



SCREENING OF COWPEA (*Vigna unguiculata* (L.) Walp.) GERMPLASMS FOR ADAPTATION TO DROUGHT IN THE SUDAN SAVANNA ZONE OF NIGERIA.

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Abstract

Cowpea is cultivated commonly as a rain-fed crop. However, annual rain ceases within five months in the Northern region, an area with a high production bulk. Despite the crop's inherent capacity for withstanding stress more than any other legume, an erratic rainfall pattern exposes cowpea to drought early, mid or late in the cropping season, causing damage, injury, and low yield. Although high yield potential is the target of most crop breeding programs, and this could be achieved by the used high yield potential traits in a moderate stress environment. This study was carried out at IITA Research Farm, located near Wase Dam (12° 03'N and 8° 34'E) in the Sudan Savannah of Minjibir Local Government Area, about 20km northeast of the state capital Kano Nigeria; during the 2016 and 2017 dry seasons. The objectives are to evaluate the growth and yield attributing characters of 10 cowpea germplasms as they are influenced by genetic variations under drought imposed and also to determine genetic variations of drought response among the germplasms root system and related traits. The experiment was laid in a randomized complete block design (RCBD) and replicated three times. The results revealed that IT98K1092-2, IT97K-499-39, Tvu-11610, and Tvu-1000 were considered drought escape (flowered and matured early) with good yield characters. Delayed in flowering were discovered on Aloka local, Dan'ila, and Tvu-10408. Following were found with enhanced levels of drought tolerance IT98K1092-2, Tvu-10408, and Tvu-10302. Susceptibility to drought was recorded on Tvu-1000, Tvu-11610, and IT97K-499-39. Among the genotypes, Ife-brown, Dan'ila, Tvu-1330, and Aloka local developed stay green character, widest root stem, long taproot, and deep (steep) architectural root system were regarded with drought avoidance. For developing more drought tolerance, it is recommended that cross genotypes with the character of drought escape (flowered and matured early), drought tolerance, and drought avoidance are the most promising traits for breeders to consider as potential parents. When the combination of such genes added to susceptible variety can increase yield, it gives more grower profit, thereby enhancing the economy to small scale farmers, particularly in the Sudan Savanna agro-ecological zone of Nigeria.

Keywords: cowpea; drought escape; drought tolerance; drought avoidance.

1. Introduction

Cowpea (*Vigna unguiculata* (L.) Walp.) is an important food legume with a very long history of cultivation; tropical Africa is believed as the center of its domestication (Singh *et al.*, 1997). Leaves, seeds, and Pod are the essential parts of the crop and are consumed as food, while its residues are fed to livestock as protein-rich fodder and income through sales (Clark *et al.* 1991). About 68% of the World's cowpea is produced in Africa and Nigeria, the leading producer and consumer with 2.2 Million Metric tons of dried grain. Niger Republic is the second-largest producer, followed by Burkina Faso, Myanmar, Cameroon, and Mali (FAOSTAT, 2010). Based on Nigeria's area, the bulk of production occurs in the Northern part of the country, and Dawanau Market Kano State is the largest cowpea Market in the World. However, cowpea can be grown in all ecological parts of the country (FAOSTAT, 2004).



Cowpea is cultivated commonly as a rain-fed crop by small-scale farmers in Nigeria. About 70% of them relied on the rainy season for their farming activities, where annual rain ceases within five months in the North, an area with a high bulk of production (FAOSTAT, 2004). The vast majority of farmers cannot afford irrigation facilities because of poverty to meet cowpea's demands throughout the year. Regarding these, cowpea yield has been far below the potential level and has resulted in protein food insecurity (CBN, 2006). Despite the crop's inherent capacity for withstanding stress more than any other legume (Boukar *et al.*, 2012). An erratic rainfall pattern exposes cowpea to drought at early, mid, or late in the cropping season, causing damage and injury to the crop. In earlier studies in Southern Nigeria on drought tolerance in cowpea, (Fatokun *et al.* 2012) found some germplasm lines with better drought tolerance. Still, there is limited progress so far in increasing drought tolerance. Therefore, these have become necessary to screen cowpea varieties that can adapt to drought, particularly in the northern part of Nigeria's tropical Sudan savannah.

1.2 JUSTIFICATION OF THE STUDY

Efforts were made in the past on developing drought-tolerant cowpea varieties but have met with limited success. Plant breeders need traits that can be readily used to discriminate between tolerant and susceptible plants to select or crosses to be effective. There is a tendency that genes that could contribute to drought tolerance exist in some of the unexploited cowpea germplasm lines maintained in the Gene Bank of the International Institute of Tropical Agriculture (IITA). To identify such varieties that could be sources of genes for tolerance to drought, this study will identify those with the desirable genes. Belko *et al.* (2012) reported that roots are the first organ that responds to drought in legume crops; therefore, screening cowpea genotypes under drought imposes and studying the interaction between root and its surrounding soil environment (root phenotyping). So it is possible to figure out varieties that are resistant to drought. Such crops will improve productivity and enhance the economy of small-scale farmers in Nigeria and Africa.

1.3 AIM AND OBJECTIVES

This study aims to screen cowpea germplasms for Adaptation to drought in the Sudan savanna zone of Nigeria. The following objectives are set to achieve at the end of this research:

1. To evaluate growth and yield attributing characters of cowpea germplasms as they influence by genetic variations under drought impose.
2. To determine genetic variations of drought response among the cowpea germplasms root system and related traits (root architecture, stem diameter, and taproot at different depths 5, 10, and 15cm).

2. MATERIALS AND METHODS

2.1 The study area

This study was conducted at IITA Research Farm, located near Wase Dam (12⁰ 03'N and 8⁰ 34'E) in the Sudan Savanna of Minjibir Local Government Area, about 20km northeast of the state capital Kano Nigeria; during the 2016 and 2017 dry seasons. The first trial was sown on 28th February 2016, while the second one was on 25th February 2017.

2.2 Treatments and experimental design

The treatments consisted of 10 cowpea varieties (5 tropical *Vigna unguiculata* (Tvu), 2 improved varieties, and 3 local checks) obtained from the Gene Bank of IITA. These genotypes have a wide range of variations due to their genetic background differences and were also selected based on variability in some drought resistance, yield, and roots parameters. All the 10 varieties were randomly sown and replicated three times in a Randomized Complete Block Design (RCBD) with 30 entries and 5 blocks in each replication. The field ware marked in border rows, alternate ridges, and alleyways between blocks to enhance movement and other agronomic operations within the plots. The varieties (genotypes) used for the study are presented in Table 1.



2.3 Plot size and sowing

The gross plot area was 4 by 3 m (12 m²) and consisted of four ridges with 0.75 m spacing between the ridges. The net plot size was 9.0 m² comprising two center ridges. Three viable seeds of different cowpea varieties per hole were sown at 75 cm × 20 cm (Inter and Intra rows spacing). Later the seedlings were thinned to two per stand one week after emergence.

2.4 Irrigation

During the study period, irrigation was employed by using sprinkler systems as water pumps with the help of a tractor engine machine sourced from Wase Dam near the farm field. The fields were well-irrigated a day before sowing and another two days after sowing for good germination. Subsequent irrigation was at three days intervals and withdrawn at 5 weeks after sowing.

2.5 Data collections

The data collected were growth habits, crop injury score, number of days to the first flower, number of days to 50% flowering, number of days to 95% pod maturity, number of pods per peduncle, pod dry weight, root architecture, stem diameter and taproot diameter at 5, 10 and 15(cm) depths. All the data collected were subjected to Analysis of variance (ANOVA) to test significant difference among the means using statistical analysis software (SAS 9.0), and the treatment means were separated using Duncan Multiple Range Test (DMRT) as described by Gomez and Gomez (1984).

Table1. Source and descriptions of the cowpea germplasm used for the study.

Varieties	Source	Growth habits	Seed Type (colour)
IFE-BROWN	IAR	Semi erect	Brown Smooth
IT97K-499-35	IITA	Semi erect	Cream rough
IT98K 1092-2	IITA	Spread	Cream smooth
TVU-1000	IITA	Semi erect	Black smooth
TVU-10302	IITA	Erect	Cream Smooth
TVU-10408	IITA	Erect	Cream Smooth
DAN'ILA	IAR	spread	White rough
ALOKA LOCAL	IAR	Semi erect	Cream rough
TVU-11610	IITA	Spread	White rough
TVU-1330	IITA	Semi erect	Black Smooth

IITA= International Institute of Tropical Agriculture (Kano station) Nigeria.

IAR= Institute for Agricultural Research (Ahmadu Bello University) Zaria, Nigeria.

3. RESULTS AND DISCUSSIONS

The drought reaction on growth habit was highly significant ($P \leq 0.01$) in all two seasons. Following varieties Tvu-10302, Tvu-11610, IT98K1092-2, and Dan'ila were statistically the same and resulted in higher growth behavior (spread type growth) than other genotypes. However, Tvu-1000 and Aloka local (semi-spread) were statistically higher in growth behavior than Tvu-1330, Tvu-10408, IT97K-499-39, and Ife brown (erect types). At withdrawal of irrigation, both growth characters perform well in this study as erect crops were observed with the advantage of a more sweeping canopy for active chlorophyll and photosynthetic utilization than spread or semi-spread type.

Drought has also significantly ($p \leq 0.01$) influenced injury on the crops in both seasons as dropping leaves were critically observed on some plants. In 2016, Tvu- 1000 showed higher injury by drought as compared to other



varieties. This was followed by Tvu-11610 and Dan'ila, which were statistically at par, and their leaves also turned yellow and senescence within 20 days after suspension of irrigation. The above plants were considered as susceptible to drought in this study. Despite the high temperature and drought, many evaluated crops such as Tvu-1330, Tvu-10302, Tvu-10408, IT98K1092-2, IT97K-499-39, Aloka local, and Ife brown were statistically the same, and they remained healthy in retained green leaves up to the termination of this study. This ability is regarded as tolerance to drought shown by the crops. In the year 2017, Tvu-10408 scored a higher injury than other varieties except Tvu-1330. This outcome is contrary to Agbicodo *et al.* (2008) report, who stated that stomatal conductance was associated with drought tolerance in cowpea.

Table 2: Growth habit and crop injury score of evaluated cowpea varieties affected by drought in 2016 and 2017 dry seasons.

Treatments (Varieties)	2016		2017	
	Growth habit	Crop-injury score	Growth habit	Crop-injury score
TVU-1330	1.00c	1.00c	1.00c	3.00ab
TVU-10408	1.00c	1.00c	1.00c	4.00a
TVU-10302	3.00a	1.00c	3.00a	1.33bc
TVU-1000	2.00b	3.00a	2.00b	2.00bc
TVU-11610	3.00a	2.00b	3.00a	1.00c
IT98K1092-2	3.00a	1.00c	3.00a	2.00bc
IT97K-499-39	1.00c	1.00c	1.00c	1.67bc
ALOKA LOCAL	2.00b	1.00c	2.00b	2.00bc
DAN'ILA	3.00a	2.00b	3.00a	2.00bc
IFE BROWN	1.00c	1.00c	1.00c	2.00bc
LEVEL OF SIGNIFICANCE	**	**	**	**
SE±	0.00	0.00	0.00	0.289

Means followed by unlike letter (s) within a column of any treatment group are significantly different at 5% level of probability using DMRT.

** = Highly significant at 1% level of probability

Days to first flowering, 50% flowering, and 95% pod maturity were significantly ($P \leq 0.01$) affect by drought in all the two seasons. The range of days to first flowering occurred between 20 to 35 days after sowing. However, 50% of flowering took place between 27 to 41 days. Variety IT98K1092-2 attained first flower and 50% flower earlier than other varieties. These were due to the crop's rapid phenological development compared to Aloka local, Dan'ila, and Tvu-10408 that delayed flowering. This observation was contrary to the report by Boukar *et al.* (2012), who state that cowpea flowered and matured earlier under drought stress than in optimum moisture condition (rain-fed). The number of days to 95% pod maturity usually ranged from 60 to 80 days. Crops that matured in 80 days and above are considered as late in this study. IT98K1092-2, Tvu-1000, and Ife-brown had matured earlier (60 to 70 days) compared to other varieties. Many days to 95% pod maturity, was carefully observed on crops that showed late in days to first and 50% flowering. Simultaneously, Tvu-10302, Tvu-11610, Tvu-10408, and IT97K-499-39 were considered with a medium number of days to maturity (72 to 79 days), respectively. This rapid phenological development in days to flowering resulted from gene variations among the germplasm for inability to produced flowers at the same time. Hall *et al.* (2003) reported that an early erect cowpea cultivar started flowering about 35 days and produced 2000kg/ha grain in 65 days. He also added that such varieties that flowered early and maintained stay green character should give farmers some grain yield even with irregular rainfalls.



Table 3: Days to first flowering, 50% flowering, and 95% pod maturity of the evaluated cowpea varieties affected by drought in 2016 and 2017 dry seasons.

Treatments (Varieties)	2016		2017			
	Days to first flowering	Days to 50% flowering	Days to 95% pod maturity	Days to first flowering	Day to 50% flowering	Days to 95% pod maturity
TVU-1330	27.33b-d	34.33b-d	75.00c-e	33.00b	41.00a	76.00bc
TVU-10408	28.67ab	35.33a-d	75.33cd	27.67cd	35.33cd	76.67bc
TVU-10302	26.67b-d	33.67d	75.00c-e	29.00c	34.67d	75.00b-d
TVU-1000	25.67d	31.67e	71.67e	33.00b	39.00b	71.67e
TVU-11610	27.67b-d	34.67a-d	74.00de	26.00d	32.00f	74.00c
IT98K1092-2	20.33e	27.33f	74.33de	25.67d	34.00de	77.67b
IT97K-499-39	28.00bc	35.67a-c	78.00bc	26.67d	35.00cd	75.00b-d
ALOKA LOCAL	30.67a	36.00ab	80.00a	35.67a	36.67c	82.67a
DAN'ILA	28.00bc	36.33a	79.00b	34.00ab	32.33ef	75.67b-d
IFE- BROWN	26.00cd	34.00cd	73.00de	29.00c	35.33cd	73.00de
LEVEL OF SIGNIFICANCE	**	**	**	**	**	**
SE+	0.401	0.302	0.603	0.414	0.345	0.506

Means followed by unlike letter (s) within a column of any treatment group are significantly different at 5% level of probability using DMRT.

** = Highly significant at 1% level of probability

The Pod per peduncle of evaluated cowpea was significantly ($P \leq 0.01$) affected by drought in both experiment seasons. In 2016, Tvu-10408 and IT98K1092-2 were found with the highest number of pods per peduncle than Tvu-11610, Dan'ila, and Ife brown. In 2017, all the varieties were statistically the same and enhanced many pods except Dan'ila and Ife brown, which gave the lowest. Dan'ila and Ife-brown's less performance was due to high relative humidity and delayed pesticide spray at the first-year trial that caused pests and diseases attacked on the peduncles, suppressing the yield. Besides, the crops show susceptibility to diseases and pest attacks. This outcome is similar to the finding (Emechibe *et al.* 1991), who reported that cowpea under drought stress is more liable to insect and disease problems. Drought also has significantly ($P \leq 0.01$) affected pod dry weight of evaluated cowpea in all the two seasons. In 2016, Tvu-1330 gave the heavier dry Pod against all other varieties. However, IT98K1092-2 gave statistically the same pod dry weight with other varieties except for Tvu-10408, Aloka local, and Dan'ila, which resulted lower and their seeds dispersed (shattered) exacerbated by drought and high temperature. While in 2017, IT98K1092-2 performed better than all other varieties. This outcome agrees with the earlier finding of Magashi *et al.* (2012), who reported that low pod yield in cowpea is usually happening on genotypes with shattering character. Therefore, several handpicking before the crop matured can promote yield.

The root system architecture of evaluated cowpea varieties was significantly ($P \leq 0.01$) influenced by drought in all the seasons. In 2016, Tvu-1000, Tvu-11610, Tvu-1330, and Tvu-10408 statistically recorded with the same shallow (spread) root architecture over IT98K1092-2, IT97K-499-39, Aloka local and Dan'ila, which are deeper roots while variety Ife-brown found dimorphic (root between deep and shallow). In 2017, Tvu-1000, Tvu-11610, Tvu-10408, and Ife-brown were statistically at par as shallow root architecture than others that are deeper except Tvu-1330 found dimorphic. Both designs of roots perform well under high temperatures and drought. However, crops with a deeper root are better in extracting nutrients and water from the soil layer at a time of limited water condition than shallow crops (spread root). These outcomes were similar to the study by Belko *et al.* (2017), who reported that legume crops with more in-depth root systems could develop mechanisms for avoiding drought during deficit water conditions than shallow ones. The tree plants' root system tended to be shallow and wider in dry and hot climates and became more in-depth and narrower in cold and wet conditions.



Table 4: Pod per peduncle and pod dry weight of evaluated cowpea varieties affected by drought in 2016 and 2017 dry seasons.

Treatments (Varieties)	2016		2017	
	Pod per peduncle	Pod dry weight (g)	Pod per peduncle	Pod dry weight (g)
TVU-1330	1.67b-d	123.00a	2.00a	36.67b-e
TVU-10408	3.00a	29.47c	2.00a	31.87c-e
TVU-10302	1.33cd	44.00bc	2.00a	56.18b
TVU-1000	1.67b-d	52.67bc	2.00a	22.60de
TVU-11610	1.00d	38.83bc	2.00a	51.00bc
IT98K1092-2	2.33b	69.70b	2.00a	76.20a
IT97K-499-39	2.00bc	36.67bc	2.00a	42.13b-d
ALOKA LOCAL	2.00bc	29.00c	2.00a	17.17e
DAN'ILA	1.00d	28.50c	1.00b	17.00e
IFE BROWN	1.00d	36.73bc	1.00b	26.50de
LEVEL OF SIGNIFICANCE	**	**	**	**
SE+	0.123	5.970	0.00	3.798

Means followed by unlike letter (s) within a column of any treatment group are significantly different at 5% level of probability using DMRT.

** = Highly significant at 1% level of probability

The drought was significantly ($P \leq 0.01$) affected the stem diameter of evaluated cowpea in all the two seasons. The result shows that in 2016, Tvu-1000 recorded with a broader stem diameter (14.60cm) followed by Tvu-1330, Aloka local, and Ife brown. The least stem diameter (6.0cm) was from the Tvu-10408 variety. While in 2017, Ife brown and Tvu-1330 recorded the wider stem diameter (12.13 and 12.07cm), respectively. Stem shrinkage, leaf folding, stomatal closure, reductions of nodules size, and the number was on crops found with the least stem diameter, and these were resulted by drought. A similar observation was trace by Aniya (2004), who reported in his study that cowpea with more comprehensive stem and rooting density have better growth potential because they absorb more water and nutrient in their system.

Table 5: Root system architecture and stem diameter of evaluated cowpea varieties affected by drought in 2016 and 2017 dry seasons.

Treatments (Varieties)	2016		2017	
	Root system architecture	Stem diameter (cm)	Root system architecture	Stem diameter (cm)
TVU-1330	2.00a	11.70b	1.00b	12.07a
TVU-10408	2.00a	6.00f	2.00a	6.00d
TVU-10302	1.00b	9.77c	2.00a	8.47c
TVU-1000	2.00a	14.60a	2.00a	10.87ab
TVU-11610	2.00a	8.73d	2.00a	8.33cd
IT98K1092-2	1.00b	9.83c	1.00b	7.73cd
IT97K-499-39	1.00b	7.60e	1.00b	7.60cd
ALOKA LOCAL	1.00b	11.37b	1.00b	9.57bc
DAN'ILA	1.00b	8.50d	1.00b	8.87bc
IFE BROWN	1.00b	12.13b	2.00a	12.13a
LEVEL OF SIGNIFICANCE	**	**	**	**
SE+	0.00	0.160	0.00	0.458



Means followed by unlike letter (s) within a column of any treatment group are significantly different at 5% level of probability using DMRT.

** = Highly significant at 1% level of probability

Taproot diameter was significantly ($P \leq 0.01$) affected by drought across the two seasons, and the result further shows, most of the evaluated cowpea performs better at different depths of determinations. At 5cm depth, variety Ife-brown was the highest (8.17cm) and least (3.50cm) from IT98K1092-2. At 10cm depth, Ife-brown has still measured the highest in terms of long taproot diameter (5.57cm), were least (3.03cm) from IT97K-499-39 and Tvu-1330. At 15cm depth, the same Ife-brown measured the highest (4.67cm) and least from Tvu-10302 (1.93cm). Uarrota (2010) stated that several studies reported the significance of a deep rooting system for uptake of water from deeper soil layers under deficit water conditions in various crops such as sorghum, legumes, rice, maize, and wheat. The author added that taproot in the active root zone area (up to 30cm depth) improved water uptake, carbon assimilation, and nutrient, leading to high yield and avoiding drought. Abiola *et al.* (2017) added that the significance of a robust and more in-depth root system for more yield and drought avoidance had similarly found in soybean, chickpea, wheat, barley, and maize.

Table 6: Taproot diameter at 5, 10, and 15 cm depth of evaluated cowpea varieties affected by drought in 2016 and 2017 dry seasons.

Treatments (Varieties)	Tap root diameter (cm)					
	2016			2017		
	At 5 cm	At 10 cm	At 15 cm	At 5 cm	At 10 cm	At 15 cm
TVU-1330	7.13b	3.77c	2.73cd	6.67a	3.03c	2.43ab
TVU-10408	4.33e	3.57c	2.53cd	4.33bc	3.20c	2.10b
TVU-10302	6.270cd	4.33b	2.40cd	5.63ab	4.03a-c	1.93b
TVU-1000	6.20cd	4.40b	2.30d	6.00ab	4.40ab	2.17ab
TVU-11610	6.50bc	4.27b	3.33b	5.47ab	3.30bc	2.57ab
IT98K1092-2	4.47e	3.37c	2.30d	3.50c	3.30bc	2.07b
IT97K-499-39	4.47e	3.27d	2.47cd	4.47bc	3.03c	2.10b
ALOKA LOCAL	5.63d	4.33b	2.53b	4.67bc	3.67bc	2.30ab
DAN'ILA	6.23cd	4.60b	2.87c	5.67ab	3.90bc	2.60ab
IFE BROWN	8.17a	5.57a	4.67a	6.50a	5.07a	3.10a
LEVEL OF SIGNIFICANCE	**	**	**	**	**	**
SE+	0.131	0.091	0.088	0.302	0.199	0.170

Means followed by unlike letter (s) within a column of any treatment group are significantly different at 5% level of probability using DMRT.

** = Highly significant at 1% level of probability

4. CONCLUSION

Clearly, the addition of crops with the ability to flower earlier as exhibited by many genotypes evaluated in this study and those with stay green character. These should produce progeny that combine both attributes. Early cultivars can provide farmers with quick incomes at the beginning of cropping season; they can also be grown in diverse cropping systems and escape some insect infestation and terminal drought. Therefore, based on the result obtained, it recommended that cross genotypes with the character of drought escape (flowered and matured early),



drought tolerance, and drought avoidance are the most promising traits for breeders to consider as potential parents in the development of more drought populations. When the combination of such genes added to susceptible variety can increase yield, it gives more grower profit, thereby enhancing the economy to small scale farmers, particularly in the Sudan Savanna agro-ecological zone of Nigeria.

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