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COMPARISON OF PHENOTYPICAL AND PHYSIOLOGICAL RESPONSES OF COWPEA [*Vigna unguiculata* (L.) Walp.] GENOTYPES AS AFFECTED BY DROUGHT AND NORMAL CONDITIONS

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ABSTRACT

Production of cowpea [*Vigna unguiculata* (L.) Walp.] is often limited by the low rainfall. Identification of cowpea genotypes adapted to drought may be a feasible strategy to overcome the poor plant growth and production in the southern highland region (SHR). Two experiments were conducted; the first one was conducted during 2007, 2008 and 2009 under midseason drought (MSD) and late-season droughts (LSD) environments. In both seasons, the drought stress (DS) and non stress (NS) plots were grown adjacent to each other both in a similar design and plot size. Overall average of DII for the trials conducted in 2008, 2009 and 2010 were 0.352, 0.394 and 0.458 for MSD and 0.605, 0.615 and 0.661 for LSD indicating that under MSD experiments were subjected to medium drought stress while LSD experiments were subjected to sever drought stress. Phenotypical, physiological traits and quantitative indices of stress tolerance were identified at both environments. Eight IITA genotypes, promising genotypes and the farmer cultivar, based on high yielding under both NS and DS conditions were evaluated during 2010, 2011 and 2012 under relatively dry cropping seasons at eight locations; Dabab, Demnah, Hifan, Shikheen, Torpah, Qaidah, Aodain and the station representing low rainfall drought stress conditions. The most effective selection criterion, for identifying drought resistant for phenotypic yield were seed/plants, and for morphological and for physiological traits growth recovery resistance, relative water content, water use efficiency and proline content and for quantitative indices of stress tolerance we consider the susceptible tolerant index (STI) was the most useful trait can be used as selection criterion under both NS and DS as these traits were positively and significantly correlated trait with the yield under both non stressed (Yp) and

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stressed (Ys) environments. The results also showed that the IITA genotypes IT93K-503-1, IT97K-1069-6, IT98K-128-4, IT96K-610, IT98K-529, IT98K-499-39, IT00K-901-5 and IT98K-205-8 were the most tolerant genotypes and had superior performance under both non stressed (NS) and drought stressed (DS) environments in comparison with the local and other genotypes. By using stability analysis only IT93K-503-1, IT98K-128-4, IT96K-610, IT98K-499-39 and IT98K-205-8 were high average yields, with *b*-value of 1.00 and a very low (s^2d) approaching zero, low ecovalence value (W) and highly significant coefficient of determination (r^2). Coefficient of determination ranged between 53.1% for IT98K-529 and 83.6% for IT98K-128-3 suggesting that linear regression accounted for 53–84% variation in cowpea yield. Thus, these genotypes performed best across the environments indicating wide adaptability. These genotypes could be introduced to farmers in these agro-ecological zones.

Keywords: traits, drought tolerance indices, DLS, CSI, RWC, WUE, STI and stability indices

1. INTRODUCTION

The cowpea is grown in almost throughout the southern highland region (SHR) of Yemen under drought environments and, therefore subject to water scarcity due to poor rainfall distribution, that its productivity is so low that it fails to produce significant quantities of grain under severe droughts due to the likely climate change since the last thirty years of these region, and reaching to its maximum yield only < 500 kg ha^{-1}. While when improved cultivars are grown under optimal agronomic conditions high yields > 2000 kg ha^{-1}) can be obtained (Molaaldoila et al., 2009).

However, cowpea is the most grown crop under varied rainfall high variability in amount and distribution of rainfall and water stress conditions in the semiarid rainy season of the SHR - Taiz - Yemen, year-to-year fluctuations in the amount (annual precipitation ranges between 200-650 mm). The ability of crop cultivars to perform reasonably well in variable rainfall and water stressed environments is an important factor for stability of production under drought stress environments. In addition, droughts may occur during the cropping season in the early vegetative sage, midseason and late-season droughts in SHR - Taiz - Yemen, but midseason and late-season droughts is the most important because it impacts directly on yield formation.

Cowpea has been indicated to be one of the most drought tolerant crops (Ehlers & Hall, 1997; Singh *et al.*, 1999a). Nonetheless, cowpea, still suffers from considerable yield reduction when exposed to severe drought stress during the vegetative growth and particularly during flowering and pod filling stages. Drought stress during flowering and pod filling is particularly important since it impacts negatively on flower development, pollination (Boyer & McPherson, 1975), pod setting and grain filling leading to reduced number of pods per plant and seed weight, and consequently low seed yield

Significant differences exist among cowpea genotypes in drought tolerance (Watanabe et al., 1998a; Mai-Kodomi et al., 1999ab; Singh et al., 1999b). There were significant differences in yield and yield components between genotypes in both non-stress and drought-stress conditions. The genotypes with severe yield reduction also had severe reduction in number of pods per plant. Greater yield reduction was mostly recorded in high yielding genotypes. In general, the low yielding genotypes did not register severe yield reduction. The number of seeds per pod and hundred seed weight were in general less reduced by drought stress (Chiulele, et al., 2011).

Challenges and opportunities for enhancing sustainable cowpea production for drought adaptation is one of aim of the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. In this context, A large number of cowpea germplasm accessions have been developed and evaluated for drought tolerance in various parts of the world and desirable lines identified. In addition, more drought-tolerant breeding lines still need to be evaluated in order to identify new and better adapted sources of drought tolerance under various environmental conditions.

The most common method of screening cowpea genotypes for drought tolerance has been the use of: visual symptoms of wilting, plant death and recovery (Watanabe, 1998b; Watanabe & Terao, 1998; Mai-Kodomi *et al.,* 1999a,b; Singh *et al.,* 1999a,b; Muchero *et al.,* 2008), physiological and morphological responses (Chiulele & Agenbag, 2004), morphological and yield response of genotypes under stressed and non-stressed conditions (Matsui & Singh, 2003). This requires therefore, the identification of specific traits under adequate moisture that are easy to measure and are associated with drought tolerance (Fischer and Wood, 1979). Furthermore, in plants, a better understanding of the morpho-anatomical and physiological basis of changes in water stress resistance could be used to select or create new varieties of crops to obtain a better productivity under water stress conditions (Nam et al., 2001; Martinez et al., 2007).

The most effective selection criterion, among various morphological, physiological, phenological, yield, and yield related traits for identifying drought resistant genotypes was average seed yield (the arithmetic and geometric) of DS and NS environments (Abebe *et al*., 1998: Ramirez-Vallejo and Kelly. 1998). Also, through a good drought tolerance index one should be able to identify superior genotypes in both drought prone and favorable environments. On the other hand, stress tolerance index has been indicated to be the most suitable for screening genotypes for drought tolerance because it enables the identification of high yielding and drought tolerant genotypes. Very few studies have used quantitative indices of stress tolerance to assess drought tolerance in cowpea (Chiulele, et al, 2011). Therefore, this study was conducted to assess cowpea genotypes for variability in drought tolerance using the quantitative indices of stress tolerance such as stress intensity, mean productivity, tolerance index, stress susceptibility index, geometric mean productivity and stress tolerance index.

Therefore, the objectives of the present study are (i) To identify drought resistant genotypes previously developed in IITA and local cultivars, (ii) Attempt to identify optimal selection criterion as morpho-physiological traits that might impart "drought resistance" (iii) To assess cowpea genotypes for variability in drought tolerance using the quantitative indices of stress tolerance and (iv) To study the response and stability of cowpea cultivars grown in diverse cowpea growing SHR - Taiz regions of Yemen using stability indices.

2. MATERIALS AND METHODS

2.1. Experimental environments:

The severest environmental conditions at Southern Highland Region (SHR)- Yemen (Taiz) regions (latitude 13°36' N, longitude 44°12' E, longitude, 1200 m above sea level). Two drought types occur in the cropping seasons in (SHR)- Yemen (Taiz); the first type is midseason drought (MSD) (started from January-February and ended in April-May) and the second type is late-season droughts (LSD) (started from May-June and ended in July-August). MSD is characterized by low soil moisture in the beginning of the season and high rainfall occurs in the end of the season, while LSD is characterized by high rainfall occurs in the beginning of the season particularly during the pod set and low soil moisture in the end of the season. Monthly rainfall during low rainfall growing season was recorded.

By taking advantage of this situation, observation trials on > forty genotypes deserved from (IITA) made during summer high rainfall season 2006 at research station and 14 genotypes in addition two local and recommended cultivars (Taiz-401 and Awlaki) were selected based on yield, morphological and physiological traits and disease infection that might or might not impart drought resistance. Thereafter, two trials were conducted; the first one was conducted during MSD and LSD on 2007, 2008 and 2009. The trial were planted as a completely randomized block design with three replication and genotypes planted in six rows of 5 m length with a row-to-row distance of 0.6 m and a plant-to-plant spacing of 0.20 m.

2.2 Plant phenology and production parameters:

Plant phenology, production and agronomic scores were recorded when the genotypes reached physiological maturity in both seasons. After three weeks of drought stresses leaf area (cm^2), dry weight of the roots drought weight g $plant^{-1}$ (RDW) and shoots drought weight g $plant^{-1}$ (SDW) were determined and the root/shoot ratio of plant was calculated for dry weights at the sampling stage. At harvest: seed yield (kg ha^{-1}), 100 seed weight (g $plant^{-1}$), pod numbers/plant, seeds numbers/plant and harvest index were recorded and values for the former two were adjusted to 14% moisture by weight. Days to 50% flowering (50%F) that is number of days to 50%F was also recorded. Harvest index (HI) that is seed biomass dry weight at harvest/total shoot biomass dry weight at mid-pod-filling × 100.

2.3 Visual observations, Morphological and physiological traits

After three weeks of drought stresses leaf numbers/plant (LNP), stem diameter in cm (SD), delayed leaf senescence (DLS), that is a measure of the amount of leaf area that remained "fired". We scored leaf firing at regular intervals during the stress period on a 1 to 5 scale. where 5 = less than 20 percent of leaf-area fired , and 1 = over 80 percent leaf area fired. Growth recovery resistance (GRR) that is ability of a genotype to produce new leaves and seed after rain, we scored recovery resistance on a 1 to 5 scale where 5 = over 80 percent of the plants in a row recovered and 1 = less than 20 percent recovered. Stay green (SG) that is a measure of the amount of leaf area that remained green where the green leaf during the stress period on a 1 to 5 scale, where 1 = less than 20 percent of leaf-area were green, and 5 = over 80 percent leaf area were green.

Relative water content % (RWC) is a useful measure of the physiological water status of plants was determined according to the method of (Teran, and Singh, 2002). Water use efficiency kg ha^{-1} mm^{-1} (WUE): was estimated on the basis of dividing seed yield ha^{-1} by the effective total rainfall (mm). Stomata conductance, was measured in fully expanded, uppermost leaves of plants using an infrared gas analyzer (LiCOR-6200, Portable Photosynthesis System, Nebraska, USA). Ion leakage (IL) in term of percent of injury %: IL was determined according to the method of Premachandra *et al.* (1991). Chlorophylls and chlorophyll stability index (CSI) were estimated according to the method of Welfare *et al*. (1996). Proline content μ mole g^{-1} (PC) was determined according to the method of Bates *et al.* (1973).

2.4. Quantitative Drought resistance indices

Drought resistance indices for genotypes based on their performance in DS and NS environments were estimated. Percent reduction (PR) due to DS in relation to the NS environment was also determined for the yield (Rosielle and Hamblin, 1981). Drought susceptibility index (DSl) for seed yield for each genotype was calculated as follows; DSl = (1 - Yd/Yn)/Dll, where Yd. and Yn, are average yields of a given genotype in DS and NS environments, respectively (Fischer and Maurer. 1978). Stress tolerance (TOL) as the differences in yield between the stress (Ys) and non-stress environments (Yp), Geometric average (GM) was determined for seed yield. as GM =

(NS x DS) and average productivity (MP) as the average yield of Ys and Yp. STI was determined as [(Yp) . (Ys)/(Yp)2], which can be used to identify genotypes that produce high yield under both stress and non-stress environments (Fernandez, 1992).

2.5. Stability Analysis

Eight IITA genotypes, promising genotypes and the farmer cultivar, were evaluated during 2010, 2011 and 2012 under relatively dry cropping seasons at eight locations; Dabab, Demnah, Hifan, Shikheen, Torpah, Qaidah, Aodain and the Station representing low rainfall drought stress conditions. The length of each row was 5 m. with 6 m^2 harvested for yield. All trials were grown in fields with residual soil fertility. Plots were kept free from weeds, diseases and insect pests by averages of a hand labor. A randomized complete block design with three replications was also used for each location under farmer agricultural management.

In both experiments, the drought stress (DS) and non stress (NS) plots were grown adjacent to each other both in a similar design and plot size. The NS plots received normal irrigation (approximately 40-45 mm of water) 2-5 d before planting and an additional irrigation 10 to 12 d after emergence. The DS plots received 2-3 additional irrigations in the beginning of the experiments and thereafter irrigations were stoped. The drought intensity index (DII) for each growing season was calculated as DII = (I - Xds/Xns), where Xds and Xns are the average seed yield of all genotypes under DS and NS environments, respectively. Overall average of DII for the trials conducted in 2008, 2009 and 2010 were 0.352, 0.394 and 0.458 for MSD and 0.605, 0.615 and 0.661 for LSD indicating that under MSD experiments were subjected to medium drought stress while LSD experiments were subjected to sever drought stress.

2.6. Analysis of variance and correlation among variables:

Multiple correlation coefficients among different phenotypical, morphological and physiological traits, drought indexes were also determined. For data analysis, the cropping seasons and replications were considered as random effects and DS versus NS environments and cowpea genotypes as fixed effects (McIntosh. 1983). All data were analyzed by a SAS statistical package. In this paper, only the nine promising genotypes (IT93K-503-1, IT97K-1069-6, IT98K-128-4, IT96K-610, IT98K-529, IT-98K-499-39, IT00K-901-5, IT98K-205-8, IT00K-718-6, IT00K-898-5, IT00K-898-5, IT00K-1262,) were presented and the data which is related to the percentage of reduction and increments of overall average yield components of DS as compared with NS were not shown in tables.

3. RESULTS AND DISCUSSION

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3.1. Performance of cowpea genotypes under DS and NS conditions.

High significant differences among genotypes in their response to the drought stress intensity (MSD, LSD) and DS conditions for yield (Table 1) and yield components (Table 2). The genotypes with severe yield reduction also had severe reduction in pods number/plant, seeds number/plant, and 100 seed weight. Greater yield reduction was mostly recorded in LSD in comparison with MSD and NS genotypes. The reduction in seed yield, in pods number/plant, seeds number/plant, and 100 seed weight was to the extent of 42%, 30.4%, 40.2%, 25.4% and 50.0%, 54.8%, 60.3%, 38.2% under MSD and LSD in comparison with NS condition. In contrast, harvest index was reduced significantly to about 25% and 17% when genotypes grown under MSD and LSD in comparison with NS condition. This results indicated that seeds number/plant is the most yield trait that effected highly by drought condition and the biological yield was reduced more than seed yield under both drought stress.

From these results cowpea genotypes can be classified into four groups; the first group were express uniform superiority in both uniform superiority in both (normal and drought) conditions, these genotypes were (IT93K-503-1, IT98K-131-2, IT99K-316-2, IT96K-610, IT98K-529, IT98K-499-39, IT00K-901-5, IT98K-205-8) and we can consider them as non stress and drought stress tolerant NS-DST genotypes; the second group were the genotypes that perform favorably in MSD drought stressed environments and we can consider them as moderately drought stress tolerant MDST genotypes, these genotypes were (IT97K-1069-6, IT98K-128-3, IT97K-568-18); the third group were the genotypes that perform favorably only in non drought stressed conditions and we can consider them as non drought stress NDS genotypes, these genotypes were almost (IT00K-718-6, IT00K-898-5, IT00K-1263 and Taiz-401) and the fourth group were perform poorly under both NS and DS condition and these genotypes were local cultivars (Awlaki-1) and others and we can consider them as drought susceptible (DSUS) genotypes. Chiulele, et al., (2011) classified cowpea genotypes into four groups; high yielding and drought tolerant (not reduced by drought) (group A), high yielding and drought susceptible genotypes (reduced by drought) (Group B), low yielding and drought tolerant genotypes (group C) and low yielding and drought susceptible genotypes (group D).

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Table 1. Overall average of yield under normal stress (Yp) and drought stress (Ys) environments, harvest index (%) of cowpea genotypes as affected by MDS and LDS stresses and NS conditions

Genotypes/	NS		MSD		NS		LSD	
Traits	Yp	HI	Ys	HI	Yp	HI	Ys	HI
IT-98K-503-1	1.845	28.9	1.316	32.7	1.491	29.8	0.909	41.9
IT00K-1263	1.974	27.6	1.375	34.1	1.506	32.7	0.946	43.0
IT96K-610	1.990	32.3	1.359	37.4	1.535	36.9	0.974	47.5
IT98K-131-2	1.942	25.6	1.304	34.1	1.484	31.8	0.969	39.8
IT98K-205-8	1.841	38.0	1.396	31.8	1.446	40.0	0.918	39.9
IT00K-901-5	1.974	29.2	1.453	33.6	1.548	33.1	0.953	41.9
IT99K-316-2	1.803	33.3	1.339	36.3	1.577	38.6	0.972	44.7
IT98K-499-39	1.926	28.2	1.378	35.0	1.456	34.5	0.882	37.3
IT97K-568-18	1.616	33.5	1.216	36.4	1.242	36.0	0.891	36.3
IT98K-128-3	1.509	28.3	1.342	34.6	1.217	35.4	0.968	41.3
IT00K-898-5	1.545	29.0	1.252	30.9	1.264	36.4	0.812	35.9
IT98K-529-1	1.845	27.7	0.774	27.6	1.393	30.9	0.716	32.7
IT97K-1069-6	1.859	27.0	0.784	27.6	1.396	24.4	0.562	35.5
IT98K-628	1.818	29.7	0.622	26.6	1.425	31.8	0.526	33.0
Taiz-401	1.746	26.5	0.460	24.2	1.452	32.3	0.245	26.0
Awlaki-1	0.959	21.8	0.446	19.9	1.090	27.2	0.184	21.8
Average	1.662	28.5	0.961	29.9	1.351	32.8	0.676	34.4
LSD	212.0	4.3	245.5	5.9	0.230	6.8	0.238	8.7
CV%	19.4	15.9	17.5	13.7	16.6	14.7	12.7	12.8

Yield reduction of NS-DST genotypes were range between 24.2-32.9%, and 34.7-39.4% while yield reduction of DSUS genotypes between 53.5 and 83.2% under MSD and LSD stresses, respectively. Evidently, water stress reduced yield to less than a half in other genotypes, while all the local cultivars were very drought susceptible as they had not produced any yield in all drought conditions except Taiz-401 and Awlaki-1. However, NS-DST genotypes were proved significant and superior yield over the other genotypes in all drought conditions in yield (Table 1).

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Table 2. Overall average of pods number/plant , seeds number/plant, 100 seed weight (gm), of cowpea genotypes as affected by MDS and LDS stresses and NS conditions

Genotypes	Pods number/plant			Seeds number/plant			100 Seed Weight		
/Drought type	NS	MDS	LDS	NS	MDS	LDS	NS	MDS	LDS
IT-98K-503-1	15.4	11.8	9.6	72.0	44.2	33.3	17.3	13.6	10.4
IT00K-1263	15.2	11.7	9.2	75.9	44.9	30.7	18.6	15.1	11.1
IT96K-610	17.4	13.7	9.7	83.2	68.4	36.6	19.6	15.8	10.3
IT98K-131-2	16.1	11.6	9.6	84.7	51.4	32.1	19.2	15.5	9.3
IT98K-205-8	16.1	11.1	8.8	86.4	47.8	28.2	16.7	14.4	9.9
IT00K-901-5	15.5	11.9	9.1	79.9	46.8	31.3	17.5	14.4	9.7
IT99K-316-2	16.2	12.9	9.1	79.4	56.7	33.8	19.7	14.4	9.9
IT98K-499-39	14.8	11.6	8.5	86.1	46.1	30.2	16.4	13.7	10.1
IT97K-568-18	13.1	9.4	6.3	64.8	45.6	25.6	15.3	11.3	9.5
IT98K-128-3	13.4	10.7	8.8	62.5	51.6	24.8	14.8	11.9	10.9
IT00K-898-5	14.1	9.8	6.4	54.6	48.2	24.0	15.7	11.0	10.2
IT98K-529-1	15.8	7.9	5.8	71.7	32.2	19.4	15.1	8.7	7.4
IT97K-1069-6	16.5	8.0	4.9	76.0	28.5	17.2	15.3	9.7	7.4
IT98K-628	15.9	7.8	4.4	72.3	31.9	14.2	13.1	7.4	6.8
Taiz-401	14.1	6.9	3.7	27.9	22.1	12.8	14.5	5.7	6.3
Awlaki-1	11.3	5.9	2.3	26.0	24.9	8.6	15.3	13.3	5.8
Average	14.5	9.1	6.0	62.1	38.8	21.0	15.5	10.7	8.4
LSD	3.5	3.6	3.2	26.7	26.2	18.9	3.7	4.8	1.5
CV%	16.3	14.8	13.5	18.2	12.8	11.3	14.1	16.2	13.7

The reduction in yield was a result of reduction in pods number/plant, seeds number/plant, and 100 seed weight and among the superior genotypes, NS-DST genotypes were recorded significant and superior in the average number of pod numbers/plant, seeds numbers/plant, and 100 seed weigh over the other genotypes under both drought conditions (Table 2). These findings are in agreement with those of Chiulele, et al., (2011) who indicated that the reduction in grain yield of cowpea was a result of reduction in number of pods and seed weight due to detrimental effects of drought on pod set and grain filling. In addition, Hamidou et al. (2007) found that number of pods/plant and number of seeds/plant decreased after drought treatment by 57% in the glasshouse and by 64% in the field when compared to non-stressed plants. Genotypic differences were observed for both of the yield components.

genotype Taiz-401 was more productive than Awlaki-1 under LSD, while no significant differences between the two genotypes under MSD conditions.

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However, moderate to high drought stress can reduce biomass, number of seeds and pods, harvest index, seed yield, and seed weight in bean (Acosta-Gallegos and Adams, 1991; Ramirez-Vallejo and Kelly, 1998).

3.2. Dry matter accumulation and phenotypic traits

3.2.1. Roots, shoots dry weights and roots/shoots ratio

Roots and shoots dry weights of cowpea genotypes were significantly decreased in response to MSD and LSD stresses as compared to NS conditions. Therefore, 40.3% and 63.8% decreases in SDW, 21.7% and 34.4% decreases in RDW and 23.4% and 44.3% decreases in S/R ratio were observed in response to MSD and LSD stresses in comparison to NS condition, respectively. However, the superior NS-DST genotypes were proved significant and superior in SDW and RDW and the increases were to the extent of 31.7%, 52.5%, 27.2%, 32.6%, and 6.5%, 29.8% over the DSUS genotypes under both MSD and LSD drought stress conditions, respectively. Interestingly, although there are no significant differences among genotypes in root/shoot ratio under NS and MSD conditions, genotypes varied extensively and significantly in S/R ratio in response to LSD (Table 3). These results indicated that the inhibitory effects of drought stress on shoot was more than root.

This result is supported by the findings of Kage et al. (2004) who reported that productivity of crops under drought stress condition is strongly related to the dry matter partitioning in the plant and the spatial and temporal root distribution. Drought stress mostly reduced leaf growth and increases dry matter allocation into root fraction, leading to a declining shoot/root ratio (Wilson, 1998). Root/shoot ratio decrease in the present study has been found to be similar as earlier reported by Hussain *et al.* (2009). On the other hand, White and Castillo (1992) found variation with shoot genotype, but the effect on growth and yield under drought was found to be small, compared with the effect of root genotype. However, significant differences exist among cowpea genotypes in the highest values of RDW were recorded by TN88-63 in both the control and water-stressed conditions with 2.08 and 0.59 g respectively. The inhibitory effects of drought stress on plant growth have been frequently recorded in other works using various plant species (Aly *et al.,* 2012).

Table 3. Overall average of shoot dry weight and root dry weight (gm) and shoot root ratio of cowpea genotypes as affected by MDS and LDS stresses and NS conditions

Genotypes	Shoot dry weight			Root dry weight			Shoot root ratio		
/Drought type	NS	MSD	LDS	NS	MSD	LDS	NS	MSD	LDS
IT-98K-503-1	38.4	22.1	14.1	1.19	0.89	0.84	32.3	24.8	16.7
IT00K-1263	37.5	20.5	15.2	1.06	1.01	0.86	35.5	20.4	17.8
IT96K-610	36.4	26.5	18.3	1.40	1.19	0.95	26.0	22.2	19.2
IT98K-131-2	38.7	22.5	16.7	1.31	1.02	0.92	29.6	22.1	18.1
IT98K-205-8	38.1	19.5	14.9	1.19	1.03	0.69	31.9	18.9	21.8
IT00K-901-5	37.9	22.0	16.9	1.20	1.06	0.85	31.5	20.8	19.7
IT99K-316-2	40.6	24.9	17.8	1.18	1.07	0.95	34.5	23.2	18.8
IT98K-499-39	36.5	19.6	15.4	1.16	0.86	0.66	31.6	22.7	23.3
IT97K-568-18	31.1	18.0	12.4	1.11	0.77	0.65	28.1	23.3	19.1
IT98K-128-3	31.4	19.3	11.0	1.02	0.72	0.78	30.8	26.6	14.1
IT00K-898-5	32.4	17.6	10.7	1.09	0.71	0.86	29.6	24.9	12.4
IT98K-529-1	27.4	17.7	9.7	0.90	0.77	0.46	30.4	22.9	21.2
IT97K-1069-6	25.8	18.0	9.4	0.91	0.77	0.57	28.4	23.3	16.3
IT98K-628	25.2	16.3	7.7	0.92	0.77	0.56	27.3	21.0	13.9
Taiz-401	26.1	14.8	7.8	0.96	0.74	0.53	27.3	20.1	14.8
Awlaki-1	26.1	14.4	7.6	0.86	0.71	0.62	30.3	20.2	12.3
Average	30.3	18.1	10.9	1.01	0.79	0.66	29.8	22.8	16.6
LSD	7.3	6.3	4.7	4.55	2.41	2.73	NS	NS	2.21
CV%	11.3	13.6	10.6	14.6	12.8	15.6	17.7	13.4	18.5

3.2.2. Leaves number/plant, leaf area, and stem diameter

The results showed that there was significant genotypic differences in leaves number/plant, leaf area, and stem diameter between genotypes under both MSD and LSD conditions. However, number/plant, leaf area, and stem diameter reduced significantly to the extent of 26.4%, 33.7% and 26.1% under LSD in comparison with MDS condition. These results indicated that the inhibitory effects of drought stress on leaf area > leaves number/plant > stem diameter. However, the NS-DST genotypes were recorded significant and superior in the average of leaves number/plant (23.9 and 27.4%), leaf area (14.0 and 24.0%), and stem diameter (31.5-39.0%) in comparison with DSUS genotypes under both MSD and LSD, respectively (Table 4). These results confirm those of Omae et al. (2007), Samson and Helmut (2007) and Abdou Razakou et al. (2013). who reported that water stress had the highest depressive effect on leaves number/plant, leaf area, and stem diameter and significant differences exist among cowpea genotypes in leaves number/plant, leaf area, and stem diameter under drought tolerance.

3.2.3. Days to 50% flowering

Days to 50% flowering of NS-DST genotypes were significantly decreased by MSD and LSD stresses as compared to NS conditions and was earlier under MSD in comparison with LDS condition by 6.2%. Therefore, the most resistant genotypes (NS-DST) under LSD were earlier than the most susceptible genotypes (DSUS) by about 5.8 (days to 50% flowering was between 44.4 and 50.2 days) and 8.5 days (days to 50% flowering was between 48.7 and 41.8 days) under both MSD and LSD conditions, respectively. Meanwhile, among NS-DST genotypes the earliest flowering days of 41.2 days recorded for IT98K-128-3 and IT97K-499-35 while 49.5 and 52.3 days was the longest recorded in the local cultivar Awlaki-1 under both MSD and LSD conditions, respectively. According to Ishiyaku and Aliyu, 2013, 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 the optimum and stressed conditions, respectively (Table 4). In addition, they found genotypic differences in days to 50% flowering, the earliest flowering days of 40.17 days recorded for IT97K-499-35 for stressed condition while 48.17 days was the longest recorded in IT97K-1069 and IT98K-412-13.

Table 4. Overall average leaves number/plant, leaf area (cm^2), stem diameter (cm) and 50% Flowering of cowpea genotypes as affected by MDS and LDS stresses and non stress conditions

Genotypes	Leaves number/plant		Leaf area		Stem diameter		50% Flowering	
Drought types	MSD	LDS	MDS	LDS	MDS	LDS	LDS	MDS
IT-98K-503-1	51.7	40.3	45.0	29.3	3.75	3.04	46.2	42.0
IT00K-1263	56.7	36.6	48.9	30.8	4.03	3.06	42.0	40.2
IT96K-610	49.2	38.9	48.3	36.5	4.75	3.33	43.8	41.7
IT98K-131-2	46.5	33.6	52.6	33.7	4.69	3.14	45.3	43.1
IT98K-205-8	52.7	37.3	46.6	29.3	3.98	3.58	44.8	42.5
IT00K-901-5	50.5	35.3	50.8	32.8	3.94	3.25	43.6	41.5
IT99K-316-2	53.7	38.1	50.1	32.2	4.63	3.24	47.6	43.6
IT98K-499-39	46.4	32.2	49.8	34.3	3.56	3.04	42.0	40.2
IT97K-568-18	51.2	37.5	44.3	36.8	3.48	2.74	43.7	42.0
IT98K-128-3	48.4	36.3	46.7	33.5	3.52	2.70	46.7	41.6
IT00K-898-5	50.3	34.7	47.3	35.8	3.90	2.68	45.5	46.5
IT98K-529-1	49.1	26.1	37.3	36.0	2.84	2.23	49.1	47.8
IT97K-1069-6	49.0	30.0	35.6	32.2	2.90	2.17	42.5	44.4
IT98K-628	48.9	28.8	36.7	27.9	2.92	2.06	46.8	47.1
Taiz-401	43.7	26.3	37.4	21.1	2.85	1.80	51.5	49.6
Awlaki-1	38.9	28.2	37.8	21.5	2.79	2.01	52.3	49.5

Average	48.0	31.8	42.3	31.1	3.3	2.5	46.8	45.2
LSD	1.18	1.31	4.3	3.9	10.4	1.38	5.664	3.032
CV%	15.7	13.5	14.2	11.4	13.1	15.7	17.9	19.7

3.3. Visual observations, Morphological and physiological Traits

3.3.1. Delayed leaf senescence (DLS), growth recovery resistance (GRR), and stay green (SG)

The visual observations in 2007, 2008 and 2009 had clearly demonstrated that there were marked differences in the response of these cowpea genotypes to water deficit. The results of *DLS, GRR* and *SG* scores showed that the most genotypes resistant NS-DST genotypes had between 2.9 , 3.6 and 3.1 under MSD and had between 2.4 , 3.2 and 3.4 under LSD stress, respectively as well as those of most susceptible genotypes resistant were 2.1, 2.3, and 1.6 under MSD and had between 1.3 , 1.6 and 1.3 under LSD stress, respectively. These results

indicated that the inhibitory effect under LSD stress was more harmful than MSD drought and more harmful on the DSUS genotypes than NS-DST genotypes, it was to the extent of 28.1%, 35.3%, and 48.0% under MSD and 48.4% , 54.7% and 62.5% under LSD stress, respectively (Table 5). The delayed leaf senescence (DLS) trait enhances plant survival after a mid-season drought damages the first flush of pods, which enables a substantial second flush of pods to be produced. Cultivars with high degree of DLS also have enhanced production of forage because their leaves remain green and attached to the plant until harvest (Agbicodo et al., 2009).

3.3.2. Water use efficiency (WUE), relative water content (RWC), stomata conductance (SC),

The results indicated that there were significant differences among the genotypes for RWC, WUE and SC (Table 6). RWC, WUE of NS-DST genotypes increased significantly in comparison with DSUS genotypes. The increment were to the extent to of 16.4% and 25.5% under MSD and 62.4% and 66.2% under LSD stress, respectively (Table 6). In contrast, SC reduced significantly in NS-DST genotypes in comparison with DSUS genotypes to the extent to of 52.8% and 44.0% under MSD and LSD stresses, respectively. Interestingly, RWC in MDS was higher than in LSD, while WUE and SC were higher under MDS than LSD condition. All this is in agreement with (Munne-Bosch., *et al*. 2006), who demonstrated that RWC decreased progressively under water deficit. Guerra *et al.* (2000) found that under severe drought stress, WUE in pinto cowpeas ranged from 1.5 to 4.4 kg ha^{-1} mm^{-1} water. Under favorable milder climatic conditions, the average WUE value was 10 kg ha^{-1} mm^{-1} water in the

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drought stress environment and 8.7 kg ha^{-1} mm^{-1} water in the non-stress environment. Using one of the drought adapted small seeded red genotypes (SER 16),

Table 5. Overall average delayed leaf senescence (DLS), growth recovery tolerance (GRT), chlorophyll stability index (CSI) and stay green (SG) of cowpea genotypes as affected by MDS and LDS stresses and non stress conditions

Genotypes/	DLS		GRT		SG		SC	
Drought types	MDS	LDS	MDS	LDS	MDS	LDS	MDS	LDS
IT-98K-503-1	2.59	2.04	3.31	2.64	3.03	3.52	112.4	68.5
IT00K-1263	2.72	2.26	3.59	3.37	2.98	3.48	105.8	67.6
IT96K-610	3.38	3.03	3.86	3.86	3.33	3.19	85.0	70.6
IT98K-131-2	3.04	2.60	3.47	3.50	3.30	3.53	89.5	66.1
IT98K-205-8	2.61	2.25	3.92	3.15	3.04	3.28	106.2	69.5
IT00K-901-5	2.91	2.37	3.29	3.37	3.06	3.50	95.1	79.9
IT99K-316-2	3.16	2.82	3.67	3.61	3.36	3.24	87.7	88.8
IT98K-499-39	2.61	2.21	3.88	2.37	2.94	3.64	114.0	89.1
IT97K-568-18	2.40	2.36	3.46	3.97	3.14	2.64	119.9	93.7
IT98K-128-3	2.38	2.45	3.24	2.15	2.83	3.02	115.0	96.9
IT00K-898-5	2.27	3.34	3.28	2.28	3.06	3.04	118.7	99.5
IT98K-529-1	2.24	1.71	3.17	2.05	1.95	2.26	124.8	104.2
IT97K-1069-6	2.13	1.62	3.07	2.10	1.65	2.35	124.5	109.7
IT98K-628	2.13	1.51	2.61	2.02	1.63	1.38	125.0	104.0
Taiz-401	2.02	1.25	2.34	1.33	1.62	1.34	131.4	115.6
Awlaki-1	2.06	1.03	2.08	1.05	1.63	1.13	147.0	124.1
Average	2.34	2.03	3.08	2.29	2.38	2.40	120.8	102.6
LSD	1.18	0.6	0.29	1.73	1.42	1.77	11.3	11.7
CV%	15.7	13.2	13.8	14.9	11.7	17.60	17.2	14.8

Builes *et al*. (2011) reported that WUE values up to 9.2 kg ha^{-1} mm^{-1} water under drought stress. All other factors being equal, genotypes with high WUE will survive and grow better in water-limiting environments than genotypes with low WUE. However, in nature, all other factors are rarely equal. In our experiment, WUE in the NS-DST were 5.11 – 5.70 and 2.65 – 2.91 kg ha^{-1} under MSD and LSD stresses, respectively..

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Table 6. Overall average relative leaf water content % (RWC), water use efficiency (WUE), stomata conductance (SC) and leaf ion leakage (LIL) of cowpea genotypes as affected by MDS and LDS stresses and non stress conditions

Genotypes	RWC		WUE		CSI		LIL	
/Drought type	MDS	LDS	MDS	LDS	EDS	MDS	MDS	LDS
IT-98K-503-1	65.9	51.5	5.16	2.73	3.37	2.64	0.25	0.36
IT00K-1263	66.0	53.2	5.39	2.84	3.25	2.70	0.21	0.36
IT96K-610	72.8	58.3	5.33	2.92	3.65	2.98	0.25	0.33
IT98K-131-2	68.3	54.8	5.11	2.91	3.35	2.70	0.27	0.35
IT98K-205-8	64.8	52.9	5.47	2.76	3.51	2.65	0.29	0.39
IT00K-901-5	65.6	51.4	5.70	2.86	2.80	2.72	0.30	0.36
IT99K-316-2	71.2	56.5	5.25	2.92	3.26	2.88	0.22	0.34
IT98K-499-39	65.9	51.9	5.40	2.65	2.88	2.69	0.28	0.38
IT97K-568-18	62.7	50.2	4.77	2.68	2.50	2.40	0.31	0.40
IT98K-128-3	63.8	51.0	5.26	2.91	2.42	2.44	0.32	0.38
IT00K-898-5	63.9	50.6	4.91	2.44	2.26	2.46	0.33	0.39
IT98K-529-1	62.8	47.7	3.03	2.15	1.44	1.29	0.32	0.49
IT97K-1069-6	61.8	46.5	3.07	1.69	1.31	1.01	0.33	0.48
IT98K-628	61.7	43.0	2.44	1.58	1.98	0.95	0.34	0.57
Taiz-401	55.5	41.1	1.80	0.73	1.91	0.84	0.35	0.52
Awlaki-1	52.3	36.0	1.75	0.55	1.80	0.73	0.39	0.54
Average	62.1	47.4	3.8	2.0	2.18	1.77	0.32	0.45
LSD	7.1	9.4	2.20	1.43	0.14	0.37	0.13	0.19
CV%	12.3	17.8	27	17.8	12.6	17.8	15.5	14.0

3.3.3. Chlorophyll stability index (CSI), leaf ion leakage (IL), and Proline Content (PC)

The range in *CSI* among genotypes and cultivars in the stress condition was very broad 1.90 – 3.26 and 0.84 – 2.74 under MSD and LSD stresses, respectively indicating that there were considerable differences among the tested genotypes and cultivars in their ability to produce chlorophyll pigment in comparison with drought stress condition (Table 6). *CSI* of NS-DST genotypes were higher than to the extent to 41.8% and 69.4% under both MSD and LSD stresses, respectively (Table 7). Significant differences among cowpea lines were found in chlorophyll stability index CSI under drought stress (Anyia and Herzog, 2004).

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One of the expressions of membrane damage in the leakage of some cell components; in this work, *Leaf Ion leakage LIL* was assessed under both MSD and LSD stresses i.e. increased or decreased in accordance with the rhythm of membrane stability index. Also, the lost ions were proportional with the level of stress. The results of ion leakage showed that the most resistant genotypes NS-DST genotypes had significantly low *LIL* between 0.26 – 0.36 and 0.26 – 0.43 at MSD and LSD stresses , respectively as well as those of most susceptible genotypes resistant was 0.36 and 0.54 at MSD and LSD stresses (Table 6), respectively. However, *LIL* of the investigated plants was severely deteriorated by drought stress. The stressed plants exhibited significantly high values of percentage injury which is based on a relationship between cellular constituents and the fraction which leaked out. Similar results were obtained by Al-Abssy and Al-Hakimi, 2010 who found increased rates of solute leakage into non-electrolyte media are commonly associated with stress and attributed to membrane modifications.

Proline Content (PC) accumulation had clearly demonstrated that there were marked differences in the response of these cowpea genotypes to water deficit. The results of proline content showed that the most resistant genotypes NS-DST genotypes had between 171.8 and 222.9 under both MSD and LSD stresses, respectively as well as those of most susceptible genotypes resistant was 138.5 and 167.8 under both MSD and LSD stresses, respectively. This results mean that the increment *PC* were to the extent of 19.4 and 24.7 under both MSD and LSD stresses (Table 7), respectively. Proline accumulation, particularly, is a well-known response to drought stress. It is also involved in cell osmoregulation, protection of proteins during dehydration and can act as an enzymatic regulator during stress conditions. Several authors are proposed proline accumulation under conditions of stress and that proline leads to the maintenance of membrane integrity (Parvaiz and Satyawat**,** 2008, Raifa *et al.,* 2009 and Rontein *et al*., 2002) genotypes tend to support greater environmental variations, so that genotypes derived from improvement programs tend to be more adapted to the specific cultivation conditions.

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Table 7. Overall average proline content (PC), percent of reduction (PR), drought susceptible index (DSI) and mean percent (MP) of cowpea genotypes as affected by MDS and LDS stresses and non stress conditions

Genotypes/	PC		PR		DSI		SI	
Traits	MDS	LDS	MSD	LSD	MSD	LSD	MSD	LSD
IT-98K-503-1	175.6	204.0	28.7	39.1	0.792	1.080	0.287	0.391
IT00K-1263	169.3	269.7	30.3	37.2	0.839	1.029	0.303	0.372
IT96K-610	179.9	235.5	31.7	36.6	0.876	1.012	0.317	0.366
IT98K-131-2	167.0	204.6	32.9	34.7	0.909	0.960	0.329	0.347
IT98K-205-8	171.2	218.2	24.2	36.5	0.669	1.011	0.242	0.365
IT00K-901-5	174.4	196.9	26.4	38.5	0.730	1.064	0.264	0.385
IT99K-316-2	160.1	209.2	25.7	38.4	0.711	1.061	0.257	0.384
IT98K-499-39	176.5	245.0	28.5	39.4	0.787	1.090	0.285	0.394
IT97K-568-18	172.1	210.4	24.7	28.3	0.684	0.782	0.247	0.283
IT98K-128-3	177.5	205.6	11.0	20.5	0.305	0.566	0.110	0.205
IT00K-898-5	155.5	242.9	19.0	35.8	0.524	0.990	0.190	0.358
IT98K-529-1	162.6	182.8	25.7	48.6	1.606	1.344	0.581	0.486
IT97K-1069-6	153.6	189.5	57.8	59.7	1.599	1.652	0.578	0.597
IT98K-628	156.2	180.6	65.8	63.1	1.820	1.746	0.658	0.631
Taiz-401	156.5	195.5	73.6	83.2	2.037	2.300	0.736	0.832
Awlaki-1	102.9	127.4	53.5	83.2	1.480	2.300	0.535	0.832
Average	157.3	198.9	35.0	45.2	1.023	1.249	0.370	0.452
LSD	0.29	0.59	7.9	0.320	0.268	0.249	0.251	0.74
CV%	14.6	19.8	53.5	14.5	1.520	16.7	19.7	15.1

3.4. Quantitative Drought Resistance Indice

The results shows that genotypes, averages for Yp and Ys under MSD and LDS, and drought resistance indices PR, SI and DSI exhibited rankings different than the other indices. However, the results of PR, DSI and TOL indices showed that NS-DST genotypes were the most drought resistant had significant low values of had PR and DSI in comparison with those of DSUS genotypes under both MSD and LSD stresses (Table 7).

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Table 8. Overall average of mean percent (MP), stress tolerance (TOL), geometric average (GMP), susceptible tolerant index (STI) of cowpea genotypes as affected by MDS and LDS of cowpea genotypes

Genotypes/	TOL		MP		GMP		STI	
Traits	MSD	LSD	MSD	LSD	MSD	LSD	MSD	LSD
IT-98K-503-1	0.53	0.58	1.58	1.20	1.56	1.16	0.290	0.162
IT00K-1263	0.60	0.56	1.67	1.23	1.65	1.19	0.324	0.170
IT96K-610	0.63	0.56	1.67	1.25	1.64	1.22	0.323	0.178
IT98K-131-2	0.64	0.52	1.62	1.23	1.59	1.20	0.302	0.172
IT98K-205-8	0.45	0.53	1.62	1.18	1.60	1.15	0.307	0.158
IT00K-901-5	0.52	0.60	1.71	1.25	1.69	1.21	0.342	0.176
IT99K-316-2	0.46	0.61	1.57	1.27	1.55	1.24	0.288	0.183
IT98K-499-39	0.55	0.57	1.65	1.17	1.63	1.13	0.317	0.153
IT97K-568-18	0.40	0.35	1.42	1.07	1.40	1.05	0.235	0.132
IT98K-128-3	0.17	0.25	1.43	1.09	1.42	1.09	0.242	0.141
IT00K-898-5	0.29	0.45	1.40	1.04	1.39	1.01	0.231	0.122
IT98K-529-1	0.48	0.68	1.58	1.05	1.56	1.00	0.291	0.119
IT97K-1069-6	1.07	0.83	1.32	0.98	1.21	0.89	0.174	0.094
IT98K-628	1.20	0.90	1.22	0.98	1.06	0.87	0.135	0.089
Taiz-401	1.29	1.21	1.10	0.85	0.90	0.60	0.096	0.042
Awlaki-1	0.51	0.91	0.70	0.64	0.65	0.45	0.051	0.024
Average	0.61	0.63	1.45	1.09	1.41	1.03	0.247	0.132
LSD	0.38	0.270	0.52	5.7	0.34	0.40	0.860	0.35
CV%	14.5	18.2	18.3	18.8	16.0	16.8	15.7	12.8

The average PR of NS-DST genotypes were 28.5% and 37.5% while the PR of those of DSUS genotypes were 64.5% and 76.5%. The Drought Susceptibility Index (DSI) of the NS-DST genotypes used ranged from 0.789 to 1.038 and the least susceptible of DSUS genotypes 1.779 to 2.115 under both MSD and LSD stresses (Table 7), respectively. On the other hand, the range in TOL among genotypes and cultivars in the stress condition was almost same under both MSD and LSD stresses, TOL of NS-DST genotypes were 0.55 – 1.00 in comparison with DSUS genotypes 0.57 – 1.00 under both MSD and LSD stresses, respectively (Table 8). In contrast, the ranks of genotypes for other indices MP, GMP and STI were identical and almost corresponded to the ranking for Ys, and Yp. Therefore, the results showed that NS-DST genotypes are the most resistant genotypes had significant high values of MP (1.64 and 1.22), GMP (1.61 and 1.19) and STI (0.31 and 0.17) in comparison with those of DSUS genotypes MP (1.01 and 0.82), GMP

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(0.87 and 1.64) and STI (0.09 and 0.05) under both MSD and LSD stresses (Table 8) respectively. Initial studies indicated that the ranks of parents genotypes for GMP, MP, P, SP, and STI were identical and almost corresponded to the ranking for Y, and Yp. In contrast, SSI, DSI, PR, and TOL exhibited rankings different than the other indices (Saba., *et al*. 2001).

3.5. Selection criteria for improvement drought resistance

3.5.1. Dry matter accumulation and yield attributes

Correlation among Yp and Ys were 0.89 and 0.76 under both MSD and LSD stresses indicating that selecting cowpea genotypes based on yield potential would improve yield under both DS and NS environments (Table 9). Rosielle & Hamblin (1981) indicated that under most yield trials the correlation between stressed and non-stressed yield is smaller indicating that selection for yield potential would only increase yield under non stressed environments, while the selected genotypes would perform poorly under stressed conditions. Meanwhile, strong and positive correlation between pods number/plant, and seeds number/plant with Yp and Ys under both MSD and LSD stresses while 100 seed weight was highly and significantly correlated with only Yp and HI with only Ys under both MSD and LSD stresses suggested that yield improvement would be achieved by selecting for seeds number/plant under NS and DS environments, while 100 seed weight would be useful parameter for selecting yield under only NS condition while HI can be used as yield selection criteria for both MSD and LSD stresses. The result of correlation analysis also indicated that Yp and Ys had significant and positive correlation with SDW, RDW and S/R ratio under both MSD and LSD stresses (Table 9). These results indicated that SDW, RDW and S/R ratio are desirable and has proven to be useful as yield selection criteria in some dry environments especially MSD and LSD stresses.

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Table 9. Correlation coefficient of overall average of (Yp), (Ys), pods/plant, seed/plant, 100 seed weight, harvest index, leaf area, RDW, SDW, SRR of cowpea genotypes as affected by MDS (bold figures) and LDS (light figures) stresses

Traits	Yp	Ys	PNP	SNP	100SW	HI	SDW	RDW	SRR
Yp	**1.000**	**0.448***	**0.634***	**0.377**	**0.272**	**0.617**	**0.676**	**0.766**	**-0.240**
Ys	0.474	**1.000**	**0.899****	**0.871****	**0.662**	**0.923****	**0.792****	**0.619***	**0.366**
PNP	0.863**	0.338	**1.000**	**0.919****	**0.773****	**0.945****	**0.933****	**0.820****	**0.200**
SNP	0.776**	0.708**	0.773**	**1.000**	**0.734****	**0.880****	**0.871****	**0.708****	**0.309**
100SW	0.441	0.666*	0.478*	0.520*	**1.000**	**0.651***	**0.736****	**0.742****	**-0.031**
HI	0.561*	0.913**	0.413*	0.723**	0.639*	**1.000**	**0.907****	**0.755****	**0.295**
SDW	0.482*	0.888**	0.393	0.636*	0.854**	0.777**	**1.000**	**0.872****	**0.190**
RDW	0.524*	0.794**	0.488*	0.605*	0.797**	0.795**	0.847**	**1.000**	**-0.309**
SRR	0.097	0.468*	-0.015	0.267	0.428*	0.267	0.592*	**0.076**	**1.000**

3.5.2. Morphological, visual observations and phenotypic traits

The morphological and visual observations had clearly demonstrated that Yp and Ys were positively and significantly correlated with *LA, LNP, SD, DLS, GRT and* negatively and significantly correlated with *50%F* under both MSD and LSD stresses (Table 10). The leaf area is related to the plant's metabolism, dry matter production and yield (Severino et al., 2004), being an important production factor and measurement of water use plants when exposed to water deficit (Fernandez et al., 1996). Based on the findings of Abdou Razakou et al. (2013), five morpho-physiological parameters (relative water content, plant height, number of leaves per plant, stem diameter and root dry mass) were strongly related to the dry matter partitioning in the plant and they most appropriate indicators for screening cowpea genotypes. The strong positive correlation between yield and DLS, GRT and SG and the negatively correlated with days to 50% flowering under both MSD and LSD environments were reported by several authors. Among the important visual and morphological traits that may contribute to drought adaptation is the delayed leaf senescence (DLS) trait (Gwathmey et al. 1992) growth recovery tolerant (GRT) trait and stay green (SG); these traits allows the crop to stay alive through MSD and LSD droughts and recover when rainfall resumes. However, these traits can be easily measured by visual observation using an appropriate scale.

Table 10. Correlation coefficient of (Yp), (Ys), (LNP), (SD), (DLS), (GRR), (SG) and (50%F) of cowpea genotypes as affected by MDS (bold figures) and LDS (light figures) stresses

Traits	Yp	Ys	LA	LNP	SD	DLS	GRT	SG	50%F
Yp	**1.000**	**0.448***	**0.164**	**0.291**	**0.514**	**0.273**	**0.516***	**0.499***	**-0.409***
Ys	0.474*	**1.000**	**0.772****	**0.805****	**0.876****	**0.817****	**0.826****	**0.925****	**-0.858****
LA	0.371*	0.907**	**1.000**	**0.438***	**0.497***	**0.742****	**0.633****	**0.638****	**-0.570***
LNP	0.597*	0.655**	0.426*	**1.000**	**0.838****	**0.725****	**0.768****	**0.768****	**-0.779****
SD	0.443*	0.807**	0.885**	0.485*	**1.000**	**0.731****	**0.815****	**0.899****	**-0.813****
DLS	0.540*	0.749**	0.813**	0.432*	0.932**	**1.000**	**0.706****	**0.758****	**-0.569***
GRT	0.625*	0.890**	0.745**	0.681**	0.741**	0.730**	**1.000**	**0.717****	**-0.736****
SG	0.367	0.944**	0.934**	0.564*	0.897**	0.812**	0.833**	**1.000**	**-0.870****
50%F	-0.624**	-0.701**	-0.514*	-0.611*	-0.441*	-0.442*	-0.747**	-0.542*	**1.000**

3.5.2. Some physiological and biochemical traits

Yp and Ys in response to MSD and LSD stresses was positively correlated with RWC, WUE, CSI, and PC and negatively correlated with days to 50% flowering, SC and IL (Table 11). However, WUE and PC were the most positively significant traits correlated with WUE, and CSI and negatively correlated with days to 50% flowering, SC and IL (Table 11)**.** Thus, these results indicating that these traits would be useful traits to select for drought tolerance, as these traits are highly correlated to under both MSD and LSD environments which can be directly selected for. For selection to be effective the degree of these physiological needs to have a reasonably high heritability. The strong positive correlation between yield and RWC, WUE, CSI and PC and the negatively correlated with stomatal conductance (SC), days to 50% flowering and LEI under both MSD and LSD environments were reported by several authors. Many worker have been reported the significant and positively of correlation of Yp and Ys with RWC, WUE and CSI **(**Anyia and Herzog 2004 and Souza et al. 2004) and FPC (Hamidou et al. 2007) and negatively correlated with Sc (Lu et al., 1998) days to 50% flowering (Hall and Patel 1985; Cisse et al. 1997) and LEI (Al-Abssy and Al-Hakimi, 2010**)**

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Table 11. Correlation coefficient of (Yp), (Ys), (RWC), (SC), (LEL), (CSI) and (FPC) of cowpea genotypes as affected by MDS (above bold values) and LDS (above bold values) stresses and non stress conditions

Traits	Yp	Ys	RWC	WUE	SC	IL	CSI	FPC
Yp	**1.000**	**0.448***	**0.596***	**0.447***	**-0.629***	**-0.442***	**0.440****	**0.452***
Ys	0.474*	**1.000**	**0.942****	**1.000****	**-0.831****	**-0.901****	**0.931****	**0.679****
RWC	0.695**	0.813**	**1.000**	**0.941****	**-0.837****	**-0.919****	**0.919****	**0.733****
WUE	0.474*	1.000**	0.813**	**1.000**	**-0.830****	**-0.901****	**0.930****	**0.678****
SC	-0.675**	-0.794**	-0.930**	-0.794**	**1.000**	**0.818****	**-0.848****	**-0.633***
IL	-0.666**	-0.749**	-0.848**	-0.749**	0.812**	**1.000**	**-0.972****	**-0.684****
CSI	0.435*	0.798**	0.736**	0.798**	-0.803**	-0.801**	**1.000**	**0.715****
PC	0.782**	0.733**	0.729**	0.732**	-0.660**	-0.628*	0.547*	**1.000**

3.5.4. Drought Resistance Indices

The correlation coefficient of DI, PR, DSI and TOL with either Yp or Ys were high and negative under both MDS and LSD environments, while correlation coefficient of GMP, MP and STI, with Yp or Ys were high and positive under NS and DS conditions (Table 12). Thus, Drought indexes such as MP, STI and GM, were efficient to be used in selecting genotypes with high yield capacity in MSD, LSD and NS environments. In contrast, DI, PR, DSI and TOL were efficient to be used in selecting genotypes with high yield capacity only under DS environments. Positive correlation between seed yield in DS and NS environments supported similar findings by Ramirez Vallejo and Kelly (1998). Genotypes that were high yielding in the DS were also high yielding in NS environment (Teran and Sing, 2002) but contrary to those predicted by Rosielle and Hamblin (1981). The latter researchers predicted that high yielding genotypes in drought stress were likely to be low yielding in well watered environments. Saba *et al*., 2001 also concluded that DSI and TOL were not useful indices to select for drought tolerant genotypes in plant breeding programs, because, DSI exhibited negligible heritability and TOL was less heritable than other indices usually not identifying genotypes with both high yield and drought tolerance characteristics.

Table 12. Correlation coefficient of (Yp), (Ys), (PR), (DSI), (TOL), (GMP), (MP), (STI) of cowpea genotypes as affected by MDS and LDS stresses and non stress conditions

Traits	Yp	Ys	PR	DSI	SI	TOL	MP	GMP	STI
Yp	**1.000**	**0.448**	**-0.198**	**-0.198**	**-0.198**	**0.084**	**0.735**	**0.615**	**0.626**
Ys	0.474	**1.000**	**-0.958**	**-0.958**	**-0.958**	**-0.853**	**0.935**	**0.978**	**0.971**
PR	-0.116	-0.828	**1.000**	**1.000**	**1.000**	**0.953**	**-0.805**	**-0.886**	**-0.862**
DSI	-0.075	-0.907	0.901	**1.000**	**1.000**	**0.953**	**-0.805**	**-0.885**	**-0.862**
SI	-0.074	-0.907	0.901	1.000	**1.000**	**0.953**	**-0.805**	**-0.886**	**-0.862**
TOL	0.248	-0.639	0.926	0.841	0.841	**1.000**	**-0.613**	**-0.731**	**-0.716**
MP	0.825	0.842	-0.654	-0.574	-0.574	-0.343	**1.000**	**0.984**	**0.983**
GMP	0.729	0.888	-0.754	-0.667	-0.666	-0.480	0.987	**1.000**	**0.991**
STI	0.702	0.889	-0.756	-0.669	-0.668	-0.504	0.973	0.993	**1.000**

Genetic advances are directly related to the magnitude of narrow-sense heritabilities (Kearsey, 1996). Thus, it seems that selection for drought resistance based on GMP, MP, P, SP, and STI will be more fruitful than based on SSI and TOL. For a trait or parameter to be useful in the selection of superior genotypes, it must be heritable as well as repeatable across samples of the environments (Jalaluddin, 1993). However, Saba (2001) showed that SSI exhibited negligible heritability, and TOL was less heritable than GMP, MP, P, SP, and STI, as determined by narrow-sense heritability estimates**.** Recently, Chiulele, et al., (2011) found that correlation analysis among DS and NS yield indicated that the correlation between DS and NS yield was 0.71. These results suggested that selecting cowpea genotypes based on yield potential would improve yield under both DS and NS yield environments. In contrast, Rosielle & Hamblin (1981) indicated that under most yield trials the correlation between DS and NS yield is smaller indicating that selection for yield potential would only increase yield under non stressed environments, while the selected genotypes would perform poorly under stressed conditions.

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3.6. Responses to Drought stress and Mechanism of Tolerance

The above results confirm that yield attributes, phenotypic, and morpho-physiological traits related to yield under stress were divided into those reflecting a balance among escape, avoidance and tolerance while maintaining adequate productivity. This balance was achieved by four main routs;

1. The ability to maintain pod and seed numbers under stress, the ability to accumulate high dry matter and lowering number of leaves and shoot/root ratio. Increasing the ability to delay leaf recovery and stay green of cowpea plants as these traits are also good parameters for cowpea drought adaptation under midseason drought and recover when rainfall resumes.
2. Drought escape mechanisms as expressed in the **days to 50% flowering** also could be useful criteria for screening cowpea genotypes for both MSD and LSD drought tolerance. Moreover, the early maturing cowpea cultivars tend to be very sensitive to drought that occurs during the early stages of the reproductive phase. Efforts are therefore being made to breed cowpea varieties with enhanced drought tolerance for early, mid- and terminal season drought stresses.
3. Reduction of water loss through improving RWC, WUE, maintain high FPC and **CSI** and reduced leaf conductance, and protecting membrane stability by reducing leaf electrolyte ions, as these parameters found to be related to drought tolerance mechanisms. These tolerance has been attributed to several drought avoidance mechanisms.
4. Among the stress tolerance indices; stress tolerance index (STI) considered as one of the useful mechanisms of drought tolerance can be used selection criterion for both environments NS and DS and to seek better conditions to overcome the drought stress.

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Table 13. overall average of yield (kg ha^{-1}) of promising cowpea genotypes grown under rainy season of eight locations SHR-Yemen. Dabab, Demnah, Hifan, Shikheen, Torpah, Qaidah, Aodain and the Station

Years	Genotypes	Station	Dhabab	Demnah	Hifan	Shiheen	Al-Torpah	Qaidah	Al-Aodain
2010	IT96K-610	1152	670	742	620	631	687	630	536
	IT98K-128-4	1040	782	739	618	581	607	640	515
	IT-98K-503-1	959	717	777	620	552	610	659	579
	IT98K-205-8	1040	766	899	662	582	613	612	515
	IT98K-529	1079	762	940	677	588	658	611	530
	IT99K-316-2	908	692	830	451	566	567	646	503
	IT00K-901-5	792	340	612	426	561	557	573	491
	IT-98K-499-39	1206	777	823	670	583	641	639	528
	Farmer variety	433	351	399	436	357	372	364	282
	Average	957	651	751	576	556	590	597	498
	LSD at 0.05	211	121	152	129	138	130	192	122
	CV%	15.2	17.8	18.3	14.4	16.7	14.9	12.2	19.7
2011	IT96K-610	1077	756	842	757	674	584	596	604
	IT98K-128-4	1012	646	801	566	582	639	576	623
	IT-98K-503-1	968	757	868	659	578	600	605	507
	IT98K-205-8	1032	754	791	566	662	784	689	603
	IT98K-529	1297	449	1085	501	546	689	679	460
	IT99K-316-2	942	388	951	478	592	662	640	533
	IT00K-901-5	1101	354	819	405	502	719	595	437
	IT-98K-499-39	911	752	1012	701	672	701	592	377
	Farmer variety	401	379	317	461	438	369	389	232
	Average	971	582	832	566	583	638	596	486
	LSD at 0.05	224	138	217	180	167	172	154	157
	CV%	11.3	19.4	17.3	10.8	18.8	15.8	16.2	15.3

3.7. Genotype x environment interaction and stability analysis of seed yield

The effect of genotypes and the environments (locations) were significant. The genotypes exhibited significant differences only in five out of the eight environments.

The lowest yield (498 kg ha^{-1}) was produced by Al-Aodain at Ibb during both years 2010 and 2011 and the highest (957 and 971 kg ha^{-1}) at the station (957 and 971 kg ha^{-1}) in Demnah at Taiz during both 2010 and 2011 cropping season, respectively (Table 13).

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Genotypic variation also observed during 2010, 2011 and 2012 cropping season where the genotypes IT98K-205-8, IT96K-610, IT98K-529, IT-98K-503-1 and IT98K-128-3 genotypes were the most highly and significantly in all the locations and years in yield (Table 14). The average yield for both years and eight locations were 0.723, 0.722, 0.722, 0.688 and 0.685 kg ha^{-1} for IT98K-205-8, IT96K-610, IT98K-529, IT-98K-503-1 and IT98K-128-3 , respectively. Similar results were obtained by (Showemimo, 2007; Gebeyehu and Habtu Assefa, 2003; Haji and Hunt, 1999).

Table 14. Average yield of cowpea genotypes and their stability indices *b*-value (Slops), coefficient of determination (r^2), standard deviation (s^2d) and ecovalence value (W).

Genotypes/	Mean	b	S^2 d	R^2	W
IT96K-610	0.722	0.973	0.026	0.796	0.208
IT98K-128-3	0.685	0.883	0.029	0.836	0.167
IT-98K-503-1	0.688	0.817	0.027	0.830	0.145
IT98K-205-8	0.723	0.901	0.035	0.767	0.169
IT98K-529	0.722	0.927	0.052	0.531	0.417
IT99K-316-2	0.647	0.912	0.025	0.341	0.203
IT00K-901-5	0.580	0.976	0.032	0.220	0.253
IT-98K-499-39	0.724	1.073	0.031	0.806	0.250
Farmer variety	0.342	0.124	0.027	0.660	0.022
Average	0.648	0.909	0.034	0.752	0.221

The results also showed that there were differences among slopes of regression lines and the regression model was adequate in describing the stability of the cowpea genotypes. The regression lines gave a good fit (84%) to the actual seed yields from the different environments and the usefulness of *b* is, therefore, pronounced (Table 14). The significant contribution of the linear component to the variation in yields were also reported for oats genotypes (70 to 90%) (Langer *et al*., 1978), *Brassica campastris* (83 to 87%) (Joarder *et al*., 1978) and forage vetches (82%) (Abd-El Moneim *et al.*, 1993).

Correlation between mean seed yield and the three stability parameters varied considerably (Table 15). The association between mean yield and b , S^2d , r^2, and W were not significant while b , S^2d , r^2, and W were significantly and positively correlated with each other. The usefulness of the coefficients of determination (r^2) was, however, demonstrated by Abd El-Moneim (1993) because it is standardized, the results are comparable between experiments, and independent of scale. The non- significant correlation between mean seed yield and b suggests that many high yielding genotypes did not respond to increased environmental productivity at a rate greater than the mean of all genotypes evaluated. In contrast, Gebeyehu and Habtu Assefa, 2003 found significant and negative correlation between mean yield and S^2d, and mean yield and r^2 (significant and positive) were similar in value (r = 0.53).

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Table 15. Rank correlations between stability indices for seed yield, (*b*), S^2d, r^2 and W of cowpea genotypes.

Traits	Yield	*b*	S^2d	r^2	W
Yield	1.000				
b	0.206	0.943			
S^2d	0.375	0.779	0.834		
r^2	0.181	0.799	0.938	0.666	
W	0.219	1.702	0.680	0.731	0.866

CONCLUSION

It can be concluded that the genotypes IT93K-503-1, IT98K-131-2, IT99K-316-2, IT96K-610, IT98K-529, IT98K-499-39, IT00K-901-5, IT98K-205-8 were considered as the non stress and drought stress tolerant NS-DST genotypes. These genotypes characterized as high yielding, early flowering and maintaining high water and osmolyses genotypes. Moreover, stability analysis of the promising eight cowpea genotypes which evaluated at eight locations in Yemen (Taiz) during three cropping seasons (2010, 2011 and 2012); has clearly showed that the IT98K-205-8, IT96K-610, IT98K-529, IT-98K-503-1 and IT98K-128-3 were the most highly and significantly in all the locations and years in yield. The association between mean yield and b , S^2d , r^2, and W were not significant while b , S^2d , r^2, and W were significantly and positively correlated with each other. Coefficient of determination ranged between 53.1% for IT98K-529 and 83.6% for IT98K-128-3 suggesting that linear regression accounted for 53–84% variation in cowpea yield. Thus, these genotypes performed best across the environments indicating wide adaptability. These genotypes could be introduced to farmers in these agro-ecological zones.

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