Screening For Drought Tolerance in Cowpea (*Vignaungiculata(L) Walp*) At Seedling and Flowering Stages Under Screen House Condition: Selecting for Recovery Ability Traits

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Abstract-* Prolonged drought of cowpea at the seedling stage can affect survival and productivity. One of the most important screening techniques used in cowpea selection for drought tolerance is screening at the seedling and flowering stages. This study sought to evaluate cowpea genotypes for their resistance to seedling and flowering stages during drought stress. Twenty four accessions of cowpea (Vigna unguiculata L. Walp) were collected from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria and Seed center, University of Agriculture, Makurdi to evaluated for their drought tolerance at seedling stages at preliminary trial. Fourteen were selected as the accessions proved to be tolerant and were further used The experiment was laid out in a Completely Randomized Design (CRD) with three replications at the screen house of the Department of Crop Production Technology of College of Agriculture, Science and Technology Lafia, Nasarawa stata, Nigeria. Drought stress was imposed for 3 and 5 weeks after the full expansion of the first trifoliate leaf and first flower initiation. Soil Plant Analysis Development (SPAD) chlorophyll meter readings of unifoliate, first, and second trifoliate leaves of each genotype was measured on a weekly basis due to the predictive ability of chlorophyll content on drought tolerance. Analysis of variance (ANOVA) revealed high significant differences among accessions for wilting and recovery traits, stomatal conductance, relative water content (RWC), terminal leaflet length (TLL) and width (TLW), stem girth, and yield parameters under drought stress. AC02, AC04, AC07 and AC14 were observed to be highly susceptible. AC04, ACO6 and AC11 were moderately susceptible. AC03 and AC09 were moderately tolerant, while AC10 and AC12 were the highly tolerant accessions. The moderately tolerant and the highly tolerant accessions showed a combination of superior resistance to wilting, superior recovery rates, and superior yield attributes. Accessions that showed high tolerance and great variability can be used as parents in future for breading programmes.

Key words: Cowpea Accessions, Vigna ungiculata, drought tolerance, Recover traits and Heritability.

I. INTRODUCTION

The improvement of cowpea mainly dependent on breeding and selection from existing landraces. Cowpea (*Vigna unguiculata* L. Walp.) is a grain legume crop of global economic importance and it originated from Africa (Carvalho *et al*., 2019). It is grown for its grains and fodder due to its diverse uses (Gonçalves *et al*., 2016; Ravelombola *et al*., 2020). According to Santos *et al*. (2020), dry cowpea grain has high protein levels (20.0–39.4%) and low-fat content (3.1–30.4%).

Drought is one of the most severe environmental stresses, and it has a significant negative impact on crop yield. Gomes *et al*. (2019) recommend the use of water-efficient varieties in combination with good crop husbandry practices. Cowpea plants exposed to temperatures of 30 to 38 °C from eight days after emergence to maturity had very limited vegetative growth and reproductive potential (Singh *et al*., 2010). Hall e*t al*. (2003) observed that there is a great need to screen and breed for drought-tolerant and water use efficient varieties in Africa, as cowpea is grown mostly under rain-fed conditions, with frequent exposure to intermittent droughts. Gomes *et al*. (2019) recommend the use of well-adapted, early maturing cultivars in the smallholder farming sector to escape losses from late season droughts.

The global production of cowpea is about 8.9 million metric tons cultivated in an area of around 15 million hectares (FAOSTAT, 2020). Cowpea cultivation is widely distributed throughout the tropics and subtropical regions, with the largest production in Africa coming from West Africa (Gnankambary et al., (2020). Cowpea cultivation is challenged by various factors including abiotic stresses such as drought. Cowpea yield remains one of the lowest among all grain legumes in sub-Saharan Africa, due to several constraints, such as drought. According to Ibitoye (2015), drought causes grain and fodder yield reduction by 62% and 56%, respectively. It can occur at any stage of crop development. Early-season drought stress can affect crop establishment. Drought stress during flowering or pod-filling stages may also result in yield losses (Tumwesigye & Musiitwa, 2002). It is reported that climate change will intensify the frequency of drought and flood, particularly in several African countries, and it is projected that by 2050, water shortages are expected to affect 67% of the world's population (Ceccarelli et al., 2004).

In the tropical and subtropical regions of the world, for ages, one of the major sources of protein especially among the poor is cowpea (Ezin et al., 2021). This is because, compared to animal protein, it is cheaper; and has been found to contain around 25% protein in its seeds (Ajayi et al., 2018). Aside from this, it is rich in vitamins, minerals, fiber, and carbohydrates. It is useful in an intercropping system for being able to fix atmospheric nitrogen in the soil for soil replenishment (Santos et al., 2020). It is also one of the major sources of protein for animals as the vegetative parts are fed to cattle (Nunes et al., 2022). Cowpea thrives well in the tropical ecosystem; it has a higher tolerance to a couple of abiotic stresses including heat, drought, and soil acidity compared to cereals, however, a high level of genotypic differences exists among available varieties regarding these abiotic stresses, especially as regards drought. Drought is a major threat to the crop's productivity especially during the flowering and grain filling stage (Nunes et al., 2022), despite its good attributes. Many high-yielding varieties are susceptible to drought making yield loss of devastating magnitude a common occurrence in tropical and subtropical Africa, most especially in Nigeria. It is, therefore, necessary to gather adequate information regarding the genetic differences among available varieties for drought tolerance to deploy such information in the plant breeding program of the crop. Presently, Nigeria accounts for the highest production of cowpea in the world, contributing about 2.61 metric tons per annum accounting for about 36% of the global production of the crop (Ajayi et al., 2022).

Drought at the flowering stage of crops as the consequence of heavy reliance of the agricultural systems in tropical Africa on rain-fed agriculture is devastating to yield. Rain-fed agriculture is characterized by uneven distribution and uncertainty at the reproductive stage, hence causing terminal drought stress with accompanying reduction in yield (Lemma et al., 2021), which may climax between 70 and 80% (Harshani & Fernando, 2021; Wang et al., 2021). The devastating effects of drought stress during the reproductive stage have been confirmed in several crop species including beans (Wasae, 2021), cowpea (Ezin et al., 2021; Santos et al., 2020), maize (Al-Naggar et al., 2011; Badu-Apraku et al.). Meanwhile, information regarding the mechanisms of their responses to drought during flowering is to a large scarce, making breeding for drought tolerance a difficult task (Yang et al., 2019). Therefore, screening for drought tolerance must consider the reproductive stage and also adopt simple, cheap, and non-destructive screening methods with high efficiency in identifying the level of differences as well as sources of such variations among available germplasm (Ajayi et al., 2018). Simple methods that have proven successful include stomata behavior (Agbicodo, 2009), root traits (Santos et al., 2020), leaf rolling (Matthew, et al., 1990), leaf wilting scales, and indices (Pungulani et al., 2013; Ajayi et al., 2020), plant wilting scales and percentage of wilted plants and recovery parameters under drought stress (Nkouannessi, 2005; Ajayi et al., 2018). The pot screening of genotypes at seedling stage has also been found to be a reliable technique for identifying drought tolerance, for its practicality as being an easy set-up under a controlled environment; and adaptable for screening a large number of genotypes [12]. This has been confirmed by Watanabe et al. [6] who concluded that the phenomenon conferring seedling drought tolerance is also manifested at the flowering stage.

This study was conducted with the following objectives:

i. To screen accessions of cowpea for drought tolerance at seedling and flowering stages by utilizing their shoot, physiological, and yield traits..
ii. To estimate the level of variability, heritability, and association of the drought responsive traits of cowpea under drought stress at the flowering stage.

II. MATERIALS AND METHODS

A total of 24 cowpea accessions were used in this study (14 from IITA and 10 from Seed Center, University of Agriculture, Makurdi). These accessions were screened at the seedling and the vegetative stages for their tolerance to drought and fourteen accessions were selected

Fourteen (14) cowpea accessions were further used in this study The procedure for evaluating drought tolerance described previously by Ravelombola et al. (2018) was used. The selected accessions are presented in Table 1. The fourteen (14) accessions were screened for drought tolerance at the seedling and flowering stages in the screen house of the Department of crop production of College of Agriculture, Science and Technology, Lafia (longitude 8. 5 32^0Nand Latitude 8.5 32^0 E) above sea level .between April, 2025.

Table 1. Selected accessions of cowpea and their previous drought-tolerant statuses at the Seedling and vegetative stages

S/N	Accession 1D	Location	Code
1	TIIK-3217-1	UAM	AC01
2	T108K-126-19	UAM	AC02
3	T116K-1968-3	UAM	AC03
4	IARD-17-10177	IAR	AC04
5	TII4K-2188-1	NIGER	AC05
6	T117K-2024-4	NIGER	AC06
7	T117K-1089-4	NIGER	AC07
8	T117k-1266-2-1	NIGER	AC08
9	IT97K-499-35	IITA	AC09
10	CLS 39-6-1	UAM	AC010
11	LOC FMC	UAM	AC011
12	CLS41-1-5	UAM	AC012
13	IT07K-126-21	UAM	AC013
14	LOC-1-FC	UAM	AC014

Table 2. Pre-planting properties of the topsoil used to screen the accessions of cowpea for drought tolerance at the flowering stage

S/N	Parameters	
1	pH	6.50
2	Total organic matter (%)	2.28 3 Available P (c mol/kg) 2.50
4	Total N (%) 0.35 5 H^+ (mmol) 1.057 Al^{3+} (mmol) 2.20 7 Na (ppm) 24.30	
8	Cu (ppm)	0.90
9	Mg (ppm)	52.00
10	Pb (ppm)	0.60
11	Mn (ppm) 78.00 11 Sand (%) 79.80 12 Silt (%) 10.54 13 Clay (%) 10.63	
14	Texture class	Sandy Loam

Drought treatment: Seeds were planted in plastic bags filled with 4.0kg of sieved sandy loam soil without fertilizer in the screen house. After emergence, plants were thinned to two fairly uniform plants per pot with 14 pots per treatment and three replications for each accession in a completely randomized design (CRD); a total of 84 plants were contained in the screen house. Each pot was watered with 500 ml of water per day till more than 80 percent of the plants in the screen house have flowered; thereafter watering was terminated for 21 days to impose drought stress. The 500 ml was predetermined according to Ogbaga et al. (2014) as the amount required to bring each pot to 100% field capacity.

Shoot wilting parameters

Drought stress and susceptibility was scored on days 14 and 21 for plants based on the 1983 Descriptors for cowpea of the International Board for Plant Genetic Resources (IBPGR). One plant per pot was tagged for relative water content (RWC), while the two remaining plants per pot were untagged. The drought susceptibility score (DSS) on a 1 – 7 scale was used on the untagged plants, where 1 to 3 indicated low susceptibility (plant growing well with green leaves); 4 to 5 indicated medium susceptibility (a plant having most of the leaves turned yellow / or wilting), and 6 to 7 indicated high susceptibility (dead and dry plant). The mean score of plants per replicate and across the three replicates was respectively calculated. Accordingly, the percentage of wilted plants (PPW) was documented for each accession. However, the leaf wilting index (LWI) was determined for days 7, 14, and 21 under drought stress, as the ratio of leaves per plant showing wilting signs or wilted to the total number of leaves according to Pungulani et al. (2013). Accessions were ranked from 1 to 10 based on their superiority for each of the wilting traits where 1 signified the best and 10, the poorest.

Morphological and physiological traits:
Morphological traits like plant height, number of leaves per plant, terminal leaflet length, terminal leaflet width, stem girth and physiological parameters such as stomata conductance and stomata resistance at 14 days of drought stress were also used to assess the level of tolerance of the accessions to drought stress. Plant height, terminal leaflet length and width: These were measured at the commencement of the drought stress, 7 days, 14 days and 21 days of imposition of water stress. These were measured using a meter rule. Terminal leaflet length and width were only measured at the commencement of drought stress and day 7. The average of values of two plants in each pot was determined after which the mean value of the three replicates of each accession was calculated. The relative water content (RWC) was done by the methods of Kumar et al. (2008). This was done for the initial, 7 days, and 14 days after the termination of watering from two young fully expanded leaflets from the top of each plant per pot per replicate. They were detached and weighed for the fresh weight (FW), afterwards, they were placed in small bags containing distilled water and kept in the refrigerator for 12 hours. Turgid weights (TW) were determined by first blotting the leaves to dryness after removing from water and weighing, as well as dry weight (DW) after drying the leaves in the oven for 48 hours at 60˚C. RWC (%) was determined on each leaflet by using the formula: $RWC = (FW – DW)/ (TW – DW) \times 100$. The average value for each replicate was determined per accession, after which the mean value of each accession was determined on the three replicates. Stomatal conductance was done only on the 14th day using a steady-state Leaf Porometer. This was done between 11.30 am and 5.00 pm utilizing surviving leaflets from among those used for TLL and TLW on only three selected plants of each accession per replicate. The average value of each parameter was determined for each accession per replicate and the mean for the three replicates was determined. The ranking of accessions for RWC was based on the percentage reduction in mean performance between initial and final values, where 1 signified the most superior (least reduction in mean value) and 10, the poorest (highest reduction in mean value). However, accession with the highest stomatal conductance was ranked 1 (best) while the one with the lowest mean performance was ranked 10 (poorest).

Yield parameters
To the determination of the percentage pod set, ten (10) flowers per accession per replicate were tagged on the last day of watering before the imposition of drought stress on only the matured flowers. The percentage pod set was calculated as the ratio of the number of pods formed and survived to maturity to the number of flowers tagged and expressed as a percent according to Kumar et al. (2008). The total number of pods per plant was done by counting the number of pods per plant per replicate at maturity. A mean number of pods of two plants per pot was recorded, then the mean across replicates was determined. Pod weight was determined by selecting the ten (10) best pods per replicate after the removal of seeds. The average pod weight was determined per replicate for each accession, after which the mean pod weight for three replicates was determined. The number of seeds per pod was determined by averaging the number of seeds per pod of two plants per pot. The mean number of seeds per pod for each accession was recorded and the mean for the three replicates was determined. Seed yield per plant was determined by averaging the yield of two plants in each pot. The mean seed yield for each accession was recorded and the mean for three replicates was determined.

Recovery parameters
Twenty one (21) days after imposition of drought stress, watering then resumed, and 14 days after, percentage plant recovery in each accession was recorded. Based on permanent wilting and percent recovery, plants were grouped as susceptible or

drought tolerant. Centered on this percentage, plants were ranked between 1 (highest percentage recovery) and 10 (lowest recovery percentage). Stem greenness was scored on day 14 using a scale of 1–5, where 1 indicated the recovered plant is yellow and 5 was a completely green plant. The stem re-growth was scored in three categories: 1 signified plant recovered, but with no re-growth; 3 signified plant with regrowths from auxiliary buds; and 5 signified re-growth from the shoot apexes (Pungulani et al., 2013). Accessions were ranked between 1 and 10 based on their overall mean performance for stem greenness and stem re-growth.

Statistical analysis

Analysis of variance (ANOVA) was performed in SPSS version 20. Means were divided at a $P \leq 0.05$ level of significance using the Duncan Multiple Range Test (DMRT). The mean rank (MR) of all parameters, their standard deviation (SDR), as well as the grand mean rank (GMR) were determined. Estimates of genetic parameters were done according to the procedures cited in Ajayi et al., (2017a).

III. RESULTS

Variability among accessions of cowpea under drought stress at the flowering stage

There was significant differences at the seedling and flowering stages of genotypes tested on stem greenness in week one (SGWK1), stem greenness in week two (SGWK2), stem greenness in week three (SGWK3), wilting in week one (WWK1), wilting in week two (WWK2) and wilting in week three (WWK3) (Table 3). However, yield-related traits evaluated were affected by water stress, i.e. number of pods (NP), and number of seeds per pod (NS), replicates on number of pods (NP), replicates on pod length etc. This will be achieved by careful and constant monitoring to obtain the needed output.

Table 3. Mean square values for all parameters of accessions of cowpea screened under drought stress at the flowering stage

Parameters	Accession (DF = 9)	Error (DF = 20)	CV (%)
Parameters	Accessions (DF = 13)	Error (DF= 28)	CV (%)
DSS7	4.14**	0.51	24.33
DSS 14	7.01**	0.78	20.02
PPW7 (%)	1067.41**	72.55	32.65
PPW14 (%)	2100.54**	189.44	22.41
LWI 7	0.05**	0.03	30.54
LWI 14	0.03**	0.002	15.76
LWI 7	0.01**	0.002	3.10
IRWC (%)	29.11**	22.14	11.00
RWC7 (%)	145.42**	81.65	12.32
RWC14 (%)	217.32**	89.31	17.71
PREC	1632.97**	29.44	20.34
STG	18.21**	0.13	16.46
STR	4.17**	0.24	37.67
ITLL(cm)	2.11**	1.25	8.97
TLL7(cm)	2.22**	1.43	11.02
ITLW(cm)	5.01**	0.87	12.21
TLW7(cm)	5.16**	0.86	13.21
ISG(mm)	0.21**	0.06	11.14
SG7(mm)	0.26**	0.23	10.25
SG14(mm)	0.87**	0.27	12.98
PPST (%)	453.67**	54.78	18.95
TPDP	6.43**	1.10	22.32
SPP	13.19**	1.55	10.14
SDPL	1011.71**	166.41	31.90
PDL	7.46**	0.81	5.33
SDYPL(g)	18.77**	2.16	21.53

PODW(g)	0.03**	0.005	21.64

** Significant at $P \leq 0.05$; DF: Degree of freedom.

DSS14, 21: Drought susceptibility score at day 14 and 21; PPW14, 21: Percentage of plants wilted at day 14 and 21; LWI7, 14, 21: Leaf wilting index at day 7, 14, 21; IRWC, RWC7, RWC14: Initial relative water content, relative water content at day 7, relative water content at day 14; PREC: Percentage recovery; STG: Stem greenness; STR: Stem re-growth; ITLL: Initial terminal leaflet length; TLL7: Leaflet length at day 7; ITLW: Initial terminal leaflet width; TLW7: Leaflet width at day 7; ISG: Initial stem girth; SG7, 14, 21: Stem girth at day 7, 14 and 21; PPSET: Percentage pod set; TPDP: Total pods per plant; SPP: Seeds per pod; SDPL: Seeds per plant; PDL: Pod length; SYDPL: Seed yield per plant; PODW: Pod weight

Table 4. Wilting parameters (means ± standard error) of accessions of cowpea screened under drought stress at the flowering stage

ACCESSION	DSS 14	DSS 21	PPW 14	PPW 21	LWI 7	LWI 14	LWI 21
AC01	1.67 ± 0.34^{a}	4.06 ± 0.47^{c}	8.33 ± 3.23^{ab}	57.00 ± 1.73^{abc}	0.24 ± 0.03^{abc}	0.91 ± 0.06^{a}	91.00 ± 0.00^{c}
AC02	2.54 ± 0.55^{ab}	5.01 ± 0.77^{bc}	20.00 ± 5.87^{bc}	64.00 ± 1.50^{cd}	0.37 ± 0.07^{cd}	0.83 ± 0.04^{a}	0.92 ± 0.04^{bc}
AC03	3.57 ± 0.70^{bc}	5.87 ± 0.11^{c}	40.67 ± 10.53^{e}	$87.33\pm2.^{67de}$	$0.42\pm0.^{12cd}$	0.87 ± 0.12^{a}	1.00 ± 0.00^{c}
AC04	1.75 ± 0.13^{a}	2.85 ± 0.23^{a}	8.67 ± 0.67^{ab}	28.33 ± 7.24^{ab}	0.14 ± 0.04^{ab}	0.67 ± 0.04^{a}	0.85 ± 0.02^{ab}
AC05	2.07 ± 0.28^{a}	3.60 ± 0.32^{ab}	0.00 ± 0.00^{a}	53.33 ± 3.03^{abc}	0.21 ± 0.04^{abc}	0.82 ± 0.07^{a}	0.98 ± 0.02^{c}
AC06	1.91 ± 0.33^{a}	2.61 ± 0.35^{a}	0.00 ± 0.00^{a}	26.33 ± 4.91^{a}	0.22 ± 0.07^{abc}	0.64 ± 0.12^{a}	0.81 ± 0.05^{a}
AC07	2.97 ± 0.28^{a}	5.05 ± 0.60^{bc}	28.00 ± 4.06^{cd}	65.33 ± 6.89^{cd}	0.28 ± 0.05^{bc}	0.67 ± 0.09^{a}	0.94 ± 0.00^{bc}
AC08	5.37 ± 0.45^{d}	6.78 ± 0.12^{c}	60.00 ± 5.67^{f}	90.27 ± 5.00^{bc}	0.25 ± 0.06^{abc}	0.94 ± 0.03^{a}	0.97 ± 0.02^{c}
AC09	1.06 ± 0.18^{a}	4.00 ± 1.14^{ab}	0.00 ± 0.00^{a}	56.67 ± 17.64^{bc}	0.04 ± 0.01^{a}	0.69 ± 0.17^{a}	1.00 ± 0.00^{c}
AC10	4.21 ± 0.41^{cd}	6.29 ± 0.55^{c}	37.00 ± 0.49^{de}	87.66 ± 12.33^{de}	0.23 ± 0.06^{abc}	0.72 ± 0.07^{a}	0.85 ± 0.01^{c}
AC 11	1.91 ± 0.35^{a}	2.61 ± 0.25^{a}	0.00 ± 0.00^{a}	26.33 ± 4.91^{a}	0.22 ± 0.07^{abc}	0.64 ± 0.12^{a}	0.81 ± 0.05^{a}
AC12	2.54 ± 0.69^{ab}	5.02 ± 0.67^{bc}	20.00 ± 5.77^{bc}	64.00 ± 15.50^{cd}	0.37 ± 0.07^{cd}	0.73 ± 0.04^{a}	0.82 ± 0.04^{bc}
AC13	1.68 ± 0.39^{ab}	6.16 ± 0.47^{c}	13.33 ± 3.33^{ab}	97.00 ± 1.73^{e}	0.24 ± 0.03^{abc}	0.93 ± 0.06^{a}	1.00 ± 0.00^{c}
AC03	3.57 ± 0.77^{bc}	6.84 ± 0.11^{c}	50.67 ± 10.53^{ef}	97.33 ± 2.67^{e}	0.52 ± 0.12^{d}	0.87 ± 0.12^{a}	1.00 ± 0.00^{c}

Means with the same alphabet within a column are not significantly different from one another at $P \leq 0.05$ using DMR.

DSS14, 21: Drought susceptibility score at day 14 and day 21; PPW14, 21: Percentage of wilted plants at day 14 and 21; LWI7, 14, 21:Leaf wilting index at day 7, 14 and 21

The morphological parameters of the accessions, such as terminal leaf length (TLL), terminal leaf width (TLW), and stem girth are presented in Table 5. The final TLL measured on day 7 of stress was highest (14.21 cm) in AC08 and lowest (10.00 cm) in AC07. However, the percentage reduction between initial and final ranged between the lowest (-0.36%) in AC05 and the highest (8.24%) in AC02. Also, TLW ranged between 5.30 cm in AC07 and 9.30 cm in AC04, with the lowest percentage reduction (-0.35%) in width in AC05 and the highest reduction (8.77%) in AC01. Further, the highest reduction (33.17%) of stem girth as of day 21 of stress occurred in AC01 with the least stem girth of 2.80 mm, meanwhile, both the lowest percentage reduction of stem girth (6.51%) and biggest stem girth (4.74 mm) respectively were obtained in AC09.

The yield traits of the accessions under drought stress are presented in Table 6. The highest performance for seed yield pod length (15.85 cm), (10.95 g), and pod weight (0.70 g) was obtained in AC12 while the lowest performance for seed yield (1.75 g), pod length (10.44 cm), and pod weight, respectively was obtained in AC6 and AC4. Performance for the number of seeds per pod (1.05) and the number of seeds per plant (21.45) was highest in AC10 while the lowest performance in the two traits respectively was obtained in AC04 (11.78) and AC01 (17.66). However, the percentage of pod set per plant ranged from the lowest (13.33%) in AC14 to the highest (53.35%) in AC12

Table 5. Effect of drought stress on terminal leaflet length and width (cm), and stem girth (mm) (means ± standard error) of accessions of cowpea at the flowering stage

ACCESSION	ITLL	TLL7	RD (%)	ITLW	TLW7	RD (%)	ISG	SG7	SG14	RD (%)
AC01	11.50±0.65^{ab}	11.47±0.50^{ab}	0.26	9.50±0.46^{abc}	5.93±0.49^{ab}	7.87	4.19±0.15^{a}	4.15±0.21^{a}	4.80±0.43^{a}	24.18
AC02	11.23±0.62^{ab}	11.27±0.64^{ab}	-0.36	8.60±0.70^{de}	8.63±0.77^{cd}	-0.35	4.59±0.04^{abc}	4.66±0.13^{ab}	3.70±0.14^{abc}	19.38
AC03	11.70±0.72^{ab}	11.30±0.55^{ab}	3.47	7.90±0.55^{cde}	7.57±0.43^{bc}	4.45	4.87±0.24^{cd}	4.62±0.23^{ab}	3.71±0.14^{abc}	23.81
AC04	12.63±0.86^{b}	12.57±0.83^{b}	0.48	9.37±0.47^{e}	8.30±0.46^{d}	1.47	4.71±0.19^{bcd}	4.69±0.26^{ab}	3.89±0.55^{bcd}	17.41
AC05	12.13±0.75^{ab}	11.13±1.17^{ab}	8.22	6.60±0.70^{abc}	6.53±0.69^{ab}	1.06	4.31±0.05^{ab}	4.41±0.37^{ab}	3.31±0.41^{ab}	23.2
AC06	11.93±0.63^{ab}	11.80±0.66^{ab}	1.08	8.70±0.46^{de}	8.50±0.47^{cd}	2.29	5.09±0.08^{d}	5.22±0.19^{b}	4.60±0.09^{cd}	9.63
AC07	11.03±0.23^{a}	11.03±0.23^{a}	0.00	5.30±0.32^{a}	5.30±0.32^{a}	0.00	4.67±0.04^{bcd}	4.67±0.18^{ab}	3.83±0.03^{bcd}	17.99
AC08	11.80±1.01^{b}	11.83±0.86^{b}	0.45	6.10±0.46^{ab}	5.97±0.49^{ab}	2.13	4.81±0.14^{cd}	4.60±0.26^{ab}	3.59±0.34^{abc}	25.36
AC09	13.23±0.35^{ab}	13.23±0.36^{ab}	1.52	6.70±0.15^{abc}	6.60±0.06^{ab}	2.49	5.04±0.04^{cd}	5.09±0.21^{ab}	4.74±0.19^{d}	6.51
AC10	11.17±0.46^{ab}	10.80±0.32^{ab}	3.41	7.53±0.52^{bcd}	7.23±0.40^{bc}	3.91	4.94±0.08^{cd}	4.83±0.52^{ab}	3.77±0.29^{abcd}	23.68
AC11	12.63±0.86^{b}	12.57±0.83^{b}	0.48	9.37±0.47^{e}	9.30±0.46^{d}	7.47	4.71±0.19^{bcd}	4.69±0.28^{ab}	3.89±0.55^{bcd}	17.41
AC12	12.50±0.75^{ab}	11.47±0.58^{ab}	2.26	6.50±0.46^{abc}	5.93±0.49^{ab}	2.77	4.19±0.25^{a}	4.15±0.21^{a}	4.80±0.43^{a}	5.17
AC13	12.13±0.75^{ab}	11.13±1.17^{ab}	8.24	6.60±0.70^{abc}	6.53±0.69^{ab}	1.06	4.31±0.05^{ab}	4.41±0.37^{ab}	3.31±0.41^{ab}	23.2
AC14	10.03±0.23^{a}	10.03±0.23^{a}	0.00	5.30±0.32^{a}	5.30±0.32^{a}	0.00	4.67±0.04^{bcd}	4.67±0.18^{ab}	2.83±0.03^{bcd}	33.01

Means with the same alphabet within a column are not significantly different from one another at P ≤ 0.05 DMRT. RD: Percentage reduction. ITLL: Initial terminal leaflet length; TLL 7: Terminal leaflet length at day 7; ITLW: Initial terminal leaflet width; TLW 7: Terminal leaflet width at day 7; ISG: Initial stem girth; SG7, 14: Stem girth at day 7, and 14.

Table 6. Yield traits (means ± standard error) of accessions of cowpea screened under drought stress at the flowering stage

ACCESSION	PPSET (%)	TPDP	SPP	SDPL	PDL (cm)	SYDPL (g)	PODW (g)
AC01	43.33±3.23^{ef}	4.73±0.24^{cde}	11.13±0.07^{bcd}	21.72±2.90^{bc}	18.30±0.88^{e}	10.95±0.38^{d}	0.50±0.03^{e}
AC02	43.33±6.67^{def}	4.87±0.47^{cde}	11.47±0.35^{bcd}	55.87±6.08^{c}	15.36±0.24^{bcd}	9.49±1.03^{cd}	0.42±0.05^{cde}
AC03	50.00±5.77^{ef}	5.35±1.28^{de}	14.27±0.47^{f}	22.37±21.63^{d}	16.63±0.16^{d}	6.82±1.60b^{bc}	0.27±0.01^{abc}
AC04	26.66±3.30^{abc}	1.73±0.27^{a}	11.78±1.64^{cd}	17.66±2.07^{a}	10.44±0.15^{bc}	2.78±0.22^{a}	0.52±0.12^{de}
AC05	56.66±3.33^{f}	3.27±0.51^{abc}	13.10±0.45^{de}	42.55±6.19^{abc}	16.87±0.41^{de}	5.98±0.95^{c}	0.40±0.04^{bcde}
AC06	16.67±3.33^{a}	1.89±0.11^{a}	14.29±0.46^{ef}	27.04±2.03^{ab}	15.78±0.11^{cd}	1.55±0.32^{ab}	0.38±0.07^{bcd}
AC07	42.33±3.23^{def}	6.48±0.52^{e}	8.93±0.24^{a}	57.79±4.11^{c}	12.76±0.29^{ab}	8.99±0.83^{cd}	0.29±0.03^{abc}

AC08	23.33±3.33^{ab}	4.43±0.54^{bcd}	9.93±0.44^{abc}	43.71±4.07^{abc}	15.68±0.65^{cd}	6.65±0.58^{bc}	0.44±0.06^{cde}
AC09	40.00±5.77^{cde}	4.00±0.58^{bcd}	9.33±0.88^{ab}	36.67±4.17^{abc}	12.27±0.91^{a}	6.98±0.80^{bc}	0.17±0.03^{a}
AC10	53.33±3.23^{bcd}	2.67±0.44^{ab}	15.10±0.10^{abc}	76.91±4.37^{ab}	14.85±0.57^{bc}	2.75±0.48^{a}	0.55±0.02^{ab}
AC11	26.66±3.33^{abc}	1.73±0.27^{a}	11.78±1.64^{cd}	19.66±2.07^{a}	14.44±0.15^{bc}	2.78±0.22^{a}	0.54±0.12^{de}
AC12	43.33±3.33^{def}	6.48±0.52^{e}	8.93±0.24^{a}	57.79±4.11^{c}	15.86±0.29^{ab}	10.99±0.83^{cd}	0.56±0.03^{abc}
AC13	43.33±6.67^{def}	4.87±0.47^{cde}	11.47±0.35^{bcd}	55.87±6.08^{c}	15.36±0.24^{bcd}	9.49±1.03^{cd}	0.42±0.05^{cde}
AC14	53.33±3.33^{ef}	4.73±0.24^{cde}	11.13±0.07^{bcd}	52.72±2.90^{bc}	18.30±0.88^{e}	8.95±0.36^{d}	0.50±0.02^{e}

Means with the same alphabet within a column are not significantly different from one another at P ≤ 0.05 using DMRT. PPSET: Percentage pod set; TPDP: Total pods per plant;
SPP: Seeds per pod; SDPL: Seeds per plant; PDL: Pod length; SYDPL: Seed yield per Plant: PODW: Pod weight

Table 7. Effect of drought stress on the physiological parameters (means ± standard error) of accessions of cowpea at the flowering stage

ACCESSION	IRWC (%)	RWC 7 (%)	RWC 14 (%)	RD (%)	SCND (mmol $m^{-2}s^{-}$
AC01	88.40±0.48^{ab}	83.81±6.71^{bc}	53.09±9.58^{abc}	45.96	93.43±2.05^{a}
AC02	89.50±0.78^{b}	77.04±7.19^{bc}	58.98±8.82^{bcd}	32.98	85.52±1.81^{a}
AC03	84.66±0.70^{ab}	59.09±8.94^{a}	44.16±0.59^{ab}	53.84	117.79±5.07^{a}
AC04	80.46±1.82^{ab}	75.56±5.17^{abc}	59.72±7.07^{bcd}	25.78	78.08±4.69^{a}
AC05	83.88±1.48^{ab}	69.96±0.48^{abc}	51.56±2.55^{abcd}	38.53	86.21±2.09^{a}
AC06	85.24±2.09^{ab}	70.88±4.41^{abc}	50.56±3.95^{abcd}	40.69	83.83±3.42^{a}
AC07	83.16±2.17^{ab}	66.66±1.89^{abc}	63.79±2.81^{cd}	23.29	78.72±8.60^{a}
AC08	84.52±2.44^{ab}	64.72±3.12^{ab}	46.72±2.19^{abc}	44.72	112.48±12.49^{b}
AC09	78.02±0.73^{a}	82.06±1.44^{c}	68.06±0.74^{d}	14.05	73.58±2.09^{a}
AC10	84.55±7.45^{ab}	76.61±2.84^{abc}	41.01±5.72^{a}	49.45	119.38±3.99^{b}
AC11	81.88±1.48^{ab}	67.96±0.48^{abc}	50.86±2.55^{abcd}	39.50	89.01±2.09^{a}
AC12	82.46±0.70^{ab}	58.09±8.94^{a}	43.10±0.59^{ab}	49.84	87.08±7.07^{a}
AC13	83.16±2.17^{ab}	66.66±1.89^{abc}	63.79±2.81^{cd}	23.29	78.72±8.60^{a}
AC14	84.02±1.82^{ab}	62.16±5.17^{abc}	46.00±7.07^{bcd}	52.06	114.01±4.69^{a}

Means with the same alphabet within a column are not significantly different from one another at P ≤ 0.05 using DMRT. RD: Percentage reduction. IRWC: Initial relative water content; RWC 7, 14: Relative water content at days 7 and 14; SCND: Stomata conductance.

The recovery parameters such as percentage of recovered plants (PREC), stem re-growth (STR), and greenness (STG) are presented in Table 7. Accessions AC02, AC04, AC007, AC09 and AC14 cold not recover. AC10, however, had the highest PREC (64.00%), the highest STR (3.21), and the highest STG (4.84).

Accession ranks based on wilting parameters, reduction in morphological traits, RWC, stamata conductance and yield traits are presented in Table 8. The mean of ranks (MR) and standard deviation of ranks (SDR) respectively, were highest in AC02 (7.16) and AC04 (7.10), while the lowest values were obtained in AC03 (4.06) and AC02 (1.03). Based on the MR and SDR, accessions with a mean rank lower than the grand mean (GM) of ranks (5.21) and its SDR (2.45) were classified as the highly tolerant accessions; which were AC03, AC05, AC06, AC10, AC11 and AC12. Moderately tolerant accessions included those with lower MR values but higher SDR compared to GM, such as AC06 and AC10. Moderately susceptible accessions were those with MR a bit higher than the GM and with higher SDR, including AC01 and AC04. Highly susceptible accessions were AC02, AC04, AC07, AC08 and AC09 with higher MR (>5.99) compared to GM.

Table 8. Recovery parameters (means ± standard error) of accessions of cowpea screened under drought stress at the flowering stage after two weeks of re-watering

ACCESSION	PREC (%)	STG	STR
AC01	21.00 ± 3.00^{b}	4.30 ± 0.15^{bc}	1.72 ± 0.42^{b}
AC02	0.00 ± 0.00^{a}	1.00 ± 0.00^{a}	0.00 ± 0.00^{a}
AC03	33.33 ± 5.77^{c}	4.54 ± 0.09^{bc}	2.07 ± 0.52^{b}
AC04	0.00 ± 0.00^{a}	1.00 ± 0.00^{a}	0.00 ± 0.00^{a}
AC05	21.66 ± 7.64^{b}	4.67 ± 0.17^{bc}	2.33 ± 0.33^{bc}
AC06	55.00 ± 8.66^{d}	$4.79 \pm 0.^{11bc}$	2.11 ± 0.11^{c}
AC07	0.00 ± 0.00^{a}	1.00 ± 0.00^{a}	0.00 ± 0.00^{a}
AC08	56.66 ± 9.07^{d}	4.83 ± 0.17^{bc}	2.33 ± 0.33^{bc}
AC9	0.00 ± 0.00^{a}	1.00 ± 0.00^{a}	0.00 ± 0.00^{a}
AC10	64 ± 0.40^{d}	4.84 ± 0.00^{a}	3.22 ± 0.00^{c}
AC11	42.33 ± 5.77^{c}	4.68 ± 0.09^{bc}	2.07 ± 0.52^{b}
AC12	24.00 ± 6.08^{b}	3.92 ± 0.85^{b}	2.22 ± 0.39^{bc}
AC13	20.00 ± 3.00^{b}	4.62 ± 0.15^{bc}	1.83 ± 0.44^{b}
AC14	0.00 ± 0.00^{a}	1.00 ± 0.00^{a}	0.00 ± 0.00^{a}

Means with the same alphabet within a column are not significantly different from one another at $P \leq 0.05$ using DMRT. PREC: Percentage recovery; STG: Stem greenness; STR: Stem regrowth.

Table 9. Ranking of accessions of cowpea screened under drought stress at flowering stage

ACC	DSS21%	PPW21	LWI21	RRWC	PREC	STG	STR	RTLL	RTLW	RSG	PPSET	SPP	SDPL	PDL	SYDPL	PODW	MR	SDR
AC01	7	9	8	8	7	7	6	4	10	10	2	6	4	1	1	1	5.31	2.55
AC02	5	5	3	3	4	6	3	5	10	5	3	6	5	4	2	4	7.16	1.45
AC03	10	10	2	8	9	7	7	6	9	8	8	8	41	3	5	8	4.06	3.22
AC04	2	2	1	2	3	3	4	4	5	3	9	3	3	7	9	2	7.10	3.00
AC05	3	3	3	4	5	5	5	2	1	5	1	5	8	1	7	5	4.20	1.03
AC06	1	1	6	1	6	1	1	1	6	2	6	2	2	9	8	6	4.33	2.03
AC07	6	6	1	4	2	4	6	3	2	4	2	4	5	4	3	8	6 .12	3.60
AC08	9	8	4	5	7	7	7	6	7	9	5	9	7	5	6	6	6.65	2.83
AC09	4	4	5	3	1	2	2	2	3	1	4	1	8	5	4	4	5.76	3.08
AC10	8	7	7	7	10	7	7	6	8	5	7	9	9	6	5	10	5.00	2.00
AC11	5	5	8	3	4	6	3	5	10	7	3	6	4	4	6	6	4.60	1.85
AC12	3	3	5	6	5	5	5	2	1	3	1	5	3	1	7	7	3.20	2.13
AC13	6	6	3	4	2	4	6	3	2	8	2	4	1	4	9	10	5.25	2.45
AC14	4	4	8	8	1	2	2	2	3	9	4	1	5	5	10	7	5.23	3.17
GM:																	5.21	2.45

ACC: Accessions; MR: Mean of rank; SDR: Standard deviation of rank; GM: Grand mean of rank.

DSS21: Drought susceptibility score at day 21; PPW21: Percentage of plants wilted at day 21; LWI21: Leaf wilting index at day 21; RRWC: Percent reduction in relative water content by day 14;

SCND: Stomata conductance; PREC: Percentage recovery; STG: Stem greenness; STR: Stem re-growth; RTLL: Percent reduction in leaflet length by day 7;

Estimates of genetic parameters of accessions of cowpea screened under drought stress at the flowering stage

The results for estimates of genetic parameters are presented in Table 10. Genotypic variance (GV) ranged from 0.004 in LWI14 and 21 to 600.14 in PPW21, while the phenotypic variance (PV) fell between 0.006 in LWI21 and 866.30 in PPW21. Genotypic coefficient of variation (GCV = 105.69%) and phenotypic coefficient of variation (PCV = 103.01%) respectively were highest in PREC. However, the lowest GCV (1.58%) and PCV (5.67%) were obtained in the IRWC. Heritability in the broad sense (H^2b) ranged from 7.45% in IRWC to the highest (90.68) in STG. Furthermore, genetic advance as a percent of the mean (GAM) ranged from the lowest (0.01%) in IRWC to the highest (172.32%) in PPW14. Heritability was high in all wilting traits except in LWI7 and 14. It was high for all recovery parameters and yield traits except for the number of seeds per plant and low for all morphological and physiological parameters except for stomatal conductance.

Table 10. Estimation of genetic parameters of accessions of cowpea screened at seedling and flowering stages.

TRAIT	MEAN	GV	PV	GCV%	PCV%	H^2B%	GAM%
DSS14	2.45	1.25	1.86	40.08	48.71	67.76	63.29
DSS21	5.90	2.20	3.19	30.15	36.30	68.97	51.58
PPW14 (%)	21.68	370.04	446.74	92.61	101.76	82.83	171.52
PPW21 (%)	67.63	600.71	866.30	36.95	44.23	69.79	63.58
LWI7	0.25	0.02	0.03	40.00	56.57	50.00	58.27
LWI14	0.79	0.004	0.04	6.93	21.92	31.61	14.28
LWI21	0.95	0.004	0.005	5.77	7.44	60.00	9.19
IRWC (%)	79.05	1.97	25.39	1.58	5.67	7.65	0.01
RWC7 (%)	67.31	29.73	103.75	7.65	14.28	28.71	8.45
RWC14 (%)	48.12	46.54	136.09	13.26	21.97	36.48	16.47
SCND	83.55	190.07	299.06	15.57	19.39	64.54	25.77
PREC (%)	22.80	592.43	623.96	104.33	103.01	95.27	220.16
STG	2.68	5.59	5.82	86.04	87.84	90.68	173.61
STR	1.39	1.45	1.71	86.63	94.08	84.79	164.32
ITLL (cm)	10.45	0.32	1.66	4.82	10.97	19.28	4.36
TLL7 (cm)	10.52	0.28	1.65	4.59	11.15	16.97	3.89
ITLW (cm)	6.43	1.44	2.20	16.37	20.24	45.45	27.28
TLW7 (cm)	7.19	1.51	2.25	17.16	20.95	67.11	28.96
ISG (mm)	3.99	0.07	0.13	11.83	16.57	53.85	8.44
SG7 (mm)	3.57	0.01	0.25	2.13	10.66	4.00	0.87
SG14 (mm)	3.79	0.22	0.50	12.38	18.66	44.00	16.91
PPSET (%)	35.98	159.38	216.05	32.65	38.01	73.77	57.76
SPP	10.53	4.04	5.39	17.43	20.14	74.95	31.09
SDPL	38.53	281.92	470.81	37.71	48.73	59.88	60.11
PDL (cm)	15.39	2.62	3.02	09.52	11.05	72.16	17.41
SDYPL (g)	6.02	4.23	6.95	33.21	41.00	65.45	61.78
PODW (g)	0.31	0.012	0.020	29.42	37.09	53.63	48.53

IV. DISCUSSION

Accession differences for measured parameters under drought stress at the flowering stage

Drought is one of the most severe environmental stress, and it has a significant negative impact on crop yield. The consequence of drought stress can be visually observed, allowing different wilting intensities to be recorded on cowpea seedlings. This study revealed that moisture is a very important component in plant growth and reproduction. The high significant variability revealed by the ANOVA among accessions for all traits studied at the flowering stage indicated the existence of sufficient genetic variations among the accessions. This agrees with Abimiku, et al: (2021). Visual observation of wilting resulting from drought stress is possible in cowpea, and this allows the classification of genotypes based on the intensity of wilting. It was observed from the results that responses were accession-specific and time-dependent. Wilting parameters showed that as early as day 7, accessions AC02, AC03, AC04, AC07, AC08, AC10, AC12 and AC14 were already showing signs of wilting as conveyed in Nkomo et al. (2020), suggesting that susceptible accessions can easily be identified within the first week of withholding moisture (Pungulani et al., 2013). However, the most susceptible on day 21 were AC03, AC09, AC14, AC10, AC08 and AC05 with a combination of the highest PPW and LWI. This is similar to the responses of the accessions at the seedling and vegetative stages (Ajayi et al., 2018; 2020). The percentage of completely dead or wilted plants for each accession was also in accordance to the level of susceptibility of each accession as earlier reported [12].

After two weeks of re-watering, seedlings of some accessions completely recovered while some continued to die. Among these accessions that died completely were, AC02, AC04, AC07, AC09 and AC14. Those accessions in which wilting was slow at the beginning with consistently lower DSS and lower PPW at the end such as AC04, AC06, AC10, AC11 and AC12 had very high recovery rates while accessions with highest susceptibility never recovered. Accessions with high re-growth and stem greenness apparently possess an inherent mechanism to slow their moisture loss by minimizing transpiration rate much unlike those with high wilting scores. The importance of stem greenness to drought tolerance in cowpea has been previously emphasized (Guofo et al., 2017). Similar results were recorded during the seedling and the vegetative stages (Ajayi et al., 2018; 2020) and also in line with other reports on soybean, common bean, and cowpea. (Ibitoye, 2015; Nkomo et al., 2020).

Pungulani et al. (2013) stated that the physiological and morphological traits promoting water loss from leaf tissues might be a key factor responsible for early wilting among the accessions showing droopiness within seven days of being stressed. Stomata behavior at the initiation of drought stress might be a crucial factor since late wilting accessions were able to regulate stomatal opening to prevent water loss (Agbicodo, 2009). In this study, accessions had high stomatal conductance. Plants of the accessions with the slowest rate of wilting (AC04, AC05, AC06, AC09, AC11 and AC13 were among those with the lowest stomatal conductance. These results show that these accessions can maintain photosynthesis under restricted moisture through minimal stomatal openings as reported by Mukeshimana (2013).

The relative water content (RWC) was reduced among accessions at the flowering stage up to day 14 of drought stress. According to Alidu et al.; 2019, an RWC of above 40% among cowpea genotypes is considered one of the best indicators of drought tolerance. In the present study, the tolerant accessions possessed an RWC of between 50 and 67% in line with Alidu et al. (2019) for inbred lines of cowpea. Accessions with slow wilting had the highest RWC on day 14 of drought stress. Reduction of RWC between the initial and day 14 was generally the lowest among accessions with low wilting parameters. Maintenance of higher water status among tolerant accessions could be linked to lower stomatal conductance exhibited by them in line with the findings of Shanmugam et al. (2021) in rice. This result contradicts the findings of Agbicodo (2009) who observed no correlation between the leaf water status of cowpea plants and stomatal conductance under water deficit. Panda et al., 2022, observed that Plants growing under drought conditions can experience increased osmotic potential leading to a decrease of 60 – 80% in RWC, which can be most pronounced among the highly sensitive accessions. This is in agreement with the findings of this study. For example, the most sensitive accessions; AC10, AC03, and AC08, were among those in which RWC reduced the most as a result of drought.

Significant differences were observed among the accessions for morphological traits such as TLL and TLW under drought stress until day 7. The significant reduction in the TLL and TLW among the most susceptible accessions at day 7 indicates that drought stress led to reduced leaf area of existing leaves which in turn led to leaf shedding on the plants. The highly sensitive accessions were amongst those with the highest reduction in TLL and TLW (AC03, AC09, AC10 and AC12). These are similar to the findings of Samson and Helmut (2007) and also consistent with their responses at the seedling and vegetative stages (Ajayi et al., 2018; 2020). Accessions that are the most susceptible at the flowering stage were among those with the highest reduction of stem girth resulting from drought stress. These findings are in agreement with the findings of Abdou Razakou (2013) who conveyed that drought imposed on cowpea plants reduced their stem girth between 2.43% and 50%.

Severe drought has been found to cause a significant reduction in seed yield which is linked to a reduction in plant water status in many legumes (Garg et al., 2005). Significant genotypic differences were observed among the accessions for the number of pods, percentage of pod set, the total number of pods, seeds per pod, seeds per plant, pod length, seed yield, and pod weight at the flowering stage. The percentage pod set and the number of pods ranged from low to moderate among highly susceptible accessions. Those accessions with the highest reduction of RWC (AC03 and AC14) produced the lowest seed yield under imposed drought, while accessions exhibiting a lesser decrease in RWC set higher pod percentage, with higher number of seeds, and higher seed yield. Comparable outcomes were conveyed by Kumar et al., (2008). Agbicodo (2009) reported a significant reduction in grain, fodder, and total yields of cowpea, and stated that imposed drought at the early stages of flowering and pod formation enforced significant damage to plant functions and consequently total biomass yield. In this study, AC10 and AC12 which displayed the least levels of drought susceptibility at the flowering stage had a low highest pod set, the highest number of pods, and were among accessions with the highest seed yield. This indicated that these accessions maintained more tissue moisture by redirecting moisture to pod production rather than exhausting it on tissue build up.

Ranking based on key traits of accessions of cowpea screened for drought tolerance at the flowering stage
A high level of variations for all traits amongst accessions was responsible for the strength of the accession ranking in clearly separating accessions into different classes of tolerance. Determination of the most desirable drought-tolerant genotypes employing mean rank, the standard deviation of ranks, and rank-sum of parameters has been previously reported in crop species (Al-Rawi, 2016; Wasae, 2021). Accordingly, it is common for different traits to rank different accessions as tolerant. Hence, the determination of the most tolerant accessions needs to consider the mean of ranks in conjunction with their standard deviation for all parameters measured. Accessions exhibiting the lowest mean of ranks coupled with the lowest standard deviation of ranks are selected as the most drought– tolerant.

The coefficient of variations on genotypic (GCV), and phenotypic (PCV) levels, heritability, and genetic advance as a percentage of the mean (GAM) are important to divide phenotypic differences into genetic and non-heritable constituents. These parameters are important for trait improvement and as well as for the effective selection of genotypes for different environmental constraints (Ajayi et al., 2017a). In the study, GCV was revealed to be lower than PCV for all traits, also, both PCV and GCV were lowered under drought stress compared to the initial values among the wilting parameters except for RWC, TLL, and TLW, similar to the seedling stage (Ajayi et al., 2017a). The reduction of PCV and GCV by drought has been linked to the effect of the environment, suggesting that the performance of genotypes is better under normal growing conditions compared to drought stress (Sabiel et al., 2014). However, GCV and PCV increased under drought stress in the present study in RWC and all morphological traits as reported by Hefny (2013). The marginal differences between GCV and PCV among traits suggest that the traits are mostly governed by the genes. All traits demonstrated moderate to high heritability under the imposed drought. Heritability was higher under drought stress in traits such as LWI21, RWC14, and TLW7. Wilting parameters (except LWI), stomatal conductance, TLW7, and all the yield parameters (except seeds per plant) showing both high heritability and GAM under stress suggest that these traits can be used directly to select drought-tolerant cowpea. This is applicable in traits with moderate heritability and high GAM such as seeds per plant, LWI7, LWI14, and RCW14. These findings are similar to the reported data among the same accessions screened under drought stress at the seedling stage.

CONCLUSION

The need for fast, easy and effective selection criteria for drought tolerant cowpea accessions under controlled environments cannot be overemphasized. Integration of such techniques in breeding programmes will allow the screening of numerous varieties of cowpea at seedling stage in a relatively short time at low cost. Among all the traits studied, drought susceptibility scores, percentage permanent wilting, stem greenness and regrowth, number of leaves and stem girth were the best traits for use in the study of drought tolerance in seedlings of cowpea. Based on wilting scales and recovery parameters, the following classifications of cowpea accessions were made: 1. Highly Susceptible (AC03, AC08 and AC10) 2. Susceptible (AC09, AC05 and AC07) and 3. Moderately Susceptible (AC06, AC02, AC04 and AC01).

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