Effect of moisture stress on morphological and yield attributes of four sorghum varieties

MA Khaton¹, A Sagar², JE Tajkia², MS Islam³, MS Mahmud⁴, AKMZ Hossain*²

¹Department of Seed Science and Technology, ²Department of Crop Botany, ³Department of Agronomy, ⁴Department of Biochemistry and Molecular Biology, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh

Abstract

Drought adversely affects growth and yield of crops to various extents. Growing of drought tolerant crops is a good option to obtain economical yields from water stress areas for which quick method to screen drought tolerant plants, particularly in early stages of their growth is important. For this reason, a field experiment was conducted to evaluate the genetical potential to drought tolerance of four sorghum varieties viz Hybrid Sorgo, Safal, BD 731, BD 740. The experiment was laid out in a split plot design with three replications. The plants were grown under three drought levels viz. 100% FC (control), 70% FC and 40% FC. Growth and yield of the Sorghum varieties were found to be decreased gradually with gradual increase in drought levels as compared to the control. This reduction was associated with decreased yield components. Water stress also decreased protein and starch content. The variety BD 740 followed by BD 731 showed the better performance in respect of no. of grains panicle⁻¹, panicle dry weight, 1000-grain weight, grain yield hill⁻¹, protein content and starch content than Hybrid Sorgo and Safal at same water stress condition. Therefore Bangladeshi varieties were found more tolerant than Hybrid Sorgo variety to water stress. Findings of this research will be helpful for the farmers about the beneficial use of resource in terms of managing limited water as well as increasing crop productivity. Finally these research findings would certainly contribute food security in Bangladesh.

Key words: Water stress, field capacity, sorghum

Introduction

Sorghum (Sorghum bicolor L. Moench) is one of the most important cereal crops and also the major staple food crop of millions of people in semi arid tropics (SAT). It is considered as the king of millets and extensively grown in Africa, China, USA, Mexico and India. It is fourth important cereal crops of the world after wheat, rice and maize. The crop is drought tolerant and it is the crop excellence for dry areas. Now-a-days, Sorghum grain is mainly used for human food, fodder, feed and fuel purposes. Moreover, seeds are used for popcorn and preparing delicious food. This crop has tremendous potentiality to grow under adverse condition by minimum input and care and so its cultivation can be extended in drought prone (Moisture deficit) areas. In Bangladesh this crop is traditionally grown in Jamalpur, Kushtia, Pabna, Rajshahi, Sherpur, Meherpur, Bagerhat and Chittagong Hill Tracts. In the country 3200 metric tons of Sorghum grains are produced annually from about 4000 hectare of land and
average yield is 3.6 metric tons per hectare (BBS, 2012).

Drought is one of the major abiotic stresses in agriculture worldwide, limiting crop productivity (Araus et al., 2002). Generally, drought stress reduces growth (Garg et al., 2004; Samarah et al., 2004) and yield of various crops (Dhillon et al., 1995). Also reduce the nutrient uptake in plants (Baligar et al., 2001). Generally, low water availability results in reduced total nutrient uptake and frequently reduces the levels of mineral nutrients in crop plants (Marschner, 1995; Baligar et al., 2001). It is well evident that drought-stressed plants exhibit various physiological, biochemical and molecular changes to thrive under water limited conditions (Arora et al., 2002).

Drought has long been considered to be a hazard responsible for ups and downs of many civilizations in the world. Drought occurs when rainfall is absent for a prolonged period of time, causing earth to parch, wells to dry, underground water to fall, leading to crop failure. In Bangladesh, drought in the northern districts is very common. The hydrological and climatic conditions of Bangladesh are characterized by too much water in the wet monsoon season and too little water in the dry months, creating a drought environment. The impact of such drought severely affects the economy of Bangladesh. So, it is urgent need to find out possible solutions in order to alleviate the effects of drought for crop production. The wide range of agricultural crops is grown in the Rabi and pre-Kharif seasons which become vulnerable to drought at varying degrees. Genetic improvement for drought tolerance is a long term strategy and hence the selection for drought tolerance has to be either drought escape or drought avoidance or drought tolerance assumes greater importance.

Currently, Bangladesh is facing severe climate change effect, especially in pre Kharif and Rabi season. Temperature is going up; drought condition is persisting with greater intensity. The common crops are severely affected. Annually, about 2-7 million hectare area is vulnerable to drought. About 28% of the Rabi crops and 19% of the Kharif crops are highly vulnerable to annual drought problem. To face the challenges, one of the strategies to meet climate change effect is to introduce new but tolerant crops. One such crop could be Sorghum. Because it is a very hardy crop which can be grown under rain fed condition with less inputs and it has high yield potential. Superior genetic resources with improved tolerance to drought are required to reduce the risk of loss from water deficit, which requires the identification of easily measureable traits related to drought tolerance.

The study for screening of drought tolerant cultivar is very scanty and the physiological mechanisms that mediate tolerance are poorly understood. So the present study is aimed at evaluating the Sorghum germplasms for drought tolerance based on their morphophysiological and yield characteristics.

**Materials and Methods**

A pot experiment was carried out at the net house of the Department of Crop Botany, BAU, Mymensingh. Geographically the experimental area is located at 24°75' N latitude and 90°50' Longitude at the elevation of 18 m above the sea level.

The seeds of sorghum varieties viz. Safal, BD 731, BD 740 (indigenous) collected from BADC and BARI and Hybrid Sorgo, an exogenous variety, collected from Japan were used as experimental materials. In the experiment, earthen pots of 21cm diameter and 26cm depth were used. Soils were collected from Agronomy farm, BAU, Mymensingh. After pulverizing and drying in the sun, plant propagules and inert materials were removed from the soil. Manure and fertilizers were mixed thoroughly with soil and each pot was filled with 5kg of soil. Five seeds were sown in each pot and plants were thinned to two plants per pot after 10 days of sowing. Urea, TSP, MP and Gypsum were applied @190, 90,90 & 50 kg ha⁻¹ respectively.

The weight of 1 hectare soil at the depth of 15 cm was considered $2 \times 10^6$
kg soil. According to above rate, fertilizers were calculated as per kg of soil (BINA, 1999).

The two factorial experiments were laid out in a completely randomized design (CRD) with three replications. Total number of pots was 36 (4 x 3 x 3). Treatment combinations were four varieties and three levels of moisture condition. Varieties were V₁= Hybrid Sorgo, V₂=Safal, V₃= BD 731 and V₄= BD 740 and three levels of moisture stress (Field capacity=FC) were F₁=100% FC (Control), F₂=70% FC, F₃=40% FC. However, there were twelve treatment combinations viz. T₁= V₁F₁, T₂= V₁F₂, T₃= V₁F₃, T₄= V₂F₁, T₅= V₂F₂, T₆= V₂F₃, T₇= V₃F₁, T₈= V₃F₂, T₉= V₃F₃, T₁₀= V₄F₁, T₁₁= V₄F₂, T₁₂= V₄F₃.

Stress was imposed at two days interval started from tillering stage. Weeding and irrigation was done as and when necessary. All the plants of the given varieties were harvested at 120 days after planting when most of the grains became mature (about 95-100% grains were matured). Plant height, panicle length (cm), number of grain panicle¹, thousand (1000) grain weight and no. of filled grain hill¹ of different Sorghum varieties (Table 1) had no significant effect on panicle length and no. of unfilled grain hill¹ under control condition (Table 1). The highest panicle length (34.00 cm) was observed in Hybrid Sorgo and highest no. grain panicle² (1686), 1000 grain weight (35.28 g) and no. of filled grain (2905) were observed in BD 740 under control condition (Table 1). The lowest plant height (63.67 cm), panicle length (8.667 cm), no. grain panicle³ (325.3), 1000-grain weight (9.893 g), no. of filled grain (577.7), no. of unfilled grain hill¹ (54.33) were observed in Safal at 40% FC (Table 1).

**Grain yield**

Plants exposed with water stress significantly decreased grain yield of different varieties of Sorghum. The highest grain yield was observed in BD 740 with 100% FC (5.390 ton) and the lowest was observed in Safal at 40% FC (0.8167 ton) (Figure 1).

![Figure 1](image)

**Figure 1.** Interaction effect of moisture stress and varieties on grain yield of Sorghum (vertical bar indicates LSD at 1% level of probability).
Drought stress on sorghum morphology and yield attributes

Table 1. Combined effect variety and moisture stress on Sorghum varieties

| Variety       | Moisture stress | Plant height (cm) | Panicle length (cm) | No. of grains panicle \(^1\) | Wt. of 1000 grain (g) | No. of filled grain hill \(^1\) | No. of unfilled grain hill \(^1\) |
|---------------|-----------------|-------------------|---------------------|----------------------------|-----------------------|-----------------------------|-----------------------------|
| Hybrid sorgo  | 100% FC         | 192.70b           | 34.00               | 1457b                      | 24.49                 | 2905a                       | 124.0                       |
| (V\(_1\))     | 70% FC          | 169.70d           | 28.33               | 1320c                      | 18.02                 | 2628c                       | 173.3                       |
|               | 40% FC          | 136.00f           | 23.33               | 1140d                      | 15.68                 | 2273.00f                    | 237.0                       |
| Safal(V\(_2\))| 100% FC         | 100.40h           | 15.33               | 513.30f                    | 18.67                 | 1526.00i                     | 54.33                       |
|               | 70% FC          | 74.67i            | 11.67               | 416.7g                     | 10.86                 | 878.30j                     | 76.67                       |
|               | 40% FC          | 63.67j            | 8.667               | 325.3h                     | 9.89i                 | 577.70k                     | 106.3                       |
| BD 731(V\(_3\))| 100% FC        | 214.30a           | 29.00               | 1478b                      | 32.15b                | 2548d                       | 221.7                       |
|               | 70% FC          | 153.30e           | 24.67               | 1300c                      | 28.41d                | 2139g                       | 266.7                       |
|               | 40% FC          | 137.00f           | 23.33               | 1024e                      | 21.97f                | 1837h                       | 316.3                       |
| BD 740(V\(_4\))| 100% FC        | 185.70c           | 26.00               | 1686a                      | 35.28a                | 2744b                       | 73.67                       |
|               | 70% FC          | 131.30f           | 23.00               | 1423b                      | 32.14b                | 2468e                       | 125.7                       |
|               | 40% FC          | 119.70g           | 17.67               | 1048e                      | 30.18c                | 2132g                       | 170.3                       |
| LSD\(_{0.05}\) |                 | 6.89              | 2.64                | 91.41                      | 1.31                  | 63.87                       | 27.48                       |
| Level of sig. | **              | NS                | **                  | NS                         | **                    | *                            | NS                          |
| CV (%)        | 2.93            | 7.12              | 4.96                | 3.38                       | 1.86                  | 10.06                        |

** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Non significant

Effect of different moisture stress on chemical composition of Sorghum varieties

Protein content

The interaction between moisture levels and varieties had significant effect on protein content of Sorghum. Protein content of the Sorghum varieties were gradually decreased by the increasing drought level. The highest protein content (9.96 %) was observed in BD731 with 100%FC which was statistically identical with BD 740 at 100% FC whereas The lowest was observed in Hybrid Sorgo with 40% FC (8.46%) which was statistically identical with Safal (59.33) and Hybrid Sorgo (60.83) at 100% FC (Table 2).

Starch content

Starch content of the sorghum varieties were gradually decreased by the increasing drought levels. The highest starch content (71.14 %) was observed in BD731 with 100%FC which was statistically identical with BD 740 at 100% FC whereas The lowest was observed in Hybrid Sorgo with 40% FC (8.46%) which was statistically identical with Safal (59.33) and Hybrid Sorgo (60.83) at 100% FC (Table 2).

Discussion

In the semi-arid tropics where dryland farming is practiced, drought is a common phenomenon that occurs at different periods during the growing season (Blum, 1988). Drought is a combination of stress effects caused by high temperatures (Prasad et al., 2008) and a lack of water (Campos et al., 2004). Drought can occur at both seedling, pre-flowering and post-flowering stages of development, and has the most adverse effect on yield (Tuinstra et al., 1997; Kebede et al., 2001).
Most of the morphological and physiological characters at seedling stage are affected by water stress in sorghum (Bibi et al. 2010). Drought stress suppressed shoot growth more than root growth (Salih et al. 1999; Younis et al. 2000; Oğcu et al. 2005; Bibi et al. 2010). Reduction in seedling growth is the result of restricted cell division and enlargement, as drought stress directly reduces growth by decreasing cell division and elongation (Kramer, 1983).

### Table 2. Combined effect of variety and moisture stress on chemical composition of Sorghum

| Variety     | Moisture stress | Protein (%) | Starch (%) |
|-------------|-----------------|-------------|------------|
| Hybrid Sorgo (V1) | 100% FC | 9.273<sup>c</sup> | 68.33<sup>c</sup> |
|             | 70% FC | 8.590<sup>d</sup> | 64.3<sup>b</sup> |
|             | 40% FC | 8.460<sup>f</sup> | 60.83<sup>e</sup> |
| Safal (V2)  | 100% FC | 9.88<sup>a</sup> | 66.67<sup>a</sup> |
|             | 70% FC | 9.270<sup>d</sup> | 64.00<sup>d</sup> |
|             | 40% FC | 8.860<sup>e</sup> | 59.33<sup>e</sup> |
| BD 731 (V3) | 100% FC | 9.960<sup>a</sup> | 71.14<sup>a</sup> |
|             | 70% FC | 9.140<sup>d</sup> | 69.00<sup>b</sup> |
|             | 40% FC | 8.860<sup>e</sup> | 63.33<sup>e</sup> |
| BD 740 (V4) | 100% FC | 9.960<sup>a</sup> | 70.00<sup>ab</sup> |
|             | 70% FC | 9.550<sup>b</sup> | 67.00<sup>c</sup> |
|             | 40% FC | 9.410<sup>c</sup> | 59.0<sup>c</sup> |

LSD<sub>0.05</sub> = 0.226  1.86

** = Significant at 1% level of probability,
* = Significant at 5% level of probability,
NS = Non significant

Water plays a vital role in the growth, yield and nutrient uptake of plant. Insufficient water vigorously affects the germination of seed, cell division, tillering and nutrient uptake of the plants. Nutrients from the soil reach the surface of root by mass flow and diffusion processes. Mass flow and diffusion processes are positively correlated with moisture content of the soil. Movement of nutrients through the plant body is also associated with soil water content. Application of water without proper planning results not only the wastage of water but also hamper crop growth and yield.

The effect of moisture stress on growth and yield attributes of different varieties was observed. The higher values of growth and yield attributes were observed in normal treatment than drought treatment. The interaction effect of moisture stress on growth and yield attributes of different varieties was statistically significant at 1% level of probability except number filled grains hill<sup>1</sup>.

An experiment was conducted to study the growth and yield attributes of four sorghum varieties viz. Hybrid Sorgo, Safal, BD 731, BD 740. The plants were grown under normal and drought condition. The different varieties showed variable results on different attributes. Results revealed that different parameters were decreased with the increasing drought stress due to different physiological constraints.

Due to water deficit, stomatal conductance, transpiration, photosynthesis and different physiological process become reduced. For different parameters such as plant height; the effect of varieties: my be arranged as V<sub>4</sub> &gt; V<sub>1</sub> &gt; V<sub>3</sub> &gt; V<sub>2</sub> for number of filled grains hill<sup>1</sup>, V<sub>4</sub> &gt; V<sub>2</sub> &gt; V<sub>3</sub> &gt; V<sub>2</sub>, for thousand grain weight, V<sub>2</sub> &gt; V<sub>1</sub> &gt; V<sub>3</sub> &gt; V<sub>2</sub> no. of grain per panicle, V<sub>4</sub> &gt; V<sub>3</sub> &gt; V<sub>1</sub> &gt; V<sub>2</sub> for grain yield, V<sub>4</sub> &gt; V<sub>3</sub> &gt; V<sub>1</sub> &gt; V<sub>2</sub> for protein content, V<sub>4</sub> &gt; V<sub>2</sub> &gt; V<sub>3</sub> &gt; V<sub>1</sub> for starch content. Considering all the parameters, it may be concluded that V<sub>4</sub> (BD 740) showed better performance considering morpho-physiological attributes in compare to other varieties. The Safal showed to be an inferior variety.

**Conclusion**

From the present research work, it could be concluded that the growth, yield contributing characters and chemical compositions of all the varieties were reduced
under increasing drought stress condition. Among the varieties, BD 740 was found comparatively more tolerant under increasing drought stress condition than Hybrid sorgo, BD 731 and Safal. Among the varieties, BD 740 was found comparatively more tolerant under increasing drought stress condition than Hybrid sorgo, BD 731 and Safal. Thus BD 740 variety can be cultivated in the drought prone areas of Bangladesh.

Acknowledgements

The authors are highly acknowledged to Bangladesh Agricultural University Research System, for providing all the funds required for this research works.

References

Akram M (2011). Growth and yield components of wheat under water stress of different growth stages. Bangladesh Journal of Agricultural Research 36, 455-468.

Araus JL, Slafier GA, Reynolds MP, Royo C (2002). Plant breeding and relations in C3 cereals: what to breed for? Annals of Botany 89, 925–940.

Arora A, Sairam RK, Srivastava GC (2002). Oxidative stress and antioxidant systems in plants. Current Science 82, 1227-1238.

Bakul MRA, Akter MS, Islam MN, Chowdhury AA, Amin MHA (2009). Water stress effect on morphological characters and yield attributes in some mutants T-aman rice lines. Bangladesh Research Publications Journal 3, 934-944.

Baligar VC, Fageria NK and He ZL (2001). Nutrient use efficiency in plants. Communications in Soil Science and Plant Analysis 32, 921-950.

BBS (Bangladesh Bureau of Statistics) (2012). Statistical pocketbook. Bangladesh: 168.

Benmoussa M, Achouch A (2005). Effect of water stress on yield and its component of some cereals in Algeria. Journal of Central European Agriculture 6(4), 427-434.

Bibi A, H.A Sadaqat, HM Akram, MI Mohammed (2010). Physiological markers for screening sorghum (Sorghum bicolor) germplasm under water stress condition. Int. J. Agric. Biol.12: 451–455.

Blum A (2011). Drought resistance and its improvement. In: Blum A. (ed) Plant Breeding for Water-Limited Environments. Springer Science and Business Media, NY, pp. 53-137.

Blum A (1988). Plant Breeding for Stress Environments. CRC Press, Boca Raton, Florida.

Campos H, Cooper M, Habben JE, Edmeades GO, Schussler JR (2004). Improving drought tolerance in maize: A view from industry. Field Crops Research 90:19-34.

Cruz, RT., Jordan WR, Drew MC (1992). Structural changes and associated reduction of hydraulic conductance in roots of Sorghum bicolor L. following exposure to water deficit. Plant Physiol. 99: 203–212.

Dhillon RS, Third HS, Saseena UK, Sharma RK, Malhi NS (1995). Tolerance to excess water stress and its association with other traits in maize. Crop Improvement 22(1), 22-28.

Garg BK, Burman U, Kathju S (2004). The influence of phosphorus nutrition on the physiological response of moth bean genotypes to drought. Journal of Plant Nutrition and Soil Science 167, 503-508.

Gomez KA, Gomez AK (1984). Statistical Procedures of Agricultural Research. 2nd edition. John Wiley and Sons. New York. p. 207–215.

Gupta SN, Dahiya BS, Malik BPS, Bishnoi NR (1995). Response of chickpea to water deficits and drought stress. Haryana Agricultural University Journal of Research 25, 11-19.

Kebede, H, Subudhi PK, Rosenow DT, Nguyen HT (2001). Quantitative trait loci influencing drought tolerance in grain sorghum (Sorghum bicolor L. moench). Theor. Appl. Genet. 103: 266-276.

Khayatnezhad M, Gholamin R, Jamaatie-Somarin SH, Zabihi-Mahmooodabad R (2010). Effects of PEG stress on corn cultivars (Zea mays L.) at germination stage. World Appl. Sci. J. 11(5): 504-506.
Khodarahmpour, Z. (2011). Effect of drought stress induced by polyethylene glycol (PEG) on germination indices in corn (Zea mays L.) hybrids. Afr. J. Biotechnol. 10(79): 18222-18227.

Kramer PJ (1983). Water Relations of Plants, pp: 155–106. Academic Press, Inc. New York.

Kulkarni M, Deshpande U (2007). In Vitro screening of tomato genotypes for drought resistance using polyethylene glycol. Afr. J. Biotechnol. 6(6): 691-696.

Leishman MR, Westoby M (1994). The role of seed size in seedling establishment in dry soil conditions -experimental evidence from semi-arid species. J. Ecol. 82(2): 249-258.

Marschner H (1995): Mineral Nutrition of Higher Plants. 2nd Edition. Academic Press, London.

Meo AA (2000). Impact of variable drought stress and nitrogen levels on plant height, root length and grain numbers per plant in a sunflower variety”Shmas”. Pakistan J. Agric. Sci. 37: 89–92.

Michel BE, Kaufmann MR (1973). The osmotic potential of polyethylene glycol 6000, Plant Physiol. 51: 914-916.

Mohammadkhani N, Heidari R (2008). Water stress induced by polyethylene glycol 6000 and sodium chloride in two corn cultivars. Pakistan J. Biol. Sci. 11(1): 92-97.

Murray SC, Sharma A, Rooney WL, Klein PE, Mullet JE, Mitchell SE, Kresovich S (2008). Genetic improvement of sorghum as a bio-fuel feedstock: I. QTL for stem sugar and grain non-structural carbohydrates. Crop Sci. 48:2165-2179.

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

Prasad PVV, Pisipati SR, Mutava RN, Tuinstra MR (2008). Sensitivity of grain sorghum to high temperature stress during reproductive development. Crop Science 48:1911-1917.

Rajendran RA, Muthiah AR, Manickam A, Shanmugasundaram P, John JA (2011). Indices of drought tolerance in sorghum (Sorghum bicolor L. Moench) genotypes at early stages of plant growth. Res. J. Agric. & Biol. Sci. 7: 42-46.

Rauf S (2008). Breeding sunflower (Helianthus annuus L.) for drought tolerance Communication in Biometry and Crop Science 3(1): 29-44.

Salih AA, Ali IA, Lux A, Luxova M, Cohen Y, Sugimoto Y, Inanaga S (1999). Rooting, water uptake, and xylem structure adaptation to drought of two sorghum cultivars. Crop Sci.39: 168–173.

Samarah N, Mullen R, Cianzio S (2004): Size distribution and mineral nutrients of soybean seeds in response to drought stress. Journal of Plant Nutrition 27, 815-835.

Shao B, Yuxiu Y, Chen X, Wang Z, Yanq J, Zhu Q, Zhanq H (2004): Effect of water stress during grain filling on the grain yield and quality of two line hybrid rice. Journal of YangZhou University, Agricultural and Life Sciences 25(1), 46-50.

Simpson GM (1981). Water Stress in Plants. Praeger, NY.

Taiz L, Zeiger E (2006). Stress physiology. pp. 671–681. In: Taiz L, Zeiger E, (eds.) Plant Physiology, 4th ed. Sinauer Associates, Inc., Sunderland, MA.

Tuinstra MR, Grote EM, Goldbrough PM, Ejeta G (1997). Genetic analysis of post-flowering drought tolerance and components of grain development in Sorghum bicolor L. Moench. Mol. Breed. 3:439-448.

Vajrabhaya M, Kumpun W, Chadchawan S (2001). The solute accumulation: The mechanism for drought tolerance in RD23 rice (Oryza sativa L.) lines. Sci. Asia 27:93-97.

Xiong L, Wang R, Mao G, Koczan JM (2006). Identification of Drought Tolerance Determinants by Genetic Analysis of Root Response to Drought Stress and Abscisic Acid. Plant Physiology 142:1065-1074.

Younis, ME, El-Shahaby OA, Abo-Hamed SA, Ibrahim AH (2000). Effects of water stress on growth, pigments and assimilation in three sorghum cultivars. J. Agron. Crop Sci.185: 73–82.