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MORPHO-PHENOLOGICAL AND YIELD RESPONSES OF MAIZE (*Zea mays* L.) TO NON-IRRIGATED WATER STRESS CONDITION

U.K. Ray, S. Sikder*, M.M. Bahadur and S.K. Pramanik

Department of Crop Physiology and Ecology, Hajee Mohammad Danesh Science and Technology University, Dinajpur 5200, Bangladesh

ABSTRACT

To evaluate the responses of morpho-phenological and yield traits of maize under non-irrigated water stress, four maize varieties *viz.* BARI hybrid maize-7, Fortune Gold, Golden Star and KC 505 were grown under well water and water deficit stress condition. Drought tolerant varieties showed greater ability to retain water in leaf and required more days for attaining different phenological stages compared to sensitive variety under stress condition. Length of leaf blade and leaf sheath, leaf breadth, plant height, tassel length, cob length, seed weight cob^{-1} and grain yield under water deficit stress condition contributed to better tolerance of BARI hybrid maize-7 over the other maize varieties. However, in response to different morpho-phenological and yield traits, BARI hybrid maize-7 was more drought tolerant and Fortune Gold was considered as drought susceptible, whereas the Golden Star and KC 505 varieties were moderately drought tolerant.

Key words: Drought tolerance, phenology, water stress, yield traits, *Zea mays*

INTRODUCTION

Maize (*Zea mays* L.) is one of the important cereal crop that plays a great role in human nutrition (Emam 2004). In Bangladesh, maize ranks third in respect of total acreage after rice and wheat but ranks first as produced the highest yield, 2.87 t/ha (BBS 2017). Drought stress is one of the most important environmental stresses affecting agricultural productivity worldwide and can result in considerable yield reductions (Lauer 2003). It is responsible for several changes in the subjected plants, including relative leaf water content, electrolytes leakage of plasma membrane, soluble protein content, photosynthetic pigments, carotenoids etc., which in turn decrease the efficiency of expected rate of photosynthesis and photo-assimilate production that leads finally reduction of crop yield (Rosales *et al.* 2012). Growth and developmental traits such as plant height, leaf area, plant biomass, stem diameter etc. are negatively affected by drought stress condition (Zhao *et al.* 2006). Besides, drought stress seriously hinders the growth and development of maize by reducing the productivity like other crops (Tai *et al.* 2011). In this circumstance, drought tolerant varieties might be an effective way to increase the maize production under soil moisture deficit condition. Therefore, the present study was undertaken for comparative identification of drought tolerant varieties using four prominent maize cultivars through evaluating the morpho-phenological and yield responses to drought stress condition. This study will also be helpful for expanding year round and sustainable maize production in Bangladesh, especially in the northern regions under water deficit condition.

MATERIALS AND METHODS

The experiment was conducted at the laboratory and research field of Department of Crop Physiology and Ecology, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh during December 2015 to May 2016. The experiment was laid out in split plot design with three replications. The unit plot size was 3m × 2m having a plot to plot and block to block distance of 0.75

*Corresponding author: Email: srisikder@gmail.com, Cell phone: +8801715204206

and 1m, respectively. The two growing conditions: a) well water condition (three irrigation levels that applied 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 maize varieties (BARI hybrid maize-7, Golden Star, KC 505 and Fortune Gold) were placed randomly in the sub plots. Different phenological stages *viz.* seedling emergence, four-leaf stage, eight-leaf stage, twelve-leaf stage, tassel emergence stage, silking stage and maturity stage were observed and recorded in days when 50% plants of each plot reached a respective stage. Relative leaf water content (RLWC) was determined at tassel emergence stage followed by Kocheva *et al.* (2014) using the formula below.

$$\text{RLWC (\%)} = \frac{Fresh\ weight - Dry\ weight}{Turgid\ weight - Dry\ weight} \times 100$$

Different morphological traits such as length of leaf blade, length of leaf sheath, leaf breadth, plant height and tassel length were recorded at dry silk stage. Yield traits such as cob length, seed weight cob^{-1} and grain yield were recorded properly during harvesting. The grain yield was adjusted to 12% moisture. Stress tolerance index (STI) was calculated as Goudarzi and Pakniyat (2008) using the following formula-

$$\text{Stress tolerance index} = \frac{Variable\ measured\ under\ stress\ condition}{Variable\ measured\ under\ normal\ condition}$$

The data were analyzed by partitioning the total variance using MSTAT-C program and the means were compared using Duncan's Multiple Range test (DMRT) (Gomez and Gomez 1984) at 5% level of probability.

RESULTS AND DISCUSSION

Phenology: Table 1a and 1b show that the interaction effect of growing conditions and maize varieties significantly affected the twelve-leaf, silking and maturity stages, whereas the seedling emergence, four-leaf, eight-leaf and tassel emergence stages were not significant. For each variety a definite number of days were required to attain certain phenological stages, but this was differed from variety to variety. Under well water condition, BARI hybrid maize-7 required 6, 17, 48, 58, 103, 107 and 145 days for attaining seedling emergence, four-leaf, eight-leaf, twelve-leaf, tassel emergence, sliking and maturity stages, respectively, whereas for Fortune Gold the corresponding growth durations were 9, 19, 51, 62, 109, 114 and 154 days, respectively. Under non-irrigated water stress condition, all varieties showed earliness for attaining different phenological stages compared to well water condition.

Table 1a. Days required for attaining different phenological stages of four maize varieties as affected by growing conditions

Maize varieties	Days to seedling emergence		Days to four-leaf stage		Days to eight-leaf stage		Days to twelve-leaf stage	
	Well water	Water stress	Well water	Water stress	Well water	Water stress	Well water	Water stress
BARI hybrid maize-7	6	6	17	16	48	46	58bc	57c
Golden Star	8	7	17	17	48	46	59bc	57c
KC 505	9	8	18	17	49	46	60ab	58bc
Fortune Gold	9	7	19	17	51	47	62a	59bc
Level of significance	NS		NS		NS		0.05	
CV (%)	4.22		4.34		6.32		8.46	

Means followed by the same letter(s) did not differ significantly at 5% level by DMRT. NS indicates not significant.

Table 1b. Days required for attaining different phenological stages of four maize varieties as affected by growing conditions

Maize varieties	Days to tassel emergence stage		Days to silking stage		Days to maturity stage	
	Well water	Water stress	Well water	Water stress	Well water	Water stress
BARI hybrid maize-7	101	103	107de	105e	145cd	143d
Golden Star	102	105	109cd	107de	148bc	146cd
KC 505	104	107	112ab	108cd	151ab	148bc
Fortune Gold	105	109	114a	110bc	154a	150b
Level of significance	NS		0.05		0.01	
CV (%)	7.17		5.95		6.72	

Means followed by the same letter(s) did not differ significantly at 5% level by DMRT. NS indicates not significant.

Among the studied varieties the earliness for attaining different phenological stages was higher in Fortune Gold. Similar to well water condition BARI hybrid maize-7 needed the lowest numbers of days for attaining different phenological stages at water stress condition. In this case, the growth durations for BARI hybrid maize-7 were 6, 16, 46, 57, 101, 105 and 143 days for seedling emergence, four-leaf stage, eight-leaf stage, twelve-leaf stage, tassel emergence, silking and maturity stages, respectively which was closely followed by variety Golden Star, whereas Fortune Gold showed the higher duration for the mentioning phenological parameters were 7, 17, 47, 59, 109, 114 and 154 days, respectively. Drought stress during vegetative growth reduces growth rate, prolongs vegetative growth stage and conversely duration of reproductive growth stage is reduced. Result from other studies (Khalili *et al.* 2013 and Shin *et al.* 2015) found water stress decreased the number of days for attaining silking and maturity in maize that support our findings.

Relative leaf water content: Table 2 shows that the relative leaf water content at tasseling stage was significantly influenced by the interaction effect of growing conditions and maize varieties. All varieties showed comparatively higher RLWC in well water condition than water limiting condition. At water stress the highest reduction of RLWC was found in Fortune Gold (13.38%) while the lowest reduction was observed in BARI hybrid maize-7 (5.89%). The other two varieties Golden Star and KC 505 showed 9.24 and 11.08% reduction, respectively. Farshadfar *et al.* (2014) reported relative water content as a useful character for selecting drought tolerant genotypes. Findings obtained by Abo-El-Kheir and Mekki (2007) on leaf water content of maize under drought condition also support the findings of our study.

Table 2. Relative leaf water content of four maize varieties as affected by growing conditions

Maize varieties	Relative leaf water content (%)		% change over well water
	Well water	Water stress	
BARI hybrid maize-7	91.82a	86.43c	-5.89
Golden Star	88.65b	80.46e	-9.24
KC 505	82.55d	73.40g	-11.08
Fortune Gold	78.32f	67.84h	-13.38
Level of significance	0.01		-
CV%	4.7		

Means followed by the same letter(s) did not differ significantly at 5% level by DMRT.

Length of leaf blade: Table 3 shows that the interaction effect of maize varieties and growing conditions significantly influenced the length of leaf blade. Under well water condition, variety Golden Star had the highest length of leaf blade (89.44 cm) which was statistically at par with BARI hybrid maize-7 (87.89 cm), while KC 505 showed the shortest leaf blade (82.33 cm). Under water stress condition, the length of leaf blade was reduced in all maize varieties. BARI hybrid maize-7 showed the lowest reduction (5.69%), whereas Fortune Gold showed the highest reduction (15.51%). Moderate reduction was observed in Golden Star and KC 505 (14.37 and 14.02%, respectively). The reduction in length of leaf blade might be due to the hamper of vegetative development under non-irrigated condition which was previously reported by Sikder *et al.* (2009) and Farhad *et al.* (2011).

Length of leaf sheath: Table 3 presents that the interaction effect of maize varieties and growing conditions was not significant for length of leaf sheath. Under well water condition, BARI hybrid maize-7 produced the longest leaf sheath (18.89 cm) which was followed by Fortune Gold (18.61 cm), whereas the shortest leaf sheath was produced by KC 505 (17.11 cm) which was followed by Golden Star (17.33 cm). Under non-irrigated water stress condition, the length of leaf sheath was reduced in all maize varieties. But the reduction was lower in BARI hybrid maize-7 and Golden Star (14.19 and 15.35%, respectively) compared to KC 505 and Fortune Gold (15.54 and 16.39%, respectively). At water stress condition, again BARI hybrid maize-7 produced longest leaf sheath (16.21 cm) and variety KC 505 produced the shortest leaf sheath (14.15 cm). Reduced length of leaf sheath under water stress condition was stated by Cha-um *et al.* (2010) that consistent with our findings.

Leaf breadth: Leaf breadth of maize varieties was not significantly influenced by the interaction effect of maize varieties and growing conditions (Table 3). Under well water condition, the variety BARI hybrid maize-7 had the highest leaf breadth (9.33 cm), whereas the lowest leaf breadth (8.33 cm) was observed in KC 505. Leaf breadth was reduced under non-irrigated water stress condition in all varieties. But the reduction was lower in BARI hybrid maize-7 (8.36%) followed by Golden Star and KC 505 (11.52 and 17.29%, respectively) while the highest reduction in leaf breadth (19.29%) was found in Fortune Gold. In water stress condition, the variety BARI hybrid maize-7 again attained the highest leaf breadth (9.10 cm), whereas the variety KC 505 attained the lowest leaf breadth (6.89 cm). Olaoye *et al.* (2009) reported that with decrease in field capacity, leaf area of different maize hybrids decreased significantly. Our output also supported by Abo-El-Kheir and Mekki (2007), who also observed that water stress reduced leaf breadth in maize.

Plant height: The interaction effect of growing conditions and maize varieties on plant height was statistically significant (Table 3). Under well water condition, Fortune Gold produced tallest plant (192.44 cm) which was at par with other two varieties *viz.* Golden Star (192.33 cm) and BARI hybrid maize-7 (186.77 cm), whereas the shortest plant was obtained in KC 505 (177.22 cm). Under non-irrigated water stress condition all the varieties significantly reduced their plant height. But the reduction was lower in BARI hybrid maize-7 and Golden Star (11.30 and 15.17%, respectively) compared to KC 505 and Fortune Gold (20.26 and 24.49%). However, at water stress condition BARI hybrid maize-7 produced the tallest plant (165.66 cm), whereas KC 505 produced shortest plant (141.32 cm). Reduction of plant height under water stress might be due to negative effect of water stress on growth. Findings from previous research work (Farhad *et al.* 2011 and Khoshvaghti *et al.* 2013) also reported that plant height reduced significantly under water stress condition in maize that support our outputs.

Table 3. Morphological traits of four maize varieties as affected by growing conditions

Maize varieties	Length of leaf blade (cm)		Length of leaf sheath (cm)		Leaf breadth (cm)		Plant height (cm)	
	Well water	Water stress	Well water	Water stress	Well water	Water stress	Well water	Water stress
BARI hybrid maize-7	87.89a	82.22c (-5.69)	18.89	16.21 (-14.19)	9.33	8.55 (-8.36)	186.77a	165.67c (-11.30)
Golden Star	89.44a	75.56d (-14.37)	17.33	14.67 (-15.35)	8.77	7.76 (-11.52)	192.33a	163.15c (-15.17)
KC 505	82.33c	70.55f (-14.02)	17.11	14.45 (-15.54)	8.33	6.89 (-17.29)	177.22b	141.30d (-20.26)
Fortune Gold	84.33b	72.44e (-15.51)	18.61	15.56 (-16.39)	8.97	7.24 (-19.29)	192.44a	145.32d (-24.49)
Level of significance	0.01		NS		NS		0.05	
CV (%)	1.26		1.30		5.93		4.01	

Means followed by the same letter(s) did not differ significantly at 5% level by DMRT. Values within parenthesis of water stress indicate percent reduction over well water condition. NS indicates not significant.

Tassel length: Tassel length of four maize varieties was significantly influenced by the interaction effect of growing conditions and maize varieties (Table 4). Under well water condition, KC 505 produced the longest tassel (42.65 cm), whereas the shortest tassel (38.78cm) was found in Golden Star. Under water stress condition, again, BARI hybrid maize-7 produced the longest tassel (38.89 cm) and Golden Star produced the shortest tassel (34.77 cm). Non-irrigated water stress reduced the tassel length in all varieties. But the reduction was minimum in BARI hybrid maize-7 (7.07%) and maximum in Fortune Gold (13.13%). Moderate reduction was found in Golden Star (10.34%) and KC 505 (11.96%). Reduction in tassel length in maize under water stress was also observed by Sikder *et al.* (2009) and Shin *et al.* (2015) which were consistent with present findings.

Cob length: Table 4 indicates that the cob length was significantly influenced by the interaction effect of four maize varieties and growing conditions. From the results it was found that BARI hybrid maize-7 produced the longest cob (27.70 cm), whereas Fortune Gold produced shortest cob (22.55 cm) under well water condition. Under water limiting condition, again BARI hybrid maize-7 attained the longest cob length (25.22 cm), whereas Fortune Gold attained the shortest cob length (19.01 cm). Under non-irrigated water stress all the varieties reduced their cob length in different magnitude. However, the lowest reduction was found in BARI hybrid maize-7 (8.95%) followed by Golden Star, (KC 505 and Fortune Gold (11.11, 13.00 and 15.70%, respectively). The results of the present study are in parallel with the previous investigations (Vafa *et. al.* 2014 and Meskelu *et. al.* 2014), where they also reported reduced cob length of maize due to water stress condition.

Seed weight cob^{-1}: Table 4 shows that seed weight cob^{-1} of four maize varieties was significantly influenced by the combine effect of maize varieties and growing conditions. Under well water condition, BARI hybrid maize-7 attained the maximum seed weight cob^{-1} (144.28 g), whereas Fortune Gold attained the minimum seed weight (126.16 g). Under non-irrigated water stress condition, all the varieties significantly reduced seed weight cob^{-1}. But the reduction was minimum in BARI hybrid maize-7 (13.78%), whereas Fortune Gold had the maximum reduction (17.70%), followed by Golden Star (15.78%) and KC 505 (17.54%). The results of the present study are in agreement with the results made by other researcher (Meskelu *et al.* 2014 and Sabagh *et al.* 2015) in maize varieties.

Grain yield: Table 4 shows that grain yield of maize varieties was significantly influenced by the combine effects of varieties and growing conditions. At well water condition, maximum grain yield (7.63 t/ha) was observed in BARI hybrid maize-7 followed by Golden Star and KC 505 (6.84 and 6.65 t/ha, respectively), whereas minimum grain yield was obtained in Fortune Gold (5.83 t/ha). Non-irrigated water stress reduced grain yield of all varieties in different magnitude. However, minimum reduction was found in BARI hybrid maize-7 (9.44%), while the greater reduction was investigated in Fortune Gold (16.81%). Moderate yield reduction found in Golden Star and KC 505 (13.45 and 14.73%, respectively). Water stress affects growth, development, and physiological processes of maize plants, which can reduce biomass production and ultimately grain yield decreased due to reduction in the number of kernel per ear or the kernel weight (Traore *et al.* 2000). Vafa *et al.* (2014) and Sabagh *et al.* (2015) also found that grain yield was significantly reduced by water stress. These studies support the findings of the present investigation.

Table 4. Yield and yield components of four maize varieties as affected by growing conditions

Maize varieties	Tassel length (cm)		Cob length (cm)		Seed weight cob^{-1} (g)		Grain yield (t/ha)	
	Well water	Water stress	Well water	Water stress	Well water	Water stress	Well water	Water stress
BARI hybrid maize-7	41.85a	38.89b (-7.07)	27.70a	25.22abc (-8.95)	144.28a	124.32c (-13.78)	7.63a	6.91b (-9.44)
Golden Star	38.78b	34.77c (-10.34)	26.10ab	23.20bcd (-11.11)	135.20ab	113.87d (-15.78)	6.84b	5.92d (-13.45)
KC 505	42.65a	37.55b (-11.96)	23.70bc	20.62de (-13.00)	130.16bc	107.33de (-17.54)	6.65c	5.67e (-14.73)
Fortune Gold	42.47a	36.89bc (-13.13)	22.55cd	19.01e (-15.70)	126.16bc	102.13e (-17.70)	5.83d	4.85f (-16.81)
Level of significance	0.01		0.01		0.01		0.05	
CV%	3.72		6.93		4.61		3.26	

Means followed by the same letter(s) did not differ significantly at 5% level by DMRT. Values within parenthesis of water stress indicate percent reduction over well water condition.

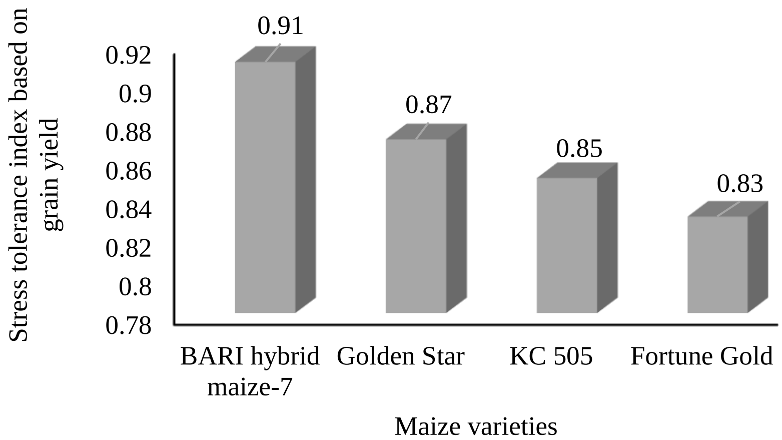

Figure 1. Stress tolerance index of four maize varieties based on grain yield.

Stress tolerance index: Figure 1 indicates the stress tolerance index of different maize varieties based on grain yield. It was observed that BARI hybrid maize-7 had the highest STI value (0.91), whereas Fortune Gold had the lowest STI value (0.83). Moderate STI value was found in Golden Star (0.87) and KC 505 (0.85).

CONCLUSION

It was observed that all the studied maize varieties showed a decreasing trend in response to different morpho-phenological and yield traits under water stress condition compared to normal one. However, among the maize varieties, BARI hybrid maize-7 was considered as drought tolerant, while Fortune Gold as drought susceptible variety. The other two varieties (Golden Star and KC 505) were accounted as moderately drought tolerant.

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