RESEARCH ARTICLE Agricultural Science Digest, Volume 40 Issue 1: 44-48 (March 2020)

Preliminary Evaluation of Growth Response of Two Cowpea Accessions to Water Stress

Rashied Tetteh, Samuel Kwasi Boateng, Kwaku Junior Asamoah[1]

10.18805/ag.D-186

ABSTRACT

Water deficit is one of the most important factors that affect plant growth and development. To assess the effect of water stress on growth of two cowpea accessions (i.e. UCC 321 and GH 4769), a field study was conducted at the experimental site of CSIR-Plant Genetic Resources Research Institute, Bunso, Eastern Region-Ghana during the minor season. The treatments comprised of non-watered and well-watered cowpea plants for thirty-two days. The experiment was a 2 x 2 factorial replicated three times in a randomised complete block design. Growth was determined by measuring plant height, number of leaves per plant and plant dry mass (i.e. leaf, stem, root and total plant). Water stress reduced plant height, number of leaves and plant dry mass. Dry-mass accumulation in above-ground plant organs was lower in non-watered plants than in the well-watered treatment. This indicated that irrigation was necessary to optimize cowpea production, and that a deficit in irrigation might affect plant growth as soil becomes dry.

Key words: Cowpea, Dry mass, Plant growth, Water stress.

INTRODUCTION

Drought is the most severe abiotic stress factor limiting plant growth and crop production (Rohbakhsh, 2013).With global warming, it is anticipated that water deficit would be escalated by increasing evapotranspiration, increasing the frequency and intensity of drought with an increase from 1% to 30% in extreme drought land area by 2100 (Fischlin *et al*., 2007). Yield losses in agricultural crops due to drought have been estimated at 17% (Ashraf *et al*., 2008).

Drought is defined as a period of below-average precipitation, when the amounts of available water in the plant rhizosphere drop below the limits required for efficient growth and biomass production (Deikman *et al*., 2012; Osmolovskaya *et al*., 2018). It is characterized by a reduction of water content, diminished leaf water potential and turgor loss, closure of stomata and decrease in cell enlargement and growth. Severe water stress may result in the arrest of photosynthesis, disturbance of metabolism and finally the death of plant (Jaleel *et al*., 2008). Reduced absorption of photosynthetically active radiations, impaired radiation use efficiency and decreased harvest index are the major yield reducing factors under limited supply of soil moisture (Earl and Davis, 2003). According to Duan *et al*. (2007), plants show certain changes in their growth patterns and physiological process to cope with the drastic effects of drought stress. CO_2 assimilation by leaves is reduced mainly by stomatal closure, membrane damage and disturbed activity of various enzymes, especially those of CO_2 fixation and adenosine triphosphate synthesis (Farooq *et al*., 2008). Earl and Davis (2003) reported that three main mechanisms reduce crop yield by soil water deficit: reduced canopy absorption of photosynthetically active radiation, decreased radiation-use efficiency and reduced harvest index. Furthermore, Wahid and Rasul (2005) indicated that a major effect of drought on crops is the reduction in photosynthesis, which arises by a decrease in leaf expansion, impaired photosynthetic machinery, premature leaf senescence and associated reduction in food production.

Cowpea [*Vigna unguiculata* (L.) Walp.] is an important food and forage legume in the semi-arid tropics that includes parts of Asia, Africa, Southern Europe, Southern United States, and Central and South America (Singh, 2005; Timko *et al*., 2007). It is an important source of protein and one of the most drought-resistant food legumes that is widely grown in the semiarid regions where drought is a major production constraint (Dadson *et al*., 2005). Cowpea leaves and green pods are consumed as a vegetable and the dried grain is used in many different food preparations. Protein content of cowpea leaves ranges from 27 to 43% and protein concentration of the dry grain ranges from 21 to 33% (Abudulai *et al*., 2016).

In Ghana and other African countries, cowpeas are often cropped in areas with limited rainfall or soil moisture. Cowpea

CSIR-Plant Genetic Resources Research Institute, P.O. Box 7, Bunso, Eastern Region, Ghana.
[1]University of Development Studies, P.O. Box TL 1350, Tamale, Ghana.

Corresponding Author: Rashied Tetteh, CSIR-Plant Genetic Resources Research Institute, P.O. Box 7, Bunso, Eastern Region, Ghana. Email: rashbalm@yahoo.com

How to cite this article: Tetteh, R., Boateng, S.K. and Asamoah, K.J. (2020). Preliminary Evaluation of Growth Response of Two Cowpea Accessions to Water Stress. Agricultural Science Digest. 40(1): 44-48.

Submitted: 14-08-2019 **Accepted:** 19-11-2019 **Published:** 06-03-2020

farmers in the dry areas of sub-Saharan Africa obtain low yields, estimated at about 350 kg per hectare (Danso, 2017). Farooq *et al.* (2017) indicated that yield reduction in cowpea can vary between 34 and 68% depending on the developmental timing of the drought stress. Studies by Anita and Lakshmi (2015) revealed that plant height and number of branches were maximum when cowpea plants were irrigated. Nkoana *et al*. (2019) reported that cowpea genotypes responded differently to drought stress. In soybean, a significant reduction was observed in plant height at pod development stage under water stress condition (Shadakshari *et al.*, 2014). Although cowpea is regarded as drought tolerant, much variation has been reported to occur within genotypes (de Ronde and Spreeth, 2007). The objectives of the present study were to assess the effect of water stress on growth of two cowpea accessions and ascertain whether differences exists between genotypes.

MATERIALS AND METHODS

The study was conducted at the experimental site of CSIR-Plant Genetic Resources Research Institute, Bunso, Eastern Region-Ghana in the minor season from 11 January to 25 February, 2018. Seeds of two cowpea accessions (i.e. UCC 321 the white type and GH 4769, the red type) obtained from the same institute were sown in the field on 11 January, 2018 at a rate of three seeds per hill and later thinned to one. A spacing of 60cm x 30cm was used. The experiment was a 2 x 2 factorial replicated three times in a randomised complete block design.

Agronomic practices which were undertaken during the experimental period include fertilizer application (NPK-15-15-15) at a rate of 5g per plant at two weeks after planting. Watering and weeding were carried out as and when necessary. Insect pests were controlled using K-optimal insecticide (Landa-cyhalothrin 15g/l +Acetamiprid 20g/l: EC) at a recommended rate of 40ml to 15l of water at two weeks interval.

The water stress treatment commenced at two weeks after sowing on 25 January, 2018. These comprised of well-watered plants daily and water-stressed plants for thirty-two days during the growing period. The highest daily maximum air temperature was observed in February (36.0°C) and the minimum in January (21.0°C) (Table 1). The average daily relative air humidity was in the range of 73-84% during the experimental period. No rainfall was recorded during the experimental period.

Plant height in centimetres and number of leaves per plant were measured at one week interval after treatment in both cowpea accessions. Five cowpea plants were sampled from each treatment in each replication from both accessions. Sampled plants were washed to remove debris and separated into roots, stems, and leaves for the determination of plant dry mass. Samples were oven dried at 80°C for 3 days and weighed using an electronic balance. The total plant dry mass was calculated as the sum of the root, stem, and leaf masses. The root to shoot ratio was calculated as a ratio of below ground to above ground dry masse.

Statistical analyses were conducted using SPSS Statistics 21 (IBM, Chicago, IL, USA). Two-way ANOVA was used to test the effects of treatment and accession. When a significant interaction between treatment and accession was detected, Tukey's HSD test was be performed to identify significant differences between drought treatments.

Table 1: Air temperature, relative humidity and rainfall amount during the experimental period.

Period (2018)	Air temperature (°C)			Relative humidity (%)			Rainfall
	24 h-average	Daily max.	Daily min.	24 h-average	Daily Max.	Daily min.	(mm)
11-31 January	22.3	23.5	21.0	77.9	84.0	73.0	0.0
1-24 February	34.7	36.0	34.0	76.6	81.0	73.0	0.0

Source: Ghana Meteorological Agency, Bunso, Eastern region, Ghana.

Table 2: Effect of water stress on plant height in two cowpea accessions.

Accession	Treatment	Plant height (cm)			
		1 WAT	2 WAT	3 WAT	4 WAT
UCC 321	Watering	19.49 (2.87)	29.57 (4.90)	39.39 (8.74)b	64.86 (8.11)b
	No watering	20.24 (1.52)	21.89 (0.66)	23.38 (3.01)b	24.44 (6.11)c
GH 4769	Watering	21.78 (2.89)	36.61 (1.78)	83.31 (12.73)a	114.92 (8.13)a
	No watering	22.36 (1.17)	31.20 (0.68)	32.10 (2.00)b	41.67 (5.49)c
ANOVA	Treatment (T)	n.s.	**	***	***
	Accession (A)	n.s.	***	**	***
	T x A	n.s.	n.s.	**	**

Each value is the mean of three replicates and the standard deviation is shown in parentheses. Two-way ANOVA: n.s= not significant, **p<0.01, *** p<0.001. When significant interaction between Treatment (T) and Accession (A) was detected, Tukey's HSD test was performed to identify significant differences between the 2 treatments. Values with different letters are significantly different at p<0.05.

RESULTS AND DISCUSSION

Table 2 shows the effect of water stress on plant height of UCC 321 and GH 4769 cowpea accessions. Significant differences were observed in plant height at 2, 3 and 4 weeks after treatment (WAT) with no significant difference at 1 WAT. The well-watered treatment of GH 4769 obtained the highest plant height at 3 and 4 WAT. The well-watered treatment of UCC 321 was not significantly different from the non-watered treatment at 3 WAT. Both accessions differed significantly at 3 and 4 WAT. Growth occurs through cell division, cell enlargement and differentiation and involves genetic, physiological, ecological and morphological events and their complex interactions (Farooq *et al*., 2009). Although water stress affects most of the functions of plant growth, this effect depends on the level of water stress, the length of time to which the plant is subjected to water stress and the genotype of plant species (Boutraa *et al*., 2010). The decrease in plant height under water stress in the present study could be attributed to reduced turgor, which affected cell division and expansion since growth involves both cell growth and development (Okon, 2013). Furthermore, under severe water deficiency, cell elongation of higher plants can be inhibited by interruption of water flow from the xylem to the surrounding elongating cells (Nonami, 1998). In pea, drought stress impaired early seedling growth of five cultivars tested (Okcu *et al*., 2005). Khan *et al*. (2001) reported that plant height decreased significantly with increasing water deficit in maize.

Table 3 shows the effect of water stress on number of leaves of two cowpea accessions. Water stress had no significant effect on leaf number at 1 and 2 WAT. Significant ($p<0.001$) difference was observed at 3 and 4 WAT. The well-watered plants had the highest number of leaves in both cowpea accessions. The production of leaves represents an increase in the photosynthetic surface area for plants. The reduction in number of leaves observed in the present study may lead to lower photosynthetic activity. However, reduced turgor pressure and slow rate of photosynthesis under drought conditions mainly limit leaf expansion (Rucker *et al*., 1995). Tisné *et al.* (2010) and Shahinnia *et al.* (2016) reported that leaves which develop under water deficit generally have smaller cells and higher stomatal density. Studies on soybean by Zhang *et al*. (2004) and others crops by Farooq *et al.* (2009) showed that water stress reduced leaf growth and consequently reduced leaf area. Perhaps, the reduction in leaf number under water stress in the present study might be a drought avoidance mechanism.

The effect of water stress on leaf, stem, root and total plant dry masses and R/S ratio of UCC 321 and GH 4769 are shown in Table 4. Water stress had significant ($p<0.05$) effect on leaf, stem, root, total plant dry mass and root to

Table 3: Effect of water stress on number of leaves in two cowpea accessions.

Accession	Treatment	Number of leaves			
		1 WAT	2 WAT	3 WAT	4 WAT
UCC 321	Watering	7.6 (1.3)	16.1 (2.0)	27.1 (2.9)	41.9 (3.4)
	No watering	8.2 (1.0)	12.8 (1.9)	13.4 (2.4)	14.3 (3.1)
GH 4769	Watering	6.9 (1.3)	14.3 (1.8)	27.9 (5.6)	40.1 (6.9)
	No watering	6.7 (0.3)	13.5 (1.0)	15.5 (1.3)	17.6 (1.3)
ANOVA	Treatment (T)	n.s.	n.s.	***	***
	Accession (A)	n.s.	n.s.	n.s.	n.s.
	T x A	n.s.	n.s.	n.s.	n.s.

Each value is the mean of three replicates and the standard deviation is shown in parentheses. Two-way ANOVA: n.s= not significant, *** $p<0.001$. When significant interaction between Treatment (T) and Accession (A) was detected, Tukey's HSD test was performed to identify significant differences between the 2 treatments.

Table 4: Effect of water stress on biomass yield of two cowpea accessions.

Accession	Treatment	Dry mass (g)				
		Leaf	Stem	Root	Total	R/S ratio
UCC 321	Watering	5.17 (1.01)	3.96 (1.94)	0.78 (0.07)	9.90 (2.36)	0.08 (0.02)
	No watering	0.76 (0.25)	0.63 (0.20)	0.21 (0.05)	1.60 (0.47)	0.16 (0.05)
GH 4769	Watering	3.87 (1.20)	4.96 (1.74)	0.78 (0.04)	9.61 (2.96)	0.09 (0.02)
	No watering	1.04 (1.13)	1.29 (0.28)	0.31 (0.04)	2.64 (0.43)	0.13 (0.01)
ANOVA	Treatment (T)	***	**	***	***	*
	Accession (A)	n.s.	n.s.	n.s.	n.s.	n.s.
	T x A	n.s.	n.s.	n.s.	n.s.	n.s.

Each value is the mean of three replicates and the standard deviation is shown in parentheses. Two-way ANOVA: n.s= not significant, *$p<0.05$, **$p<0.01$, *** $p<0.001$. When significant interaction between Treatment (T) and Accession (A) was detected, Tukey's HSD test was performed to identify significant differences between the 2 treatments.

shoot ratio in both cowpea accessions. The well-watered plants had the highest leaf, stem, root and total plant dry masses with the non-watered plants obtaining the lowest. The highest root to shoot ratio was observed in the non-watered plants. No significant difference was observed between both accessions. Plant productivity is strongly related to biomass partitioning under water stress (Li *et al*., 2008). Yin *et al.* (2005) observed a significant reduction in shoot height, dry mass accumulation, leaf number, total leaf area, and root mass under water stress. According to Leport *et al.* (2006), drought disturbs the balance of assimilates as most of them are translocated to the roots in order to improve water uptake. The export of assimilates from source to sink generally depends upon the rate of photosynthesis and the sucrose concentration in leaves (Komor, 2000). Nam *et al.* (1998) indicated that water stress inhibits dry matter production through its inhibitory effect on leaf expansion and consequently reduced light interception. Drought stress caused low seed yield due to deficiency of irrigation at critical stage (Boukecha *et al*., 2018). The high root to shoot ratio observed under water stress in the present study could be interpreted as a strategy to maximize absorptive root surfaces and increase the water and nutrient uptake rate (Cornelissen *et al*., 2003).

CONCLUSION

Water stress significantly reduced growth performance in both cowpea accessions used in the study. Significant reductions were observed in plant height, number of leaves, stem dry mass, root dry mass and total dry mass under water stress in both cowpea accessions. Root to shoot ratio was significantly higher under water stress than in the well-watered treatment in both cowpea accessions. Both cowpea accessions differed significantly in plant height. It is therefore recommended that cowpea growers should ensure that their crop does not suffer from water stress during growth stages.

ACKNOWLEDGEMENT

The authors express their gratitude to CSIR-Plant Genetic Resources Research Institute, Bunso, Ghana for the facilities. We are also grateful to Dr. Daniel Ashie Kotey for climatic data acquisition.

REFERENCES

Abudulai, M., Seini, S. S., Haruna, M., Mohammed, A. M., and Asante, S. K. (2016). Farmer participatory pest management evaluations and variety selection in diagnostic farmer field Fora in cowpea in Ghana. Afr. J. Agric. Res. 11: 1765-1771.

Anita, M.R. and Lakshmi, S. (2015). Growth characters of fodder cowpea varieties as influenced by soil moisture stress levels. Indian J. of Agric. Res. 49: 464-467.

Ashraf, M., Athar, H.U.R., Harris, P.J.C. and Kwon, T.R. (2008). Some prospective strategies for improving crop salt tolerance. Adv. Agron. 97:45-110.

Bender, J., Tingey, D. T., Jäger, H. J., Rodecap, K. D. and Clark, C. S. (1991). Physiological and biochemical responses of bush bean (*Phaseolus vulgaris*) to ozone and drought stress. J. Plant physiol. 137: 565-570.

Boukecha, D., Laouar, M., Mekliche-Hanifi, L. and Harek, D., 2018. Drought tolerance in some populations of grass pea (*Lathyrus sativus* L.). Legume Res.: An Int. J. 41: 12-19.

Boutraa, T., Akhkha, A., Al-Shoaibi, A.A. and Alhejeli, A.M. (2010). Effect of water stress on growth and water use efficiency (WUE) of some wheat cultivars (*Triticum durum*) grown in Saudi Arabia. J. Taibah Univ. Sci. 3:39-48.

Cornelissen, J.H.C., Lavorel, S. and Garnier, E. (2003). A handbook of protocols for standardised and easy measurements of plant functional traits worldwide. Aust. J. Bot. 51: 335–380.

Dadson, R.B., Hashem, F.M., Javaid, I., Joshi, J., Allen, A.L. and Devine, T.E (2005). Effect of water stress on the yield of cowpea (*Vigna unguiculata* L. Walp.) genotypes in the Delmarva Region of the United States. J. Agron. Crop Sci. 191: 210-217.

Danso, J. (2017). Growth and yield of cowpea (*Vigna unguiculata*) following nitrogen fertilizer application and inoculation (Doctoral dissertation).

Deikman, J.; Petracek, M.; Heard, J.E. (2012). Drought tolerance through biotechnology: Improving translation from the laboratory to farmers'fields. Curr. Opin. Biotechnol. 23:243-250.

DeRonde, J.A. and Spreeth, M.H. (2007). Development and evaluation of drought resistant mutant germplasm of Vigna unguiculata. Water SA. 33: 381-386.

Duan, B., Yang, Y., Lu, Y., Korpelainen, H., Berninger, F. and Li, C., (2007). Interactions between drought stress, ABA and genotypes in Picea asperata. J. Exp. Bot. 58:3025-3036.

Earl, H. and Davis, R. F. (2003). Effect of drought stress on leaf and whole canopy radiation use efficiency and yield of maize. Agron. J. 95: 688–696.

Farooq, M., Aziz, T., Basra, S.M.A., Cheema, M.A. and Rehamn, H. (2008). Chilling tolerance in hybrid maize induced by seed priming with salicylic acid. J. Agron. Crop Sci. 194: 161-168.

Farooq, M., Wahid, A., Kobayashi, N., Fujita, D. and Basra, S.M.A. (2009). Plant drought stress: effects, mechanisms and management. In Sustainable agriculture: 153-188.

Fischlin, A., Midgley, G.F., Price, J.T., Leemans, R., Gopal, B., Turley, C.M., Rounsevell, M.D.A., Dube, P., Tarazona, J. and Velichko, A. (2007). Ecosystems their properties goods and services. Climate Change 2007: Impacts Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change ML Parry OF Canziani JP Palutikof PJ van der Linden and CE Hanson Eds. Cambridge University Press Cambridge. Assessment Report of the Intergovernmental Panel on Climate Change 4, pp. 211-272.

Jaleel, C.A., Manivannan, P., Lakshmanan, G.M.A., Gomathinayagam, M. and Panneerselvam, R. (2008). Alterations in morphological parameters and photosynthetic pigment responses of Catharanthus roseus under soil water deficits. Colloids and Surfaces B: Biointerfaces. 61: 298-303.

Khan, M.B., Hussain N, Iqbal, M. (2001). Effect of water stress on growth and yield components of maize variety YHS 202. J. Res. Sci. 12: 15-18.

Komor, E. (2000). Source physiology and assimilate transport: the interaction of sucrose metabolism, starch storage and phloem export in source leaves and the effects on sugar status in phloem. Aust. J. Plant Physiol. 27: 497-505.

Leport L., Turner N. C., French R. J., Barr M. D., Duda R., Davies S. L. (2006). Physiological responses of chickpea genotypes to terminal drought in a Mediterranean-type environment. Eur. J. Agron. 11: 279-291.

Li, F.L., Bao, W.K., Wu, N., You, C. (2008). Growth, biomass partitioning, and water-use efficiency of a leguminous shrub (Bauhinia faberivar. microphylla) in response to various water availabilities. New Forest. 36: 53-65.

Nam, N.H., Subbaroa, G.V., Chauhan, Y.S., Johansen, C. (1998). Importance of canopy attributesin determining dry matter accumulation of pigeon pea under contrasting moistureregimes. J. Crop Sci. 38: 955-961.

Nkoana, K.D., Gerrano, A.S. and Gwata, E.T. (2019). Evaluation of diverse cowpea [*Vigna unguiculata* (L.) Walp.] germplasm accessions for drought tolerance. Legume Research. 42: 168-172.

Nonami, H. (1998). Plant water relations and control of cell elongation at low water potentials. J. Plant Res. 111: 373-382.

Okçu, G., Kaya, M.D. and Atak, M. (2005). Effects of salt and drought stresses on germination and seedling growth of pea (*Pisum sativum* L.). Turk. J. Agric. For. 29: 237-242.

Okon, J.E. (2013). Effect of water stress on some growth aspects of two varieties of cowpea, *Vigna unguiculata* (L.) Walp Fabaceae. Bulletin of Environment, Pharmacology and Life Sciences. 2: 69-74.

Osmolovskaya, N., Shumilina, J., Kim, A., Didio, A., Grishina, T., Bilova, T., Keltsieva, O.A., Zhukov, V., Tikhonovich, I., Tarakhovskaya, E. and Frolov, A. (2018). Methodology of drought stress research: Experimental setup and physiological characterization. Int. J. Mol. Sci. 19: 4089.

Rohbakhsh, H. (2013). Alleviating adverse effects of water stress on growth and yield of forage sorghum by potassium application. Adv. Environ. Biol. 7: 40-46.

Rucker, K. S., Kvien, C. K., Holbrook C. C., Hook J. E. (1995). Identification of peanut genotypes with improved drought avoidance traits. Peanut Sci. 24: 14-18.

Shadakshari, T.V., Yathish, K.R., Kalaimagal, T., Gireesh, C., Gangadhar, K. and Somappa, J., (2014). Morphological response of soybean under water stress during pod development stage. Legume Res.: An Int. J. 37: 37-46.

Shahinnia, F., Le Roy, J., Laborde, B., Sznajder, B., Kalambettu, P., Mahjourimajd, S., Tilbrook, J. and Fleury, D. (2016). Genetic association of stomatal traits and yield in wheat grown in low rainfall environments. Genetic association of stomatal traits and yield in wheat grown in low rainfall environments. BMC Plant Biol. 16:150.

Singh, B.B. (2005). Cowpea [*Vigna unguiculata* (L.) Walp. In: Singh, R.J., Jauhar, P.P. (eds) Genetic Resources, Chromosome Engineering and Crop Improvement. Volume 1, CRC Press, Boca Raton, FL, USA, pp. 117-162.

Timko, M.P., Ehlers, J.D. and Roberts, P.A. (2007). Cowpea. In: Kole C (ed) Genome Mapping and Molecular Breeding in Plants, Volume 3, Pulses, Sugar and Tuber Crops, Springer Verlag, Berlin Heidelberg. pp. 49-67.

Tingey, D.T. and Hogsett, W.E. (1985). Water stress reduces ozone injury via a stomatal mechanism. Plant Physiol. 77: 944–957.

Tisne, S., Schmalenbach, I., Reymond, M., Dauzat, M., Pervent, M., Vile, D. and Granier, C. (2010). Keep on growing under drought: genetic and developmental bases of the response of rosette area using a recombinant inbred line population. Plant Cell Environ. 33: 1875-1887.

Wahid A. and Rasul, E. (2005). Photosynthesis in leaf, stem, flower and fruit, in: Pessarakli M. (Ed.), Handbook of Photosynthesis, 2nd ed., CRC Press, Florida, pp. 479-497.

Yin, C.Y., Wang, X., Duan, B.L., Luo, J., and Li C. (2005). Early growth, dry matter allocation and water use efficiency of two sympatric Populus species as affected by water stress. Environ. Exp. Bot. 53: 315-322.

Zhang, M., Duan, L., Zhai, Z., Li, J., Tian, X., Wang, B., He Z. and Li, Z. (2004). Effects of plant growth regulators on water deficit-induced yield loss in soybean. Proceedings of the 4thInternational Crop Science Congress, Brisbane, Australia.