Asian Plant Research Journal

Volume 11, Issue 6, Page 9-18, 2023; Article no.APRJ.106939
ISSN: 2581-9992

Evaluation of Maize Varieties at Seedling Stage under Drought Stress Based on Morpho-physiological and Biochemical Attributes

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/APRJ/2023/v11i6225

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/106939

Original Research Article

Received: 01/08/2023
Accepted: 07/10/2023
Published: 17/10/2023

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ABSTRACT

A hydroponic pot experiment was driven to investigate the improvement of drought tolerance in six maize varieties (e.g. Gold Star, BHM 14, Paloan, Bharti 981, BHM 9, Pioneer) based on morpho-physiological and biochemical characteristics. Six Maize varieties were used as test crops and the experiment was laid out in a completely randomized design (RCBD) with three replications. Drought stress was imposed 14 days after sowing by using the PEG solution. The results revealed that BHM 14 possessed the longest root length (69.33 cm), higher shoot length (42.67 cm), longest total plant height (112.00 cm), highest fresh root weight (3.32 g), high leaf greenness found in BHM 14 measured by SPAD meter in both top and lower leaves, high amount of proline whereas, Paloan produced shortest total plant height (78.50 cm), lowest fresh root weight (1.52 g), lowest proline after 42 days of sowing under stress condition. The maximal photochemical efficiency (Fv/Fm) appeared to measure photosynthesis whereas Pioneer was comparatively higher in stress conditions. The fresh weight of root and shoot was significantly least affected in stress conditions, whereas BHM 14 performed better in stress conditions. On the other hand, varieties had a significant difference in total dry matter of control condition and stress condition. Therefore, it is suggested that BHM 14 showed maximum drought tolerance in respect of growth and morpho-physiological changes under drought conditions.

Keywords: Biochemical; drought; maize; morpho-physiological; stress; variety.

1. INTRODUCTION

Maize (*Zea mays* L.) occupies a key position as one of the most important cereals both for human and animal consumption. The crop is grown under various conditions in different parts of the world and its worldwide production is 785 million tons. It is an important C4 plant from the Poaceae family and is moderately sensitive to drought stress, wide intra-specific genetic variation for drought resistance exists in maize [1]. Maize plants undergo a variety of adaptations at subcellular, cellular and organ levels to grow successfully under drought. Drought resistance is a complex phenomenon, maize plants manifest several adaptations such as stomata regulations, changes in hormonal balance, activation of the antioxidant defense system, osmotic adjustment, maintenance of tissue water contents and various mechanisms of toxic symptoms under drought stress. Germination in *Zea mays* (*Z. mays* L.) decreases linearly with rising drought and drought stress creates internal stress in plants [2]. These stresses can be distinguished at several levels such as shoot, root and tissues [3]. Drought stress is an abiotic stress that can affect plant growth and physiological and biochemical activities such as photosynthetic activity and chlorophyll content (Hajer et al., 2006); [4]. Among the stages of the plant life cycle, seed germination and seedling emergence and establishment are key processes in the survival and growth of plants [5]. It is well-established that drought stress has a negative correlation with seed germination and vigor [6]. Seeds contribute as a vital component of the world's diet. The embryos present in the seed act as a miniature plant and mode of dispersal and provide food reserve to the growing seedlings. Seed germination and early seedling growth are critical events for plant development [7]. Germination becomes visible by the emergence of the structures surrounding the embryo by the radicle. Considering the importance and adaptability, the average yield performance is very low compared to other developed countries due to different stresses. Among the various factors that limit total yield, drought stress is one of the serious environmental problems in Bangladesh, although the yield potential is promising. Crop plants are subjected to a variety of environmental stresses, many of which impair plant growth and development, decreasing crop plant yield (Seki et al., 2003); [8]. Drought is the single most damaging environmental stress, reducing crop yield more than any other environmental stress [9]. Drought can affect plant water metabolism and induce major morphological, physiological, and biochemical alterations [10]. Drought stress inhibits plant growth by lowering the rate of photosynthesis [11]; (Zhang et al., 2018). Stomatal (stomatal closure owing to decreasing CO_2), nonstomatal (decreased photosynthetic activity in mesophyll tissue), or both reasons could be the main causes of decreased photosynthesis ([12,13]. Plants have evolved a variety of defense mechanisms to combat the oxidative damage induced by drought stress, including the overproduction of antioxidant molecules that prevent oxidative chain reactions from propagating [14].

The important of antioxidant activities of phenolic compounds such as phenolic acids and flavonoids have been identified to be the most widespread substantial groups of plant secondary metabolites produced from the shikimate phenylpropanoid biosynthetic pathway [5]. Many plants have a drought tolerance mechanism mediated by endogenous phenolic substances, but it varies by species, cultivars, plant tissues, and drought intensity [16]; (Al Hassan et al., 2015); [17,18]. To develop drought-tolerant cultivars for long-term crop production in the country's moisture deficit areas fundamental research has been conducted in this area to generate high-yielding genotypes suitable for drought stress, which must be analyzed morpho-physiologically to obtain high-yielding genotypes. So, it is essential to screen suitable maize varieties that will grow and perform better under water stress conditions.

2. MATERIALS AND METHODS

The Experiment was conducted at the Growth Chamber for Hydroponic Culture in Plant Physiology Laboratory, Department of Crop Botany, Bangladesh Agricultural University, Mymensingh, Bangladesh during the period from March 2019 to September 2019. The test crop under investigation was six varieties of maize (e.g. Gold Star, BHM 14, Paloan, Bharti 981, BHM 9 and Pioneer) were collected from the Bangladesh Agricultural Research Institute (BARI), Joydevpur, Gazipur. The experiment was laid out in two factorial Completely Randomized Design (CRD) with three replications. There were two factors A: Six maize varieties and Factor B: Drought stress (0 and 10% PEG-6000).

Thus, the total number of pot was 36 $(6 \times 2 \times 3)$ in the hydroponic experiment. Tank size was 4L and each tank represents a single replication. An artificial light source was used in the experiment. High-pressure sodium (HPS) light (400 watts) was used for artificial lighting. About 200-250 µmol m^{-2} s^{1} light intensity was given for proper growth. The experiment was conducted in the growth room at 25˚C with a photoperiod of 16 h. One-week-old seedlings were transferred to continuously aerated nutrient solution in 4-L Hydroponics tank on Styrofoam blocks with three holes and three plants per hole, supported with a sponge. Before transplanting macro and micronutrients were applied at recommended rates. Nutrients were added according to Hoagland's solution composition and the recommended dose used for the experiment ($Ca(NO_3)_2$:2.0 mM , K_2SO_4a : 1.0 mM , KH_2P0_4 :.2 mM $MgSO_4$: 0.5 mM , $CaCl_2$: 2.0 mM, H_3B0_4 : 1.0 µM, $MnSO_4$: 2.0 µM, $ZnSO_4$: 0.5 µM, $CuSO_4$: 0.3 mM and ($NH_4)_6Mo_70_4$: 0.01 µM along with treatments [19]. The p^H of the solution was monitored daily and maintained around 5.5 by PHS-25 precision p^H/mv meter (Lida, shanghai, china). According to their growth, 28 days old seedlings have been finalized for data collection. Parameters of the experiment measured were Shoot length, Root length, Number of leaves per plant, Leaf area, shoot fresh weight, shoot dry weight, root fresh weight, root dry weight, maximum photochemical efficiency of Photosystem-II (F_v/F_m), relative greenness, proline content, total plant height, total fresh weight, root shoot ratio, total dry weight, photosynthesis, transpiration, stomatal conductance, water use efficiency**.** The data in respect of growth were statistically analyzed to find out the statistical significance of the experimental results. The means for all the treatments were calculated and the analyses of variance for all the characters were performed by F test. The significance of the difference between the pairs of means was separated by LSD test at 5% and 1% levels of probability by using MSTAT-C package program.

3. RESULTS AND DISCUSSION

3.1 Root Length

The effects of drought in the case of root length of Maize varieties differ significantly (Table 1). In the control condition, the longest root length (76.50 cm) was recorded from the variety BHM 14 followed by Gold star (75.33 cm) and the shortest root length (54.67 cm) was achieved from Paloan followed by Bharti 981 (55.00 cm). The table showed that root length was decreased in each variety with the increasing drought level. In 10% PEG, the longest root length (69.33 cm) was recorded from the variety BHM 9 followed by Gold Star (59.67 cm) and the shortest root length (43.00 cm) was achieved from Paloan followed by Bharti 981 (51.00 cm). Turk and Hall [20], reported that root length of maize may be inhibited due to increasing salinity levels.

3.2 Shoot Length

The effects of drought on the shoot length of Maize varieties differ significantly (Table 1). In the control condition, the longest shoot length (78.33 cm) was recorded from the variety BHM 14 followed by Paloan (61.33 cm) and the shortest shoot length (45.00 cm) was achieved from BHM 9 followed by Pioneer (48.67 cm). The table showed that shoot length was decreased in each variety with the increasing drought level. In the 10% drought level, the longest shoot length (42.67 cm) was recorded from the variety Pioneer followed by BHM 14 (40.33 cm) and the shortest shoot length (32.67 cm) was achieved from Bharti 981 followed by BHM 9 (35.00 cm). Plant biomass especially shoot length was affected due to higher salinity levels (Pressland et al., 1982).

3.3 Plant Height

The effects of drought on plant height of Maize varieties differ significantly (Table 1). In the control condition, the longest plant height (154.83 cm) was recorded from the variety BHM 14 followed by Gold star (131.6 cm) and the shortest plant height (108.7 cm) was achieved from Pioneer followed by Bharti 981 (109.3 cm). The table showed that plant height was decreased in each variety with the increasing drought level. In 10% drought level, the longest plant height (112.00 cm) was recorded from the variety BHM 14 followed by Pioneer (114.00 cm) and the shortest plant height (78.50 cm) was achieved from Paloan followed by Bharti 981 (83.67 cm). Pressland et al., 1982 reported that drought-induced growth inhibition in maize has long been reported for plant height.

3.4 Shoot Fresh Weight

Six Maize varieties showed different magnitude of reductions in the shoot fresh weight due to drought stress. Significant variation was observed among the varieties weight due to and treatment (Table 1). In control condition, the maximum shoot fresh weight (11.17g) as recorded from the variety BHM 9 followed by BHM 14 (11.01 g) and the minimum shoot fresh weight (4.61 g) was achieved from Paloan followed by Pioneer (5.66 g). The table (Table 1) showed that, shoot fresh weight was decreased in each variety with the increasing Drought level. In 10% drought level, the maximum shoot fresh weight (10.83 g) was recorded from the variety BHM 9 followed by BHM 14 (8.20 g) and the minimum shoot fresh weight (4.05 g) was achieved from Paloan followed by Pioneer (4.06 g). Shoot biomass is declined due to to increase of salinity [21].

3.5 Root Fresh Weight

Six Maize varieties showed different magnitudes of reductions in the root fresh weight due to drought stress. Significant variation was observed among the varieties weight due to and treatment (Table 1). In control condition, the maximum root fresh weight (3.43 g) as recorded

Table 1. Effect of variety and treatment on morphological characteristics

Variety x treatment	Root Length	Shoot Length	Plant Height	Shoot Fresh Weight	Root Fresh Weight	Total Fresh Weight
Gold Star (Control)	75.33a	56.27bc	131.6b	8.17b	2.57b	10.74d
Gold Star (10% PEG)	55.00c	38.67efg	93.67fg	7.01c	2.10d	9.11e
BHM 14 (Control)	76.50a	78.33a	154.83a	11.01a	3.44a	14.45a
BHM 14 (10% PEG)	69.33ab	42.67efg	112ef	8.20b	3.32a	11.52c
Paloan (Control)	54.67c	61.33b	116.0cd	4.61e	1.77f	6.38gh
Paloan (10% PEG)	43.00d	35.50fg	78.50h	4.05e	1.52g	5.57i
Bharti 981 (Control)	55.00c	54.33bcd	109.3cde	7.75b	2.32c	10.07d
Bharti 981 (10% PEG)	51.00cd	32.67g	83.67gh	4.65e	1.95e	6.60g
BHM 9 (Control)	74.00a	45.00def	119.0c	11.17a	3.37a	14.54a
BHM 9 (10% PEG)	59.67bc	35.00fg	94.67def	10.83a	2.50b	13.34b
Pioneer (Control)	60.00bc	48.67cde	108.7cde	5.66d	2.36c	8.02f
Pioneer (10% PEG)	58.67bc	40.33efg	99.00def	4.17e	1.51g	5.67hi
Level of sign.	*	**	**	**	**	**

*In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT). ** =Significant at 1% level of probability, * =Significant at 5% level of probability* from the variety BHM 14 followed by BHM 9 (3.37 g) and minimum the root fresh weight (1.77 g) was achieved from Paloan followed by Bharti 981 (2.32 g). The table (Table 1) showed that, root fresh weight was decreased in each variety with the increasing Drought level. In 10% drought level, the maximum root fresh weight (3.32 g) was recorded from the variety BHM 14 followed by BHM 9 (2.50 g) and the minimum root fresh weight (1.51g) was achieved from Pioneer followed by Paloan (1.52 g). Root fresh weight decreased with the increment of drought stress [22].

3.6 Total Fresh Weight

Six Maize varieties showed different magnitude of reductions in the total fresh weight due to drought stress. Significant variation was observed among the varieties weight due to and treatment (Table 1). In the control condition, the maximum total fresh weight (14.54 g) as recorded from the variety BHM 9 followed by BHM 14 (14.45 g) and the minimum total fresh weight (6.38 g) was achieved from Paloan followed by Pioneer (8.02 g). The table (Table 1) showed that, total fresh weight was decreased in each variety with the increasing Drought level. In 10 % drought level, the maximum total fresh weight (13.34 g) was recorded from the variety BHM 9 followed by BHM 14 (11.52 g) and the minimum total fresh weight (5.57 g) was achieved from Paloan followed by Pioneer (5.67 g). Total biomass of maize plant decreased under the stress condition either natural or artificially imposed water scarcity [22].

3.7 Relative Greenness (SPAD)

The effects of drought on relative greenness of varieties differ significantly (Table 2). In control condition, the maximum relative greenness (29.77) as recorded from the variety Gold Star followed by BHM 9 (28.43) and the minimum relative greenness (22.30) was achieved from Bharti 981 followed by Paloan (23.23). The table showed that, relative greenness was decreased in each variety with the increasing Drought level. In 10% drought level, the maximum relative greenness (27.70) was recorded from the variety BHM 14 followed by Gold Star (21.33) and the minimum relative greenness (17.57) was achieved from Paloan followed by Bharti 981 (19.33). Leaf greenness as measured by SPAD unit has been found less affected in all tested maize varieties due to water deficits. Dark green plants with reduced shoot biomass without toxicity symptoms in the foliage represent the typical phenotypic trait for the first phase of drought stress [23].

3.8 Photochemical Efficiency of PS-II (Fv/Fm)

The effects of drought on the photochemical efficiency of PS-II of varieties differ significantly (Table 2). In control condition, the maximum photochemical efficiency of PS-II (0.787) as recorded from the variety Gold Star followed by BHM 14 (0.773) and minimum photochemical efficiency of PS-II (0.750) was achieved from Paloan followed by Bharti 981 (0.753). The table showed that, the photochemical efficiency of PS-II was decreased in each variety with the

Table 2. Effects of variety and treatment on physiological and morphological characteristics

Variety x treatment	Spad Value	F_V/F_M	Leaf Area
Gold Star (Control)	29.77a	0.787a	76.51e
Gold Star (10% PEG)	21.33ef	0.730e	68.68f
BHM 14 (Control)	28.10ab	0.773ab	102.4c
BHM 14 (10% PEG)	27.70b	0.746cde	73.66e
Paloan (Control)	23.23d	0.750cd	30.00j
Paloan (10% PEG)	17.57h	0.750cd	28.28j
Bharti 981 (Control)	22.30de	0.753c	59.05h
Bharti 981 (10% PEG)	19.33g	0.733de	49.53i
BHM 9 (Control)	28.43ab	0.760bc	148.1a
BHM 9 (10% PEG)	20.03fg	0.750cd	122.3b
Pioneer (Control)	27.33b	0.763bc	93.53d
Pioneer (10% PEG)	25.40c	0.756bc	63.34g
Level of sign.	**	**	**

*In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT). ** =Significant at 1% level of probability* increasing Drought level. In 10% drought level, the maximum photochemical efficiency of PS-II (0.756) was recorded from the variety Pioneer followed by BHM 9 (0.750) and the minimum photochemical efficiency of PS-II (0.730) was achieved from Gold Star followed by Bharti 981 (0.733). While working with the maize, [24] reported that both short and long-term effects of drought on (F_v/F_m) ratios were not significant. Our results indicate that the drought at first phase (osmotic effect) may not be severe enough to cause potential damages in PS-II to make any significant difference in the (F_v/F_m) ratios among the tested six maize varieties.

3.9 Leaf Area

The effects of drought on leaf area of Maize varieties differ significantly (Table 2). In control condition, the maximum leaf area (148.10 cm^2) was recorded from the variety BHM 9 followed by BHM 14 (102.40 cm^2) and the minimum leaf area (30.00 cm^2) was achieved from Paloan followed by Bharti 981 (59.05 cm^2). The table (Table 2) showed that leaf area was decreased in each variety with the increasing drought level. In 10% drought level, the maximum leaf area (122.30 cm^2) was recorded from the variety BHM 9 followed by BHM 14 (73.66 cm^2) and the minimum leaf area (28.28 cm^2) was achieved from Paloan followed by Bharti 981 (49.53 cm^2). Drought stress highly reduced the leaf area, which is due to accelerated leaf senescence caused by drought stress [25].

3.10 Shoot Dry Weight

The effects of drought on shoot dry weight of varieties differ significantly (Table 3). In control condition, the maximum shoot dry weight (0.91 g) as recorded from the variety BHM 9 followed by BHM 14 (0.73 g) and the minimum the shoot dry weight (0.34 g) was achieved from Paloan followed by Pioneer (0.44 g). The table (Table 3) showed that, root dry weight was decreased in each variety with the increasing Drought level. In 10 % drought level, the maximum root fresh weight (0.73 g) was recorded from the variety BHM 9 followed by BHM 14 (0.69 g) and the minimum shoot dry weight (0.30 g) was achieved from Paloan followed by Pioneer (0.35 g). Shoot fresh and dry weights in maize and soybean plants also significantly reduced when exposed to drought due to reduced shoot growth, increased senescence and switching over of the plant growth from shoot growth towards root growth (Humayun et al., 2010).

3.11 Root Dry Weight

The effects of drought on root dry weight of varieties differ significantly (Table 3). In control condition, the maximum root dry weight (0.21 g)

Table 3. Combined effects of variety and treatment on shoot dry weight, root dry weight, total dry weight and root shoot ratio

Variety x treatment	SDW	RDW	TDW	RSR
Gold Star (Control)	0.736b	0.143b	0.880c	0.196def
Gold Star (10% PEG)	0.530c	0.097def	0.627e	0.180def
BHM 14 (Control)	0.733b	0.210a	0.943b	0.286ab
BHM 14 (10% PEG)	0.686b	0.116bcd	0.803d	0.170ef
Paloan (Control)	0.343ef	0.106cde	0.450g	0.313a
Paloan (10% PEG)	0.300f	0.073f	0.373h	0.236bcd
Bharti 981 (Control)	0.470d	0.130bc	0.600e	0.273ab
Bharti 981 (10% PEG)	0.380e	0.103cdef	0.483fg	0.260abc
BHM 9 (Control)	0.906a	0.210a	1.117a	0.233bcd
BHM 9 (10% PEG)	0.733b	0.106cde	0.840cd	0.147f
Pioneer (Control)	0.440d	0.093def	0.533f	0.210cde
Pioneer (10% PEG)	0.353ef	0.076ef	0.430g	0.213cde
$LSD_{0.05}$	0.053	0.029	0.053	0.053
SE (±)	0.014	0.0091	0.0159	0.020
Level of sign.	**	**	**	*
CV (%)	**4.33**	**12.94**	**4.10**	**15.48**

*In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT). ** =Significant at 1% level of probability, * =Significant at 5% level of probability* as recorded from the variety BHM 14 followed by Gold Star (0.14 g) and minimum the root dry weight (0.07 g) was achieved from Pioneer followed by BHM 9 (0.106 g). The table showed that, root fresh weight was decreased in each variety with the increasing Drought level. In 10% drought level, the maximum root fresh weight (0.12 g) was recorded from the variety BHM 14 followed by Bharti 981 (0.103 g) and the minimum root fresh weight (0.029 g) was achieved from Pioneer followed by Paloan (0.073 g). Arjunan et al., [26] also stated that the weight/plant, was reduced in high water deficits condition. Therefore, the present result hypothesized that with the increasing of drought level root dry weight might be decreased.

3.12 Total Dry Weight

The effects of drought on total dry weight of varieties differ significantly (Table 3). In control condition, the maximum total dry weight (1.12 g) as recorded from the variety BHM 9 followed by BHM 14 (0.94 g) and minimum the total dry weight (0.451 g) was achieved from Paloan followed by Pioneer (0.53 g). The table (Table 3) showed that, total dry weight was decreased in each variety with the increasing Drought level. In 10 % drought level, the maximum total dry weight (0.84 g) was recorded from the variety BHM 9 followed by BHM 14 (0.80 g) and the minimum total dry weight (199237 g) was achieved from Paloan followed by Pioneer (0.43 g). Arjunan) reported that total dry weight of maize reduced under drought condition to normal condition.

3.13 Root Shoot Ratio

The effects of drought on root shoot ratio of varieties differ significantly (Table 3). In control condition, the maximum root shoot ratio (0.313) as recorded from the variety Paloan followed by BHM 14 (0.286) and minimum root shoot ratio (0.196) was achieved from Gold Star followed by Pioneer (0.210). The table showed that, root shoot ratio was decreased in each variety with the increasing Drought level. In 10% drought level, the maximum root shoot ratio (0.260) was recorded from the variety Bharti 981 followed by Paloan (0.24) and the minimum root shoot ratio (0.15) was achieved from BHM 9 followed by BHM 14 (0.17). According to Liu et al., [22] the root shoot ratio of two maize cultivars become decreased due to higher level of drought condition.

3.14 Photosynthesis (A)

The effects of drought on photosynthesis of varieties differ significantly (Table 4). In control condition, the maximum photosynthesis (11.62 $\mu molm^{-2}s^{-1}$) as recorded from the variety Pioneer followed by Gold Star (10.47 $\mu molm^{-2}s^{-1}$) and the minimum photosynthesis (8.55 $\mu molm^{-2}s^{-1}$) was achieved from Paloan followed by BHM 14 (9.09 $\mu molm^{-2}s^{-1}$). The table showed that, photosynthesis was decreased in each variety with the increasing Drought level. In 10 % drought level, the maximum photosynthesis (10.23 $\mu molm^{-2}s^{-1}$) was recorded from the variety Pioneer followed by Gold Star (9.88 $\mu molm^{-2}s^{-1}$) and the minimum photosynthesis (8.23 $\mu molm^{-2}s^{-1}$) was achieved from Paloan followed by Bharti 981 (8.55 $\mu molm^{-2}s^{-1}$). The rate of photosynthesis reduced due to lower chlorophyll concentration in maize under water stressed conditions [26].

3.15 Transpiration (E)

The effects of drought on transpiration of varieties differ significantly (Table 4). In control condition, the maximum transpiration (1.347 $mmolm^{-2}s^{-1}$) as recorded from the variety BHM 9 followed by Pioneer (1.343 $mmolm^{-2}s^{-1}$) and minimum transpiration (1.02 $mmolm^{-2}s^{-1}$) was achieved from BHM 14 followed by Paloan (1.11 $mmolm^{-2}s^{-1}$). The table showed that, transpiration was decreased in each variety with the increasing Drought level. In 10 % drought level, the maximum transpiration (1.22 $mmolm^{-2}s^{-1}$) was recorded from the variety BHM 9 followed by Pioneer (1.18 $mmolm^{-2}s^{-1}$) and the minimum transpiration (0.66 $mmolm^{-2}s^{-1}$) was achieved from Paloan followed by Gold Star (0.78 $mmolm^{-2}s^{-1}$). Higher level of drought stress reduces water transpiration rate in maize quickly [27].

3.16 Stomatal Conductance (GS)

The effects of drought on stomatal conductance of varieties differ significantly (Table 4). In control condition, the maximum stomatal conductance (0.08 $molm^{-2}s^{-1}$) as recorded from the variety Gold Star followed by BHM 14 (0.053 $molm^{-2}s^{-1}$) and the minimum stomatal conductance (0.036 $molm^{-2}s^{-1}$) was achieved from Paloan followed by Bharti 981 (0.036 $molm^{-2}s^{-1}$). The table showed that, stomatal conductance was decreased in each variety with the increasing Drought level. In 10% drought level, the maximum stomatal conductance (0.046 $molm^{-2}s^{-1}$) was recorded from the variety BHM 14 followed by Pioneer (0.046 $molm^{-2}s^{-1}$) and the minimum stomatal conductance (0.026 $molm^{-2}s^{-1}$) was achieved from Paloan followed by Bharti

Table 4. Combined effects of variety and treatment on physiological traits of maize under drought condition

Variety x treatment	A	E	GS	WUE	No of Leaf	Proline conc
Gold Star (Control)	10.47b	1.273b	0.0800a	8.23de	6.33a	5.35d
Gold Star (10% PEG)	9.88d	0.7800f	0.0333de	12.69a	4.67f	5.36d
BHM 14 (Control)	9.09f	1.020e	0.0533b	8.94c	5.33d	5.43d
BHM 14 (10% PEG)	8.75g	0.990e	0.0466bc	8.85c	4.67f	7.99b
Paloan (Control)	8.55h	1.110d	0.0366cde	7.70ef	5.33d	7.95b
Paloan (10% PEG)	8.23i	0.663g	0.0266e	12.42a	4.67f	8.02b
Bharti 981 (Control)	9.77d	1.117d	0.0366cde	8.75cd	5.67c	5.99c
Bharti 981 (10% PEG)	8.55h	0.823f	0.0266e	10.39b	4.00g	6.15c
BHM 9 (Control)	9.76d	1.347a	0.0433bcd	7.25f	6.00b	6.14c
BHM 9 (10% PEG)	9.42e	1.220c	0.0400cd	7.72ef	4.67f	8.86a
Pioneer (Control)	11.62a	1.343a	0.0533b	8.65cd	5.67c	8.87a
Pioneer (10% PEG)	10.23c	1.180c	0.0466bc	8.67cd	5.00e	8.92a
$LSD_{0.05}$	0.169	0.053	0.005	0.533	0.226	0.22
SE (±)	0.057	0.017	0.0038	0.182	0.078	0.07
Level of sign.	**	**	**	**	**	**
CV (%)	**1.04**	**2.76**	**15.29**	**3.44**	**2.62**	**1.82**

*In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT). ** =Significant at 1% level of probability, * =Significant at 5% level of probability*

981 (0.026 $molm^{-2}s^{-1}$). Anjum et al., [26] revealed that gaseous exchange was substantially declined in maize cultivars under water stressed conditions.

3.17 Water Use Efficiency (WUE)

The effects of drought on water use efficiency of varieties differ significantly (Table 4). In control condition, the maximum water use efficiency (8.94 μm^{-1}) as recorded from the variety BHM 14 followed by Bharti 981 (8.75 μm^{-1}) and minimum water use efficiency (7.25 μm^{-1}) was achieved from BHM 9 followed by Paloan (7.70 μm^{-1}). The table showed that, water use efficiency was decreased in each variety with the increasing Drought level. In 10 % drought level, the maximum water use efficiency (12.69 μm^{-1}) was recorded from the variety Gold Star followed by Paloan (12.42 μm^{-1}) and the minimum water use efficiency (7.722 μm^{-1}) was achieved from BHM 9 followed by BHM 14 (8.65 μm^{-1}). Hasan et al., [28] reported that water use efficiency reduced in maize and sorghum due to higher level of drought stress.

3.18 Number of Leaves per Plant

Six Maize varieties showed different magnitude of reductions in the number of leaves due to drought. Significant variation was observed among the varieties and treatment (Table 4). In control condition, the maximum number of leaves (6.33) was recorded from the variety Gold Star followed by BHM 9 (6) and minimum number of leaves (5.33) was achieved from BHM 14 followed by Paloan (5.33). The table showed that, number of leaves was decreased in each variety with the increasing drought. In 10% drought level, the maximum number of leaves (5) was recorded from the variety Pioneer followed by BHM 9 (4.66) and the minimum number of leaves (4) was achieved from Bharti 981 followed by Paloan (4.66). Hu et al., [29] reported that number of leaves per plant reduced due to increment of drought level in maize at seedling stage [30].

3.19 Proline Content

Six Maize varieties showed wide magnitude of changes in the proline content due to drought. Significant variation was observed among the varieties and treatment (Table 4). In control condition, the highest proline content (8.75 mg/100g FW) was recorded from the variety BHM 14 followed by pioneer (7.32 mg/100g FW) and the lowest proline content (4.90 mg/100g FW) was achieved from Paloan followed by Gold strar (5.35 mg/100g FW). The table showed that, the proline content was increased in each variety with the increasing drought level. In 10% drought level, the highest proline content (10.87 mg/100g FW) was recorded from the variety BHM 14 followed by BHM 9 (8.86 mg/100g FW) and the lowest proline content (6.15 mg/100g FW) was achieved from Paloan followed by gold star (6.363 mg/100g FW). A similar trend was endorsed by Munns and Tester (2008). This increment of proline concentration was occurred by plants might be due to maintaining osmotic pressure in the cell (Munns and Tester, 2008).

4. CONCLUSION

It can be concluded that drought stress significantly responded to different parameters. Shoot length, the number of leaves, leaf area, root length, root, shoot weight, and relative greenness were decreased by using PEG. Based on the experimental results, the PEG concentration at 10% showed a tremendous negative effect on the growth and morpho-physiological changes of maize seedlings and among the varieties, BHM 14 had the highest tolerance to drought in respect of growth and morpho-physiological attributes.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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