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*Full Length Research Paper*

# Evaluation of cowpea genotypes for soil moisture stress tolerance under screen house conditions

**Y. A. Abayomi* and T. O. Abidoye**

Department of Agronomy, University of Ilorin, P.M.B. 1515, Ilorin, Nigeria.

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**A potted experiment was conducted in a screen house at the University of Ilorin, Nigeria to evaluate the growth and grain yield responses of 10 genotypes of cowpea to soil moisture stresses. The experiment was designed as a 4 x 10 factorial and laid out in split-plots arrangement, evaluated ten genotypes of cowpea at four soil moisture stress levels with all factorial combinations replicated four times. Growth and flowering parameters were measured at full flowering, while yield components as well as grain yield per plant were determined at plant maturity. All data collected were analysed using analysis of variance and moisture stress tolerance was evaluated by the rank summation index (RSI). Plant height, numbers of leaves and flowers per plant increased significantly with decreasing soil moisture stress. However, higher soil moisture stress levels have no appreciable effects on branching, but delayed onset of and time to full flowering. Numbers of pods and seeds, HI and shelling percentage as well as grain yield decreased with increasing soil moisture stress, while biomass yield was not significantly influenced by the stress. The overall rankings of the evaluated genotypes in terms of growth and grain yield responses to soil moisture stress tolerance from the best to the worst are IT97K-499-38 > IT99K-1060 > ITA 271 > IT99K-1245 > ITA 352 > IT97K-598-18 > IT98K-131-2 > IT97K-356-1 > IT98K-491-4 > IT00K-901-5. Not withstanding these ranks, ITA 271 and ITA 352 had the best yield stability, while IT99K-1060 was drought tolerant but has low yield potential.**

**Key words:** Cowpea (*Vigna unguiculata)*, genotypes, soil moisture stress, growth and grain yield responses, yield potential, stability.

## INTRODUCTION

Cowpea (*Vigna unguiculata* (L) Walp) is one of the ancient grain legumes valued for its nutritional value, especially high protein content (25%), flavour and short cooking time (Ogbonnaya et al., 2003). The crop also has ability to maintain soil fertility through its excellent capacity to fix atmospheric nitrogen and thus does not require very fertile land for growth (Lobato et al., 2006; Peksen and Artik, 2004). Its haulms are also used to feed livestock during the dry season (Blade et al., 1997). Cowpea forms an integral part of a sustainable agriculture and land use system (Ogbonnaya et al., 2003). The crop plays a considerable role in the nutritional balance and economy of the rural population in West Africa sub-region (Krasova-Wade et al., 2006) and was also reported to have a strong influence on Brazilian commercial balance (Costa et al., 2008). West African sub-region is responsible for about 80% of the world cowpea production, with the principal producers being Nigeria, Niger and Senegal (Ogbonanaya et al., 2003).

However, it has been reported that the yield of cowpea obtained in the West African sub-region is lower than that in the USA and in Australia (Quin, 1997) and very often inconsistent (Krasova-Wade et al., 2006). The low productivity has been attributed to water deficit among other factors. Although, cowpea is said to be relatively drought tolerant, it has been shown that water stress leads to a decrease in plant water content, turgor reduction and consequently a decrease in cellular expansion and alteration of various essential physiological and biochemical processes that can affect growth and productivity (Pimentel, 2004; Costa et al., 2008; Lobato et al., 2008). Thus, it has been observed that virtually all cowpea landraces that had evolved in the Sahel did not produce significant quantities of grain in the years and locations with the most severe droughts due to the likely

*Corresponding author. E-mail: yabayomi2007@yahoo.com, abiyomi@unilorin.edu.ng.

climatic changes since 1968 (Hall, 2004).

Water is vital for plant growth, development and productivity. Permanent or temporary water deficit stress limits the growth and distribution of natural and artificial vegetation and the performance of the cultivated plants more than any other environmental factor (Shao et al., 2009). Water availability is considered the climatic factor with greatest effect on agricultural productivity (Rockstrom and Falkenmark, 2000). Aranus et al. (2003) reported that, among the environmental factors affecting crops, the water input, expressed as the sum of rainfall and irrigation during the growing period, explained the large part of the yield variability.

Cowpea is cultivated in semi-arid areas of West Africa characterized by low and variable rainfall. It has been observed that rainfed crops growing in the semiarid tropical Sahelian zone of Africa can be subjected to extremely dry and hot conditions (Hall, 2004). There is the need to evolve cowpea genotype(s) that are tolerant of soil moisture stress in order to improve grain yield in the crop. The evolved genotypes would be expected to have the potential to expand the utilisation of the crop in the sub-region and thus, be of economic importance for both commercial and subsistence farmers. Although cowpea is regarded as drought tolerant, much variation has been reported to occur within genotypes (de Ronde and Spreeth, 2007). The evaluation of a genotype in a trial subjected to a range of water stresses appears more advantageous than the simple comparison of yield in rainfed vs. irrigated trials (Rizza et al., 2004). It was the objective of this study to evaluate some of the existing genotypes for their growth and grain yield tolerance of different levels of soil moisture deficit with a view to identifying genotype(s) suitable for drought tolerant breeding programme.

## MATERIALS AND METHODS

The study was conducted in a screen house at the crop pavilion of the Department of Agronomy, University of Ilorin, Ilorin, Nigeria during the dry period of November 2003 and April 2004. The study was designed as a 4 x 10 factorial experiment in RCBD and laid out in split-plots arrangement, evaluated ten genotypes of cowpea at four soil moisture contents. The soil moisture stress levels (severe, moderate, mild and no stress) constituted the main plots and cowpea genotypes (IT97K-356-1, IT97K-499-38, IT98K-491-4, ITA352, IT00K-901-5, ITA 271, IT97K-568-18, IT98K-131-2, IT99K-1060 and IT99K-1245), obtained from the International Institute for Tropical Agriculture, Nigeria (IITA) were the sub-plots. All factorial combinations were replicated four times.

The plants were grown in 10 litre plastic pots perforated at the base and filled with 10 kg top soil. The four soil moisture stress levels were created by moistening the pots with 750, 1500, 2250 and 3000 ml water corresponding to 25, 50, 75 and 100% of soil available water (SAW) determined gravimetrically (Kramer, 1983). The soil moisture stress levels were maintained throughout the experimental period by periodic application of water as required. Ten seeds of each genotype were planted in a pot and later thinned to two seedlings per pot at two weeks after emergence. Starter dose of NPK fertilizer was made to each pot at rates equivalent to 30 kg N, 15 kg $P_2O_5$, 15 kg $K_2O$ $ha^{-1}$ using NPK (20-10-10) fertilizer at 3 weeks after planting. Weed control was achieved by hand pulling at weekly intervals. Weekly application of insecticide, Karate 2.5 EC (25 g/l lambda cyhalothrin), at a rate of 5 ml per litre of water was made from onset of flowering until pod maturity using a hand sprayer to control flower and pod boring insects.

Data collection included growth parameters of plant height, number of leaves and branches, date to the first flowering, date to full flowering and number of flowers per plant, all taken at full blooming. At maturity, the plants were harvested to determine yield components (number of pods and seeds, pod weight, average pod length, biomass yield, harvest index and shelling percentage) and grain yield per plant. All data collected were analysed using the analysis of variance with split-plot model. Significant means were separated using the least significant difference at 5% probability level ($LSD_{0.05}$). Susceptibility of the genotypes to soil water deficitstresses was estimated by considering the yield reductions of the genotypes due to stresses as described by Rizza et al. (2004). Susceptibility index was also calculated using the Fischer and Maurer Index (1978) as:

$$S = (Y_{NS} - Y_S) / (Y_{NS}D)$$

Where:

D (stress intensity) = $1 - y_s/y_{ns}$;
S = susceptibility index;
$Y_{NS}$ = yield of genotype under no stress;
$Y_S$ = yield of genotype under stress;
$y_s$ = mean yield of all genotypes under stress;
$y_{ns}$ = mean yield of all genotypes under no stress.

The overall performance of genotypes was evaluated for moisture stress tolerance by the rank summation index (RSI) (Abayomi et al., 2001), whereby genotypes were ranked (1 to 10) for growth parameters, yield components and grain yield tolerance of moisture stress. The ranking values of each genotype were then summed up to obtain the overall ranking. Genotype with the lowest overall value was the most moisture stress tolerant and vice versa.

## RESULTS AND DISCUSSION

### Effects on growth parameters

The responses of plant growth parameters to soil moisture stress are presented in Table 1. The results show that plant height, numbers of leaves and flowers per plant were significantly decreased with increasing soil moisture stress, while the onset of and date to full flowering were significantly delayed by higher soil moisture stress levels. Plant height in cowpea has been shown to be decreased by water stress (Hiler et al., 1972). Similarly, reduction in leaf production and or increase in leaf senescence and abscission due to water stress have been reported (Abidoye, 2004). Other workers have also shown that water deficit during the vegetative phase causes leaf and plant growth reductions (Kerbauy, 2004). The reduction in leaf production and or increased leaf senescence results in decreased leaf area which might be a drought avoidance mechanism. The reduction in leaf and plant growth has been attributed to decrease in cellular expansion resulting from decrease in plant water content and

**Table 1.** Effects of different soil moisture stress level on plant height, number of leaves and branches per plant and flowering parameters in ten cowpea genotype

| Soil Moisture Stress Level | Genotype | Plant HT (cm) | Number of leaves | Number of Branches | Onset of flowering | Date to flowering | Number of flower |
|---|---|---|---|---|---|---|---|
| Severe | IT97K-356-1 | 39.56 | 31.3 | 2.2 | 62.0 | 66.9 | 6.8 |
| | IT97K-499-38 | 41.33 | 27.0 | 1.7 | 56.7 | 60.0 | 7.0 |
| | IT98K-491-4 | 37.33 | 22.0 | 0.3 | 58.0 | 62.3 | 5.3 |
| | ITA 352 | 36.00 | 29.7 | 1.0 | 58.7 | 65.0 | 4.7 |
| | IT00K-901-5 | 35.33 | 28.0 | 1.3 | 65.3 | 67.3 | 4.0 |
| | ITA 271 | 40.67 | 30.0 | 0.7 | 55.3 | 58.3 | 7.3 |
| | IT97K-598-18 | 38.67 | 27.3 | 0.7 | 53.7 | 59.0 | 7.7 |
| | IT98K-131-2 | 40.00 | 26.3 | 0.7 | 58.3 | 63.3 | 8.0 |
| | IT99K-1060 | 33.67 | 28.7 | 0.3 | 46.3 | 54.0 | 7.0 |
| | IT99K-1245 | 36.00 | 29.3 | 0.7 | 49.3 | 57.7 | 8.3 |
| Moderate | IT97K-356-1 | 42.33 | 40.0 | 0.7 | 44.3 | 51.8 | 8.3 |
| | IT97K-499-38 | 46.00 | 31.0 | 0.7 | 41.3 | 49.0 | 7.0 |
| | IT98K-491-4 | 42.00 | 32.0 | 1.7 | 46.0 | 51.7 | 6.3 |
| | ITA 352 | 43.33 | 37.0 | 0.7 | 47.0 | 51.0 | 6.0 |
| | IT00K-901-5 | 49.00 | 35.0 | 1.7 | 49.3 | 56.3 | 7.0 |
| | ITA 271 | 47.67 | 38.0 | 1.0 | 46.3 | 55.3 | 8.7 |
| | IT97K-598-18 | 50.00 | 31.0 | 1.0 | 46.7 | 55.0 | 9.3 |
| | IT98K-131-2 | 48.00 | 31.0 | 1.3 | 52.7 | 57.0 | 9.0 |
| | IT99K-1060 | 39.33 | 28.3 | 0.0 | 48.7 | 53.7 | 9.3 |
| | IT99K-1245 | 37.67 | 27.0 | 0.3 | 45.3 | 51.3 | 9.7 |
| Mild | IT97K-356-1 | 49.00 | 41.0 | 1.3 | 37.8 | 42.7 | 17.0 |
| | IT97K-499-38 | 64.67 | 28.0 | 1.0 | 38.7 | 47.3 | 9.7 |
| | IT98K-491-4 | 52.33 | 48.0 | 2.3 | 39.3 | 51.0 | 7.7 |
| | ITA 352 | 52.33 | 28.0 | 0.0 | 42.3 | 50.3 | 7.0 |
| | IT00K-901-5 | 57.33 | 40.0 | 1.3 | 41.3 | 51.0 | 5.7 |
| | ITA 271 | 61.00 | 36.0 | 1.0 | 44.7 | 51.3 | 9.0 |
| | IT97K-598-18 | 58.33 | 33.0 | 1.3 | 39.3 | 52.0 | 10.3 |
| | IT98K-131-2 | 56.67 | 33.0 | 1.7 | 37.3 | 51.3 | 10.7 |
| | IT99K-1060 | 47.00 | 30.0 | 0.3 | 36.3 | 40.7 | 10.0 |
| | IT99K-1245 | 40.67 | 34.7 | 1.3 | 39.3 | 46.0 | 14.7 |
| No stress | IT97K-356-1 | 49.67 | 51.0 | 2.3 | 43.0 | 48.0 | 13.0 |
| | IT97K-499-38 | 58.00 | 29.0 | 0.0 | 40.0 | 45.7 | 10.0 |
| | IT98K-491-4 | 50.67 | 36.0 | 1.7 | 45.3 | 52.3 | 8.7 |
| | ITA 352 | 59.67 | 30.0 | 1.0 | 41.3 | 49.0 | 9.3 |
| | IT00K-901-5 | 56.67 | 50.0 | 2.7 | 41.0 | 49.3 | 7.7 |
| | ITA 271 | 54.33 | 52.0 | 2.3 | 45.0 | 51.7 | 10.0 |
| | IT97K-598-18 | 60.67 | 39.0 | 1.0 | 41.0 | 51.3 | 12.0 |
| | IT98K-131-2 | 60.00 | 39.0 | 3.0 | 45.0 | 53.0 | 15.3 |
| | IT99K-1060 | 40.67 | 22.0 | 0.7 | 35.3 | 40.7 | 12.0 |
| | IT99K-1245 | 54.67 | 33.0 | 0.7 | 39.3 | 45.7 | 13.7 |
| | **LSD(0.05):** | | | | | | |
| | Soil Moisture | 4.457 | 7.192 | 1.00 | 3.54 | 1.50 | 2.49 |
| | Genotype | 5.840 | 6.457 | 0.93 | 3.03 | 2.72 | 2.41 |
| | SM x G | ns | ns | ns | 6.44 | 5.29 | ns |

and turgor due to water stress (Kramer and Boyer, 1995). Results of this study showed non-significant effects of soil moisture stress on branching. However, Summerfield et al. (1976) have shown that water stressed cowpea plants

**Table 2.** Genotype rankings and rank summation indices (RSI) showing cowpea growth parameters tolerance of soil moisture stress.

| Genotype | Plant HT | Number of leaves | Number of Branches | Onset of flowering | Days to full flowering | Number of flowers | RSI* | Rank |
|---|---|---|---|---|---|---|---|---|
| IT97K-356-1 | 2 | 7 | 4 | 9 | 10 | 7 | **39** | 8 |
| **IT97K-499-38** | **6** | **3** | **1** | **7** | **6** | **2** | **25** | **3** |
| IT98K-491-4 | 4 | 8 | 10 | 4 | 3 | 4 | **33** | 6 |
| ITA 352 | 5 | 2 | 2 | 8 | 7 | 10 | **34** | 7 |
| IT00K-901-5 | 10 | 9 | 6 | 10 | 9 | 9 | **53** | 10 |
| **ITA 271** | **3** | **9** | **8** | **1** | **1** | **1** | **23** | **1** |
| IT97K-598-18 | 9 | 5 | 5 | 6 | 2 | 3 | **30** | 5 |
| IT98K-131-2 | 8 | 6 | 9 | 5 | 4 | 7 | **39** | 8 |
| **IT99K-1060** | **1** | **1** | **7** | **2** | **7** | **6** | **24** | **2** |
| IT99K-1245 | 7 | 4 | 2 | 3 | 5 | 5 | **26** | 4 |

*RSI = Rank Summation Index, the lower the value, the better the moisture stress tolerance of the genotype.

**Table 3.** Effects of different soil moisture stress level on yield components of ten cowpea genotypes.

| Soil Moisture Stress Level | Genotype | Pod length (cm) | Pod Wt (g) | Biomass yield (g) | Harvest Index | Shelling percent |
|---|---|---|---|---|---|---|
| Severe | IT97K-356-1 | 13.13 | 2.12 | 15.28 | 0.043 | 26.8 |
| | IT97K-499-38 | 13.03 | 4.95 | 19.50 | 0.130 | 56.7 |
| | IT98K-491-4 | 12.65 | 1.36 | 10.09 | 0.100 | 46.0 |
| | ITA 352 | 11.95 | 2.19 | 12.01 | 0.137 | 68.3 |
| | IT00K-901-5 | 12.54 | 0.68 | 18.20 | 0.010 | 33.4 |
| | ITA 271 | 11.99 | 3.06 | 15.40 | 0.153 | 74.2 |
| | IT97K-598-18 | 12.38 | 2.21 | 9.20 | 0.160 | 66.9 |
| | IT98K-131-2 | 14.73 | 2.59 | 9.38 | 0.060 | 54.4 |
| | IT99K-1060 | 11.73 | 2.17 | 7.28 | 0.273 | 78.7 |
| | IT99K-1245 | 13.32 | 2.71 | 7.62 | 0.137 | 32.0 |
| Moderate | IT97K-356-1 | 13.64 | 6.90 | 12.55 | 0.253 | 46.8 |
| | IT97K-499-38 | 13.73 | 3.19 | 11.30 | 0.200 | 71.4 |
| | IT98K-491-4 | 14.08 | 6.69 | 15.55 | 0.283 | 67.7 |
| | ITA 352 | 14.06 | 4.75 | 13.29 | 0.293 | 78.0 |
| | IT00K-901-5 | 14.58 | 7.54 | 16.68 | 0.267 | 59.4 |
| | ITA 271 | 14.30 | 5.55 | 9.90 | 0.433 | 78.3 |
| | IT97K-598-18 | 16.71 | 4.17 | 9.63 | 0.300 | 68.6 |
| | IT98K-131-2 | 15.25 | 5.26 | 8.53 | 0.430 | 80.5 |
| | IT99K-1060 | 13.74 | 4.52 | 8.63 | 0.450 | 83.4 |
| | IT99K-1245 | 14.29 | 4.91 | 8.78 | 0.343 | 62.3 |

were reduced in size and in branching. The rankings of the genotypes in terms of their growth parameters tolerance of soil moisture stress are presented in Table 2. The results show that in order of water stress tolerance of the growth parameters, the genotypes are from the best to the worst ITA 271, IT99K-1060, IT97K-499-38, IT99K-1245, IT97K-598-18, IT98K-491-4, ITA 352, IT97K-356-1, IT98K-131-2and IT00-901-5, in consonance with the earlier observation that variations occur within cowpea genotypes for water stress tolerance (de Ronde and Spreeth, 2007).

## Effects on yield components and grain yield

Results in Table 3 shows that the pod weight was highly significantly reduced by high soil moisture stress, resulting in significant decreases in most yield components. However, the effect of water stress was not significant for biomass yield, thereby suggesting that the

**Table 3.** Contd.

| | | | | | | |
|---|---|---|---|---|---|---|
| Mild | IT97-356-1 | 13.44 | 11.81 | 14.93 | 0.293 | 77.7 |
| | IT97K-499-38 | 13.37 | 5.57 | 16.64 | 0.273 | 78.4 |
| | IT98K-491-4 | 15.44 | 6.38 | 13.54 | 0.330 | 67.8 |
| | ITA 352 | 13.27 | 6.66 | 16.60 | 0.390 | 94.7 |
| | IT00K-901-5 | 13.66 | 7.80 | 18.34 | 0.237 | 55.1 |
| | ITA 271 | 14.07 | 6.10 | 14.38 | 0.463 | 76.9 |
| | IT97K-598-18 | 15.39 | 5.54 | 13.73 | 0.397 | 78.9 |
| | IT98K-131-2 | 14.98 | 6.87 | 13.15 | 0.380 | 62.7 |
| | IT99K-1060 | 12.20 | 4.87 | 6.76 | 0.563 | 77.9 |
| | IT99K-1245 | 13.61 | 5.04 | 12.80 | 0.310 | 71.7 |
| No stress | IT97K-356-1 | 14.40 | 7.88 | 18.18 | 0.333 | 76.8 |
| | IT97-499-38 | 13.43 | 5.18 | 13.52 | 0.253 | 64.4 |
| | IT98K-491-4 | 15.13 | 5.52 | 17.07 | 0.243 | 81.2 |
| | ITA 352 | 13.17 | 8.14 | 21.97 | 0.283 | 75.3 |
| | IT00K-901-5 | 14.48 | 9.54 | 22.25 | 0.327 | 77.4 |
| | ITA 271 | 14.99 | 7.35 | 18.85 | 0.350 | 91.3 |
| | IT97K-598-18 | 15.62 | 7.51 | 14.82 | 0.420 | 74.3 |
| | IT98K-131-2 | 16.38 | 7.14 | 12.22 | 0.490 | 79.5 |
| | IT99K-1060 | 11.05 | 4.62 | 7.64 | 0.433 | 70.9 |
| | IT99K-1245 | 14.00 | 6.13 | 16.74 | 0.317 | 71.4 |
| | **LSD(0.05):** | | | | | |
| | Soil Moisture | 1.374 | 4.694 | 6.249 | 0.0694 | 3.95 |
| | Genotype | 1.204 | 5.883 | 3.688 | 0.0980 | 13.86 |
| | SM x G | ns | ns | ns | ns | ns |

decrease in grain yield due to water stress in this study was due to reduced sink rather than the source as indicated by the reduction in the number of seeds per plant. Grain yield in cowpea is determined by the product of three components: the number of pods per plant that reach maturity, the average number of seeds in each pod and mean dry weight of individual seed (Akyeampong, 1985). Of these yield components, it has been shown that the most important is the number of pods that reach maturity (Doku, 1970).

Results of the present study showed that higher soil moisture stress resulted in significantly reduced number of pods per plant (Figure 3) and significantly reduced number of seeds per plant (Figure 2) with increasing soil moisture stress, resulting in significant reduction in the grain yields of the evaluated genotypes (Figure 1). It has earlier been observed that reduced number of seeds per plant may contribute to low yield in drought stressed cowpea, while diminished cowpea yield as a result of water stress is usually explained by low pod density (Shouse et al., 1981) because water stress exacerbates the loss of immature pods.

Generally, considering all genotypes used in the present study, high variability was observed in yield potential and yield stability. The results in Table 4 show that yield reduction under severe moisture stress ranged from 63% in IT99K-1060 and 98.4% for IT00K-901-5; under moderate stress, yield reduction ranged from 42.6% in IT99K-1060 to 65.8% for IT98K-491-4; while under mild stress, yield reduction ranged from 9.5% in IT97K-356-1 to 47.2% for IT98K-491-1. It has been suggested that in an environment prone to severe drought conditions, such as it occurs in the savannah ecology of sub-Sahara Africa, the most suitable genotypes should maintain high yield under both favourable and stress conditions (Rizza et al., 2004). Considering the results of the ten evaluated genotypes, ITA 352 and ITA 271 ranked among the best under stress and no stress conditions, therefore representing genotypes with good yield potentials and stability. IT97K-598-18 and IT99K-1060 showed high yields under stress conditions, therefore representing genotypes resistant to drought stress but with low yield potential. However, IT98K-491-4 and IT00K-901-5 showed high yields with adequate soil moisture but not under stress conditions, thereby suggesting high yield potentials but lower yield stability. These results are in line with the results of the growth parameters tolerance of soil moisture stress which ranked ITA 271, IT99K-1060 and IT97K-499-38 in that order as the best tolerant genetypes (Table 2).

The rankings of the evaluated cowpea genotypes as regards their yield components and grain yield tolerance

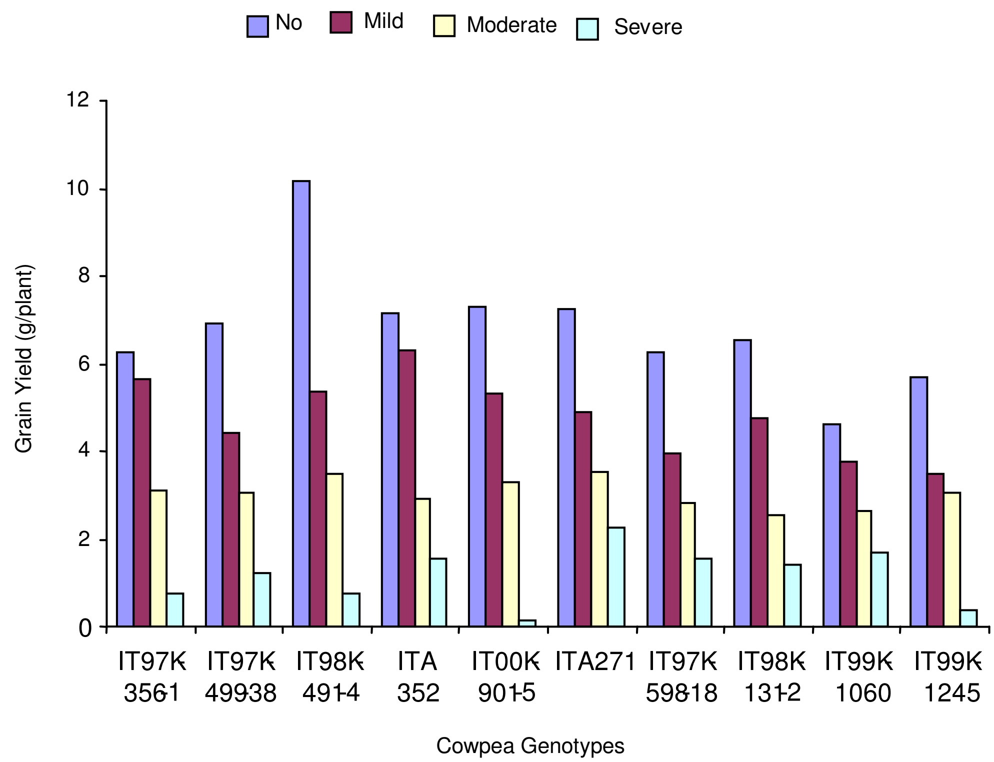


**Figure 1.** Effect of soil moisture stress on grain yields of cowpea genotypes.

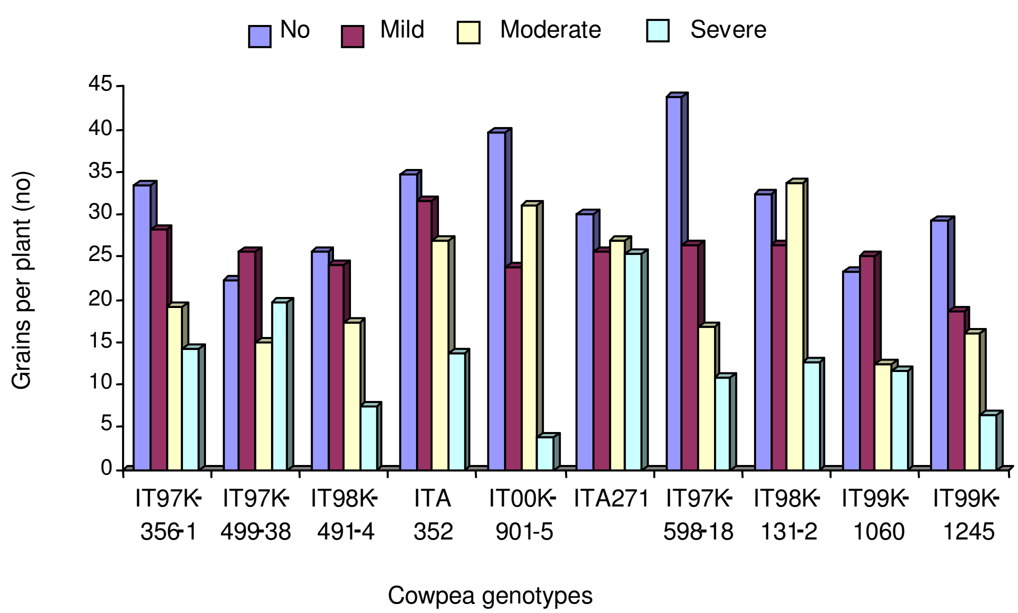


**Figure 2.** Effect of soil moisture stress on number of grains per plant of cowpea genotypes.

of soil moisture stress and rank summation indices are presented in Table 5. The results show that the water stress tolerance of the genotypes are in the order of IT97K-499-38 > IT99K-1060 > ITA 271 > IT99K-1245 > ITA 352 > IT97K-598-18 > IT98K-131-2 > IT97K-356-1 >IT98K-491-4 > IT00K-901-5. Other workers have repor-

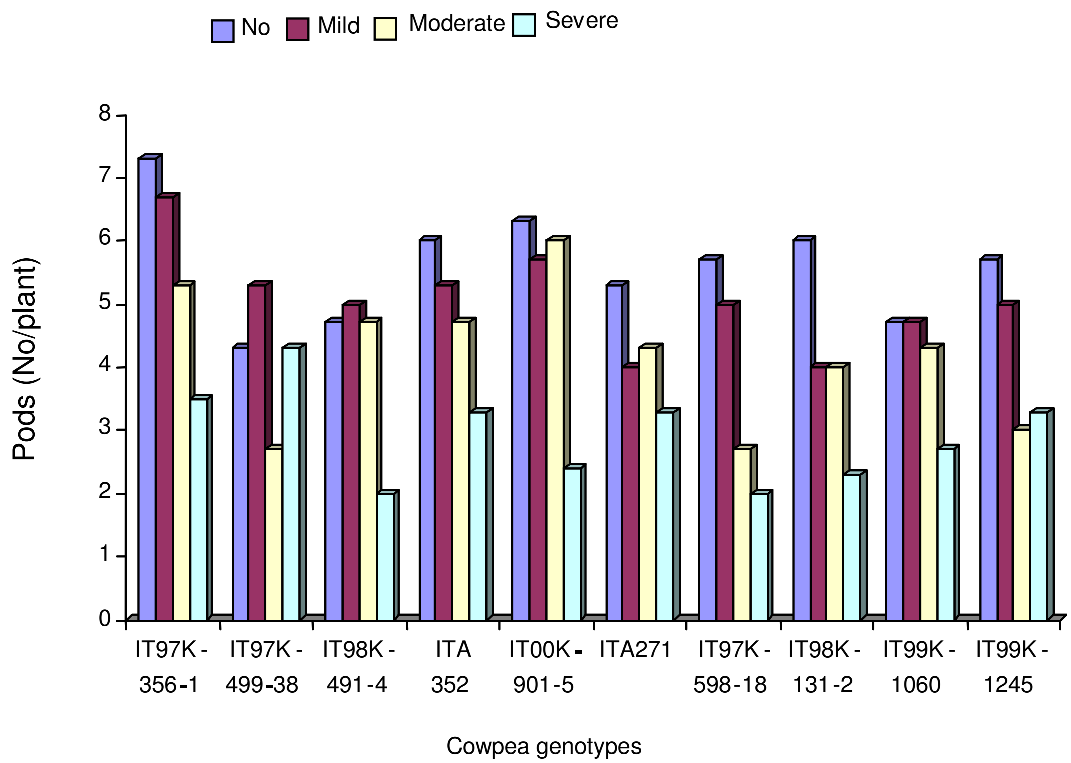


**Figure 3.** Effect of soil moisture stress on number of pods per plant of cowpea genotypes.

**Table 4.** Drought susceptibility indices and yield reductions of cowpea genotypes at different water deficit stresses.

| | Susceptibility index | | | | Grain yield reduction | | | |
|---|---|---|---|---|---|---|---|---|
| **Genotypes** | **Mild** | **Moderate** | **Severe** | **Mean** | **Mild** | **Moderate** | **Severe** | **Mean** |
| IT97K-356-1 | 0.30 | 0.85 | 1.09 | 0.75 | 9.0 | 44.6 | 90.0 | 47.8 |
| IT97K-499-38 | 1.09 | 1.01 | 0.96 | 1.02 | 33.3 | 55.8 | 80.8 | 56.6 |
| IT98K-491-4 | 1.44 | 1.11 | 1.11 | 1.22 | 43.3 | 61.5 | 91.6 | 65.5 |
| ITA 352 | 0.39 | 1.05 | 0.94 | 0.79 | 11.6 | 57.9 | 77.9 | 49.1 |
| IT00K-901-5 | 0.92 | 0.99 | 1.17 | 1.03 | 27.3 | 55.4 | 96.7 | 59.8 |
| ITA 271 | 1.09 | 0.92 | 0.84 | 0.95 | 32.8 | 51.0 | 69.2 | 51.0 |
| IT97K-598-18 | 1.09 | 0.93 | 0.92 | 0.98 | 32.7 | 51.4 | 76.2 | 53.4 |
| IT97-131-2 | 0.86 | 1.08 | 0.94 | 0.96 | 25.7 | 59.5 | 77.5 | 54.2 |
| IT99K-1060 | 0.61 | 0.81 | 0.76 | 0.73 | 18.2 | 43.3 | 62.7 | 41.5 |
| IT99K-1245 | 1.28 | 0.85 | 1.12 | 1.08 | 38.3 | 46.8 | 94.4 | 59.8 |
| **Mean** | **0.91** | **0.96** | **0.98** | **-** | **27.2** | **52.7** | **81.7** | **-** |
| $LSD_{0.05}$ | | | | | | | | |
| Stress | | ns | | | | 14.83 | | |
| Genotype | | ns | | | | ns | | |
| Stress x Genotype | | ns | | | | ns | | |

ted significant differences in the responses of cow-pea genotypes Costa et al. (2008) and barley genotypes (Rizza et al., 2004) to water stress.

## Conclusion

Although cowpea is reported to be a fairly drought tole-

**Table 5.** Genotype rankings and rank summation indices (RSI) showing yield components and grain yield tolerance of soil moisture stress in cowpea genotypes.

| Genotype | No of Pods | No of seeds | Grain yield | Pod length | Pod WT | Biomass | HI | Shelling (%) | *RSI | Rank |
|---|---|---|---|---|---|---|---|---|---|---|
| IT97K-356-1 | 6 | 4 | 8 | 4 | 7 | 3 | 9 | 10 | 51 | 7 |
| IT97K-499-38 | 1 | 1 | 1 | 2 | 1 | 1 | 2 | 4 | 13 | 1 |
| IT98K-491-4 | 7 | 7 | 7 | 7 | 9 | 8 | 6 | 7 | 58 | 9 |
| ITA 352 | 5 | 5 | 6 | 5 | 8 | 9 | 3 | 2 | 43 | 4 |
| IT00K-901-5 | 9 | 10 | 10 | 8 | 10 | 4 | 10 | 8 | 69 | 10 |
| ITA 271 | 2 | 2 | 3 | 9 | 4 | 5 | 5 | 5 | 35 | 3 |
| IT97K-598-18 | 10 | 8 | 4 | 10 | 6 | 7 | 7 | 3 | 55 | 8 |
| IT98K-131-2 | 8 | 6 | 5 | 6 | 5 | 6 | 8 | 6 | 50 | 5 |
| IT99K-1060 | 4 | 3 | 2 | 1 | 2 | 2 | 1 | 1 | 16 | 2 |
| IT99K-1245 | 3 | 9 | 9 | 3 | 3 | 10 | 4 | 9 | 50 | 5 |

*RSI= Rank Summation Index, the smaller the value, the better the moisture stress tolerance of the genotype.

rant crop, the results of this study show that the crop requires adequate moisture for optimal growth and yield. The overall water stress tolerance of the evaluated genotypes in terms of growth and grain yield under limited soil moisture is in the order of IT97K-499-38 > IT99K-1060 > ITA 271 > IT99K-1245 > ITA 352 > IT97K-598-18 > IT98K-131-2 > IT97K-356-1 > IT98K-491-4 > IT00K-901-5. Nevertheless, in terms of yield potentials and good yield stability, ITA 271and ITA 352 are the choice genotypes, while IT99K-1060 and IT97K-598-18 are drought tolerant, they have low yield potential.

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