628 were the best genotypes while Biu Local and IT00K-1263 and Kanannado were the least. In terms of GM, IT98K-412-13, IT99K-216-24-2, IT99K-7-21-2-2, IT93K-452-1 were the highest and IT00K-1263, IT97K-1069-6 and IT89KD-288, lowest. Whereas AM is influenced by seed yield performance in date 1, GM is influenced by the yield performance in date 2. This is consistent with the result obtained by Abebe *et al.* (1998) that these indices appear to be suitable for selection of lines that perform well across stress and nonstress environments. However, RD has much less correlation to yield of date 2 ($r = 0.44$, $p<0.05$) when compared to AM and GM and so it's less suitable for use in drought prone environment.

PR and DSI are similarly as indicated by the perfect correlation ($r = 1$) between them. IT98K-128-3, IT98K-628, IT97K-1069-6 and IT97K-390-2 were ranked as the most susceptible and Biu Local, Kanannado, IT93K-452-1, Sa Babba Sata and IT98K-412-13 as drought tolerant by PR and DSI. This is based on amount of decline in yield between date 1 and date 2 and the model presupposes that the more decline in yield between the dates the less tolerant the genotypes. This is because in estimating these indices, emphases were on the change in genotype performance rather than overall performance. Thus, Abebe *et al.* (1998) suggested that, PR and S should only be used in combination with yield data to identify productive cultivars in soil-moisture-stress environments., DRI showed highly significant positive correlation ($r = 0.78$, $p<0.01$) with date 2 yield, which indicates its suitability for assessing yield in stressed environments. This also indicates drought tolerance. This conforms to Acevedo *et al.* (1999) who reported that high correlation between DRI and yield under salinity stress indicates that salinity resistance (the yield not accounted for by yield potential and escape) has a strong influence on the yield under stress. However, Richards (1978) suggested that selection in stressed condition is more efficient for yield improvement than selection in optimum environment, or selection based on a drought response index.

Based on DRI, IT93K-452-1 and IT98K-412-13 were drought tolerant while IT99K-529-1, Biu Local, Kanannado, IT99K-216-24-2, Sa Babba Sata, IT96D-610 and IT97K-819-118 have some level of tolerance and the other genotypes are susceptible. These results highlighted the significance of combining screening for drought tolerance in areas of production using both yields and drought selection indices.

Muranaka *et al*. (2011) suggested a close association between drought stress and *Striga* resistance because there is probably restriction of water uptake by *Striga* that magnifies the effect of drought stress. IAR-07-1050 was completely resistant to *Striga* which highlighted its potential in improving yield performance in drought stressed environment. Other genotypes such as IT98K-412-13, IT99K-216-24-2 etc also performed well in presence of *Striga*. This indicates some level of tolerance to *Striga* in addition to drought tolerance observed. It is also clear that their seed yield may be much greater if improved for *Striga* resistance; a potential which can be derived from other genotypes such as IAR-07-1050. In the same vein, several workers have reported the identification of many other genotypes with resistance to various strains of *Striga* (Singh, 2005).

CONCLUSION

This study assessed the performance of 22 genotypes of cowpea under the stresses of drought and *Striga*. The performances of the genotypes varied with date of planting. Those planted early in August generally performed better. This reaction is generally consistent over years. One genotype, IAR-07-1050 was found to be resistant to *Striga* while others were infected to different extent as indicated by their seed yield. IT93K-452-1 and IT98K-412-13 were drought tolerant based on DRI and other indices while IT99K-529-1, Biu Local, Kanannado, IT99K-216-24-2, Sa Babba Sata, IT96D-610 and IT97K-819-118 showed some level of tolerance.

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