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EVALUATION OF DROUGHT TOLERANCE IN HYBRID MAIZE BASED ON SELECTED MORPHO-PHYSIOLOGICAL AND YIELD TRAITS

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ABSTRACT

To identify comparatively drought tolerant varieties, four prominent hybrid maize were evaluated for their morpho-physiological and yield responses to water deficit stress (WDS). The experiment consisted of two factors and was laid out in a split plot design with three replications. Water application (well water and water stress) were applied as the main plot treatments and four maize varieties (BARI hybrid maize-7, BARI hybrid maize-9, BARI hybrid maize-13 and BARI hybrid maize-15) were split as sub plot treatments. The interaction effect of water regimes and maize varieties significantly influenced morpho-physiological characters as well as yield traits of maize and WDS reduced all the investigated traits by different magnitude. Among four hybrids, BARI hybrid maize-15 showed better performance in terms of morphological and yield contributing traits except cob diameter, whereas BARI hybrid maize-9 showed the lowest performances under WDS. BARI hybrid maize-15 showed greater aptitude to hold water in flag leaf and better steadiness of flag leaf chlorophyll followed by BARI hybrid maize-7 and BARI hybrid maize-13 under WDS. However, BARI hybrid maize-15 produced the highest grain yield at both well water and WDS condition (11.89 t ha^{-1} and 10.96 t ha^{-1}, respectively) with STI value 0.92, on the contrary BARI hybrid maize-9 produced the lowest grain yield (10.32 t ha^{-1} and 9.12 t ha^{-1}, respectively) with STI value 0.88. Results indicated that BARI hybrid maize-15 was more tolerant and BARI hybrid maize-9 was more sensitive, whereas BARI hybrid maize-7 and BARI hybrid maize-13 were moderately tolerant to drought.

Key words: Drought, relative leaf water, chlorophyll, morphological and yield traits, hybrid maize

INTRODUCTION

Maize is one of the most important food grains and bio-energy crops (Bassu *et al.* 2014). It is now recognized as one of the important cereal crops in the world's agricultural economy both as eminent food security crops and the most important forage crops (Ge *et al*. 2012). In Bangladesh the area under maize cultivation was 1100 thousand acres with a total production of 3596 thousand metric tons and an average yield of 3245 kg $acre^{-1}$ during 2018-2019 (BBS 2020). Demand for maize is increasing day by day in the world as well as in Bangladesh due to its diversified uses and more nutritious status. But the average maize yield in Bangladesh is lower

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than in other maize-growing regions in the developing world. This low productivity is attributed to several factors, including drought, poor soil fertility, insect pests, and diseases.

Drought, being the most important environmental stress, severely impairs plant growth and development, limits plant production and the performance of crop plants, more than any other environmental factor (Shao *et al.* 2009). In Asian tropics, maize is largely (about 80%) grown as rain-fed crop and uneven distribution patterns of monsoon rain occasionally cause drought at different crop growth stage(s) (Zaidi *et al.* 2014). Drought stress causes several changes in morpho-physiological traits and metabolism of plants, is a major constraint to maize production (Bu *et al.* 2010, Beyene *et al.* 2016 and Ertiro *et al.* 2017). It is also predicted to occur more frequently and severely in future owing to the changing climate (Tesfaye *et al.* 2018), impairing agricultural production, especially in the tropics and subtropics (Cairns *et al.* 2013).

The identification and development of drought tolerant maize genotypes capable of satisfactory productivity under sub-optimal water availability are therefore of major interests in maize improvement (Betran *et al.* 2003). The long-term goal of evaluating genotypes for drought tolerance is to develop crop germplasm that are productive despite drought stress, and these genotypes can be used to achieve multiple productions during the cropping year (Oyekale *et al.* 2008). Thus, selection, development and distribution of maize varieties with drought tolerance and other relevant agronomic and adaptive traits is the key to sustain maize production under drought prone area around the year and to enhance the food security as well as livelihoods of farmers in Bangladesh. To stabilize maize production in the northern Bangladesh, the experiment was therefore set up to evaluate drought tolerance of four hybrid maize through their morpho-physiological responses and yield performance under water deficit stress condition.

MATERIALS AND METHODS

Experimental duration and location

The experiment was conducted during December 2017 to May 2018 at the research field and laboratory of Department of Crop Physiology and Ecology, Hajee Mohammad Danesh Science and Technology University, Dinajpur, under the Agroecological zone-1 “Old Himalayan Piedmont Plain”, Bangladesh.

Experimental design and treatment

The experiment was laid out in a split plot design with three replications. The unit plot size was 3 m × 2 m having a plot to plot and block to block distance of 0.75 and 1 m, respectively. Two growing conditions: a) well water condition (irrigation was given at 8-10 leaf stage, silking stage and grain filling stage) and b) water stress condition (no irrigation) were placed in main plots as main plot treatments, whereas four hybrid maize (BARI hybrid maize-7, BARI hybrid maize-9, BARI hybrid maize-13 and BARI hybrid maize-15) were placed randomly in sub plots as sub plot treatments.

Data collection

Data were collected and recorded on soil moisture content, morphological, physiological and yield traits. For determination of soil moisture content, the soil samples were collected by an augur from each plot at the depth of 15 cm and were taken in air tight containers. The samples were weighed and then dried in an oven at 70°C for72 hours.

The samples were then taken out from oven and weighed again. The loss in weight was the amount of soil moisture.

Soil moisture content (%) = {(Fresh weight of soil - Weight of oven fry soil) / Weight of oven dry soil} ×100

Relative leaf water content (RLWC) was determined at tasseling stage according to Kocheva *et al.* (2014) using the formula below-

RLWC = {(Fresh weight - Dry weight) / (Turgid weight – Dry weight)} ×100

Chlorophyll content of the leaf was estimated at tasseling stage according to Witham *et al.* (1986) and calculated using the formula below.

Total chlorophyll)mg g^{-1} FW(= {20.2)D_{645}(+8.02)D_{663}(} × {V/)1000 × W(}

Where, V = Volume of 80% aqueous acetone)ml(, W = Weight of fresh leaf)g(, D_{645} = Absorbance at 645nm wavelength, D_{663} = Absorbance at 663nm wavelength

Morphological parameters *viz.* number of green leaf, length of leaf blade, length of leaf sheath, plant height and tassel length were recorded properly at dry silk stage. Yield contributing traits such as number of cobs $plant^{-1}$, cob length, cob diameter, and grains cob^{-1} were recorded properly after final harvest. Grains were adjusted to 12% moisture by sun drying and then 100-grain weight and grain yield (t ha^{-1}) were measured and recorded properly.

Stress tolerance index (STI)

STI was calculated as Goudarzi and Pakniyat (2008) using the following formula-

STI = Variable measured under stress condition / Variable measured under normal condition

Statistical analyses

The collected data were analyzed by partitioning the total variance with the help of a computer using STATA (Small Stata 12.0) program and the treatment means were compared using tukey's test.

RESULTS AND DISCUSSION

Soil moisture content

Figure 1 shows soil moisture content at 0-15cm depth of well water and water stress plots at seedling emergence, tasseling and harvesting stage. It indicates that well water plots maintained higher soil moisture (33.66%, 24.33% and 16.55%) than that of water stress plots (31.37%, 13.51% and 4.35%) at seedling emergence, tasseling and harvesting stage, respectively. This figure also presents that with the advancement of time after sowing, soil moisture of water stress plots were reduced gradually. It was observed that at seedling emergence stage, soil moisture was more or less similar at both well water and water stress conditions (33.66% and 31.37%, respectively). But at tasseling and harvesting stage the variation between soil moisture at well water and water stress conditions was more (10.82% and 12.20%, respectively). The variation between early and late growing stages might be due to variation in water uptake by maize plants as well as variation in precipitation rate and evapotranspiration rate at different growing stage of maize. The findings of the present study are in an agreement with Ali *et al.* (2018) and Ray *et al.* (2020) who also found significant variation in soil moisture content of well water and water stress condition.

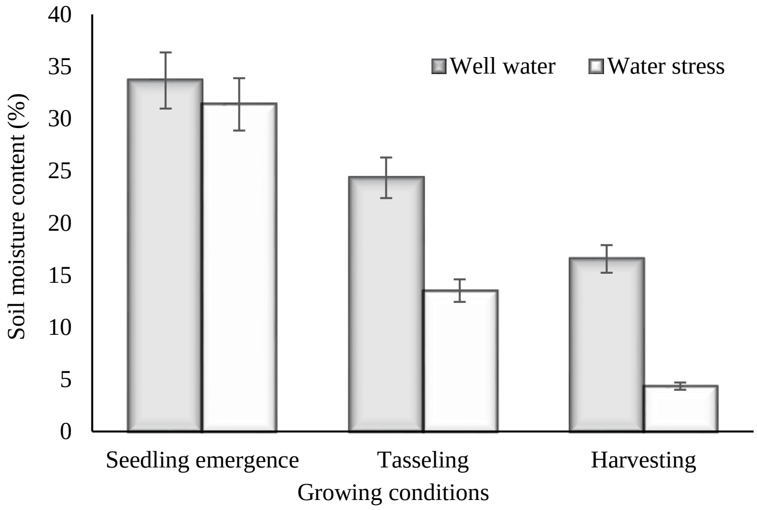

Figure 1. Soil moisture content (from 0 to 15 cm depth) at different stages of maize crop as influenced by water regimes.Vertical bar indicates the standard error (±) values.

Physiological parameters

The combined effect of water regimes and maize varieties significantly influenced the relative leaf water content and leaf chlorophyll content of maize (Table 1). All maize varieties maintained a higher leaf water content under well water condition compared to water stress condition. Under well water condition, BARI hybrid maize-15 maintained the highest leaf water (88.84%), whereas BARI hybrid maize-9 maintained the lowest leaf water (75.35%). Under water stress condition again, the highest leaf water content was found in BARI hybrid maize-15 (83.45%) and the lowest leaf water content was found in BARI hybrid maize-9 (64.86%).

At well water condition, BARI hybrid maize-15 attained the highest leaf chlorophyll content (2.42 mg chlorophyll g^{-1} FW) and it was statistically at par with BARI hybrid maize-9 (2.29 mg chlorophyll g^{-1} FW), whereas the lowest leaf chlorophyll content was observed in BARI hybrid maize-7 (1.43 mg chlorophyll g^{-1} FW). Under water stress condition, the highest leaf chlorophyll content was observed in BARI hybrid maize-15 (2.18 mg chlorophyll g^{-1} FW), while BARI hybrid maize-7 had the lowest leaf chlorophyll content (1.19 mg chlorophyll g^{-1} FW). The maize varieties under evaluation showed significant reduction in their water content and chlorophyll content of leaf at different degree due to WDS. Among the four varieties, BARI hybrid maize-9 showed more reduction in relative leaf water content (13.92%) and leaf chlorophyll content (29.69%) while less reduction (6.07 and 9.92%, respectively) was observed in BARI hybrid maize-15.

Crops response to water stress can be complex, depending not only on the intensity and duration of stress, but also on the stage of plant development (Singh *et al.* 2008 and Liu *et al.* 2010). Relative leaf water content is considered a measure of plant water status, reflecting the metabolic activity in tissues and used as a most meaningful index for dehydration tolerance **(**Anjum *et al.* 2011). Results showed that, well watered plants had higher relative leaf water content than non-irrigated water stressed plants and stress tolerant variety maintained a higher leaf water

Table 1. Interaction effect of maize varieties and water regimes on physiological parameters of maize

Maize varieties	Water regimes	Relative leaf water content (%)	Leaf chlorophyll content (mg g^{-1} FW)
BARI hybrid maize-7	Well water	85.67b	1.43d
	Water stress	77.48e (-9.56)	1.19e (-16.78)
BARI hybrid maize-9	Well water	75.35f	2.29a
	Water stress	64.86h (-13.92)	1.61d (-29.69)
BARI hybrid maize-13	Well water	79.57d	2.02bc
	Water stress	70.42g (-11.50)	1.73cd (-14.36)
BARI hybrid maize-15	Well water	88.84a	2.42a
	Water stress	83.45c (-6.07)	2.18ab (-9.92)
Level of significance (P-values)		0.01	0.01
CV (%)		4.70	7.31

In the column, means followed by the same letter)s(did not differ significantly by Tukey's test at 5% level of probability. Values within parenthesis of water stress indicate percent reduction over well water condition.

status compared to stress susceptible variety. Reduced ability to retain water in leaf under WDS was previously reported by Ray *et al.* (2020) that consistent with our findings. The decrease in chlorophyll content under drought stress has been considered as a typical symptom of oxidative stress and may be the result of pigment photo-oxidation and chlorophyll degradation (Keyvan 2010). In the present study, leaf chlorophyll content at tasseling was reduced due to water stress, as the plant suffers from severe water stress at this stage when the residual soil moisture depletes. Insufficient soil water declines the metabolic activity, reduces biomass accumulation, and decreases rate of photosynthesis by reducing the leaf chlorophyll content ultimately leading to decrease in maize yield (Zhang *et al.* 2009 and Bu *et al.* 2010). Other researchers (Khayatnezhad and Gholamin 2012) also found reduction in chlorophyll content in maize leaf under WDS. These findings are in line with the findings of our present investigation.

Morphological parameters

Number of green leaf, length of leaf blade, length of leaf sheath, plant height and tassel length at dry silk stage of four maize varieties were significantly influenced by the interaction effect of water regimes and maize varieties (Table 2). Under well water condition, BARI hybrid maize-15 had the maximum number of green leaf at dry silk stage (8.33), whereas BARI hybrid maize-9 had the minimum number of green leaf at dry silk stage (6.37) followed by BARI hybrid maize-7 (6.47). Under water stress condition again the BARI hybrid maize-15 attained the highest number of green leaf at dry silk stage (6.67), whereas the BARI hybrid maize-7 had the lowest number of green leaf at dry silk stage (4.53).

BARI hybrid maize-15 produced the longest leaf blade (90.87 cm) followed by BARI hybrid maize-13 (89.47 cm) and BARI hybrid maize-7 (87.64 cm), whereas BARI hybrid maize-9 produced the shortest leaf blade (82.31 cm) under well water condition. Under water stress condition the BARI hybrid maize-15 also produced the longest leaf blade (85.20 cm), whereas the BARI hybrid maize-9 produced the shortest leaf blade (68.58 cm).

BARI hybrid maize-15 produced the maximum length of leaf sheath (20.58 cm), whereas BARI hybrid maize-9 had the minimum length of leaf sheath (19.10 cm) followed by BARI hybrid maize-13 (19.33 cm) when grown under irrigated condition. Under WDS condition, the BARI hybrid maize-15 attained the maximum length of leaf sheath (18.26 cm), whereas the BARI hybrid maize-9 had the minimum length of leaf sheath (16.47 cm) followed by other two varieties (16.57 cm in BARI hybrid maize-7 and 16.67 cm BARI hybrid maize-13). At well water plots BARI hybrid maize-9 produced the tallest plant (235.77 cm) which was followed by BARI hybrid maize-15 (228.53 cm), whereas the shortest plant was produced by BARI hybrid maize-7 (197.38 cm) which was followed by BARI hybrid maize-13 (213.00 cm). Under water stress condition BARI hybrid maize-15 attained the longest plant height (205.06 cm), whereas BARI hybrid maize-9 produced the shortest plant height (140.17 cm) compared to other two varieties.

BARI hybrid maize-13 produced the longest tassel (45.63 cm) followed by BARI hybrid maize-9 (45.45 cm) and BARI hybrid maize-15 (44.83 cm), whereas the shortest tassel was produced by BARI hybrid maize-7 (41.76 cm) when grown under well water condition. Under non-irrigated condition, BARI hybrid maize-15 produced the longest tassel (41.87 cm), while BARI hybrid maize-7 produced the shortest tassel (37.62 cm) compared to other two varieties.

Table 2. Interaction effect of maize varieties and water regimes on morphological parameters of maize at dry silk stage

Maize varieties	Water regimes	Number of green leaf	Length of leaf blade (cm)	Length of leaf sheath (cm)	Plant height (cm)	Tassel length (cm)
BARI hybrid maize-7	Well water	6.47c	87.64ab	19.62b	197.38c	41.76b
	Water stress	4.53e (-29.98)	75.42d (-13.94)	16.57e (-15.54)	140.17e (-28.98)	37.62d (-9.60)
BARI hybrid maize-9	Well water	6.37cd	82.31c	19.10c	235.77a	45.45a
	Water stress	5.00e (-21.51)	68.58e (-16.68)	16.47e (-13.77)	171.00d (-27.47)	39.87c (-12.28)
BARI hybrid maize-13	Well water	7.20b	89.47ab	19.33bc	213.00abc	45.63a
	Water stress	5.73d (-20.42)	75.54d (-15.57)	16.67e (-13.76)	190.13cd (-10.74)	40.53bc (-11.18)
BARI hybrid maize-15	Well water	8.33a	90.87a	20.58a	228.53ab	44.83a
	Water stress	6.67 bc (-19.93)	85.20bc (-6.24)	18.26d (-11.27)	205.06bc (-10.27)	41.87b (-6.60)
Level of significance (*P*-values)		0.01	0.05	0.01	0.01	0.01
CV (%)		3.88	5.40	4.58	3.69	4.34

In the column, means followed by the same letter)s(did not differ significantly by Tukey's test at 5% level of probability. Values within parenthesis of water stress indicate percent reduction over well water condition.

WDS caused significant reduction in different morphological traits of all studied maize hybrids but the degree of reduction was different in different variety. The extends of reduction were 29.98, 13.94, 15.54, 28.98 and 9.60% in BARI hybrid maize-7, 21.51, 29.98, 13.77, 27.47 and 12.28% in BARI hybrid maize-9, 20.42, 15.57, 13.76, 10.74 and 11.18% in BARI hybrid maize-13 and 19.93, 6.24, 11.27, 10.27 and 6.60% in BARI hybrid maize-15 for number of green leaf, length of leaf blade, length of leaf sheath, plant height and tassel length at dry silk stage, respectively.

The reduction in different morphological traits of maize might be from hampering of vegetative growth and development of the plants by non-irrigated water stress condition. WDS decreases rate of photosynthesis activity, decelerates translocation and efficiency of utilization of photosynthate, thus hinders cell elongation and cell division in the growing portion which results reduced vegetation (Bu *et al.* 2010). Olaoye *et al.* (2009), Shin *et al.* (2015) and Sikder *et al.* 2009 found water stress negatively affect the vegetative growth of maize plant results in significant reduction in morphological characteristics of leaf. The reduced leaf blade and leaf sheath under water stress condition was also reported by Ray *et al.* (2020) who support the results of present study. Findings obtained by Farhad *et al.* (2011) and Khoshvaghti *et al.* (2013) on plant height of maize under water stress also support the findings of our study. The findings of present study are congruent with previous reports in maize by Shin *et al.* (2015) who also found reduced tassel under water stress and reported reduction in tassel length might be due to negative effect of water stress on vegetative stage of maize plants.

Yield and yield components

Number of cobs plant^{-1}, cob length, cob diameter, number of grains cob^{-1}, 100-grain weight and grain yield of four maize varieties were significantly varied by the interaction effect of water regimes and maize varieties (Table 3 and 4). At well water condition, the maximum number of cobs plant^{-1} (2.15) was recorded from BARI hybrid maize-15 followed by BARI hybrid maize-7 (2.03) and BARI hybrid maize-9 (2.01) and the minimum number of cobs plant^{-1} (1.95) was recorded from BARI hybrid maize-13. At water stress condition, the maximum number of cobs plant^{-1} (1.83) was recorded from BARI hybrid maize-15 followed by BARI hybrid maize-7 (1.70) and the minimum number of cobs plant^{-1} was recorded from BARI hybrid maize-13 (1.51) which was nearly followed by BARI hybrid maize-9 (1.52).

At well water condition, the longest cob (29.68 cm) was obtained from BARI hybrid maize-15 and the shortest (24.51 cm) was from BARI hybrid maize-9. At water stress condition, the longest cob (27.18 cm) was recorded in BARI hybrid maize-15, while the shortest (21.05 cm) was recorded in BARI hybrid maize-9.

At well water condition, the highest cob diameter (16.25 cm) was found in BARI hybrid maize-15, while the lowest (14.12 cm) was recorded from BARI hybrid maize-9. At water stress condition, again, the highest cob diameter (14.69 cm) was recorded from BARI hybrid maize-15 and the lowest (11.88 cm) was recorded from BARI hybrid maize-9.

At well water condition, the maximum number of grains cob^{-1} (554.31) was recorded from BARI hybrid maize-7, while the minimum (509.31) was recorded from BARI hybrid maize-9 which was statistically identical to BARI hybrid maize-13 (513.65). At water stress condition, again, the maximum number of grains cob^{-1} (494.31) was recorded from BARI hybrid maize-7 followed by that of BARI hybrid maize-15 (483.13) and the minimum number of grains cob^{-1} (420.65) was recorded from BARI hybrid maize-9, which was statistically identical to BARI hybrid maize-13 (436.31).

At well water condition, the highest 100-grains weight (32.25 g) was found in BARI hybrid maize-15, whereas the lowest 100-grains weight (34.67 g) was recorded from BARI hybrid maize-9. At water stress condition, again, the highest 100-grains weight (29.45 g) was recorded from BARI hybrid maize-15 and the lowest 100-grains weight (20.24 g) was recorded from BARI hybrid maize-9.

Water stress significantly reduced the studied yield parameters in all varieties but the magnitude of reduction was not similar for all varieties. The degrees of reduction were 16.26, 10.33, 7.54, 10.82 and 13.86% in BARI hybrid maize-7, 24.38, 14.12, 15.86, 17.41 and 17.96% in BARI hybrid maize-9, 22.56, 12.00, 11.99, 15.06 and 15.18% in BARI hybrid maize-13 and 14.88, 8.42, 9.60, 6.85 and 8.68% in BARI hybrid maize-15 for number of cobs plant^{-1}, cob length, cob diameter, number of grains cob^{-1} and 100-grain weight, respectively.

Table 3. Interaction effect of maize varieties and water regimes on yield components of maize

Maize varieties	Water regimes	Number of cobs plant^{-1}	Cob length (cm)	Cob diameter (cm)
BARI hybrid maize-7	Well water	2.03ab	28.06b	14.46c
	Water stress	1.70de (-16.26)	25.16de (-10.33)	13.37d (-7.54)
BARI hybrid maize-9	Well water	2.01abc	24.51e	14.12c
	Water stress	1.52ef (-24.38)	21.05g (-14.12)	11.88e (-15.86)
BARI hybrid maize-13	Well water	1.95bc	25.66d	15.18b
	Water stress	1.51f (-22.56)	22.58f (-12.00)	13.36d (-11.99)
BARI hybrid maize-15	Well water	2.15a	29.68a	16.25a
	Water stress	1.83cd (-14.88)	27.18c (-8.42)	14.69bc (-9.60)
Level of significance (P-values)		0.05	0.01	0.05
CV (%)		3.36	3.72	4.82

In the column, means followed by the same letter)s(did not differ significantly by Tukey's test at 5% level of probability. Values within parenthesis of water stress indicate percent reduction over well water condition.

At well water condition, the highest grain yield (11.89 t ha^{-1}) was recorded from BARI hybrid maize-15, whereas the lowest grain yield (10.32 t ha^{-1}) was recorded from BARI hybrid maize-9. Other two varieties produced more or less similar grain yield (10.55 t ha^{-1} in BARI hybrid maize-7 and 10.59 t ha^{-1} in BARI hybrid maize-13). Water stress caused reduction in grain yield in all maize varieties but the degree of reduction was different in different varieties. Maximum reduction (11.62%) was recorded from BARI hybrid maize-9, whereas minimum reduction (7.82%) was recorded from BARI hybrid maize-15. BARI hybrid maize-7 and BARI hybrid maize-13 reduced the grain yield by 9.57% and 10.20%, respectively. However, at water stress condition, the highest grain yield (10.96 t ha^{-1}) was recorded from BARI hybrid maize-15 and the lowest grain yield (9.12 t ha^{-1}) was recorded from BARI hybrid maize-9.

Shortage of available moisture hampers different growth and physiological activities of plants especially synthesis and translocation of photosynthates to the reproductive organs which ultimately reduced the final economic yield. The outcomes of this study revealed that water stress significantly affected morphology and physiology of maize plants which may lead to decrease in yield attributes and finally grain yield. Plants grown under sufficient water produced markedly larger cobs, with more seeds and greater 100-seed dry weight, leading to higher matter accumulation and grain yield than drought stressed maize. Pre-anthesis water limitations would delay silking, a symptom of water deficits at flowering, which could induce barrenness because the pollen supply was exhausted before silks appeared (Lu *et al.* 2011) which might be responsible for a reduction in grain yield. Insufficient soil water weakens the metabolic activity of maize, reduces its biomass accumulation, and decreases its photosynthetic rate eventually leading to a decrease in maize yield (Bu *et al.* 2010). Our results are consistent with previous findings, which demonstrated that due to increasing moisture stress, plants showed a significant decrease in yield components (Suralta *et al.* 2010) and reduction in grain yield (Hugh and Richard 2003 and Pervez *et al*. 2004).

Table 4. Interaction effect of maize varieties and water regimes on yield and yield components of maize

Maize varieties	Water regimes	Number of grains cob^{-1}	100-grain weight (g)	Grain yield (t ha^{-1})
BARI hybrid maize-7	Well water	554.31a	29.44b	10.55c
	Water stress	494.31cd (-10.82)	25.36d (-13.86)	9.54e (-9.57)
BARI hybrid maize-9	Well water	509.31bc	24.67d	10.32d
	Water stress	420.65e (-17.41)	20.24f (-17.96)	9.12f (-11.62)
BARI hybrid maize-13	Well water	513.65bc	27.66c	10.59c
	Water stress	436.31e (-15.06)	23.46e (-15.18)	9.51e (-10.20)
BARI hybrid maize-15	Well water	518.65b	32.25a	11.89a
	Water stress	483.13d (-6.85)	29.45b (-8.68)	10.96b (-7.82)
Level of significance (P-values)		0.01	0.01	0.05
CV (%)		6.29	6.64	5.69

In the column, means followed by the same letter)s(did not differ significantly by Tukey's test at 5% level of probability. Values within parenthesis of water stress indicate percent reduction over well water condition.

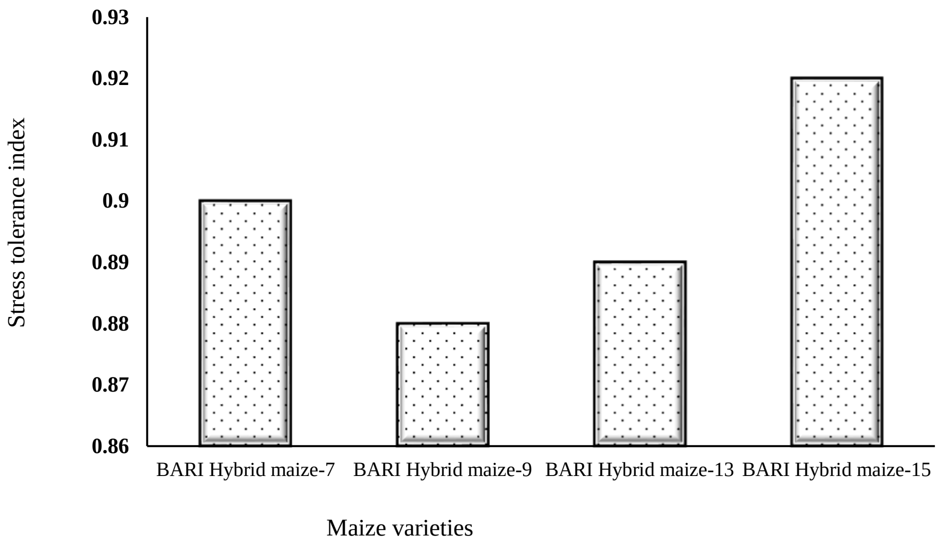

Figure 2. Stress tolerance index based on grain yield.

Stress tolerance index based on grain yield

Stress tolerance index of different maize varieties based on grain yield (Figure 2) shows that BARI hybrid maize-15 had the highest stress tolerance index value (0.92), whereas BARI hybrid maize-9 had the lowest stress tolerance index value (0.88). BARI hybrid maize-7 and BARI hybrid maize-13 showed moderate stress tolerance index value (0.90 and 0.89, respectively).

CONCLUSION

The present results showed that water deficit stress changes in morphological, physiological and yield traits of maize plants and tolerant varieties showed more stability for those traits. In WDS conditions, varieties that have more leaf chlorophyll content and relative leaf water content are more tolerant to drought stress and lead to less reduction in their yield components and finally to yield. Considering the findings of the present experiment, it can be concluded that, BARI hybrid maize-15 was found relatively drought tolerant, whereas BARI hybrid maize-7 and BARI hybrid maize-13 were moderately drought tolerant and BARI hybrid maize-9 was found drought susceptible variety.

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