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INFLUENCE OF NON-IRRIGATED WATER STRESS ON MORPHOLOGICAL AND YIELD PERFORMANCE OF MAIZE

S. Sikder, M.A. Hasan, M.S. Hossain, M.H.R. Hafiz and A.K.M.M.B. Chowdhury

ABSTRACT

Four varieties (BARI hybrid maize -5, BARI hybrid maize -2, BARI maize -7 and BARI maize -5) were tested at the Research field of Crop Physiology and Ecology Department, HSTU, Dinajpur during the period of November 2007 to April 2008 under well watered and non-irrigated water stress condition to evaluate morphological and yield performance of maize in relation to water stress. The experiment was conducted in a split plot design with three replications. The combine effects of growing conditions (water level) and maize varieties significantly influenced plant height, single plant biomass, number of green leaf at dry silk stage, length of leaf blade, length of leaf sheath,, number of cobs per plant, cob length, cob diameter, number grains per cob, single cob weight, weight of seeds per cob, 100-seed weight as well as grain yield. Two hybrid varieties (BARI hybrid maize-2 and BARI hybrid maize-5) showed relatively better performance under non-irrigated water stress condition in those morphological and yield characters compared to other varieties (BARI maize-5 and BARI maize-7). Based on drought susceptibility index BARI hybrid-2 and BARI hybrid maize-5 were found as comparatively drought tolerant than the other varieties (BARI maize-5 and BARI maize-7).

Key words: *Non-irrigated water stress,morpho-physiological characters, yield and maize*

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important principal crops of the world. It ranks third, following wheat and rice in the world production of cereal crops. In 2004-2005, maize covers about 0.09 million hectare of land in Bangladesh which produced about 0.47 million tons per year with an average yield of 5.2 t/ha (Anonymous, 2005). But the yield of maize is low in Bangladesh as compared to other maize growing countries of the world and the actual potential area for maize production are much more higher than the present areas because of congenial environment for its production. So, there is an ample scope for increasing maize production in this country.

Normally, maize can be cultivated throughout the year in Bangladesh. In winter a large amount of land remain fallow due to either lack of irrigation facilities or higher prices for irrigation water. The rainfall pattern is erratic and evapo-transpiration is high during winter and only 40% of the cultivable land can be brought under irrigation (Islam and Kaul, 1986). Appreciable grain yield reduction in maize was reported by Muhammad *et al.* (1998) due to water stress during the vegetative or the reproductive phase. This was due to the fact that number of grains per cob and 100-grain weight were inhibited by water stress and the number of sterile plants/ha was also promoted by water stress. In dense stands, yield depends on the growth and development of female inflorescences and proper anthesis. But the water stress hindered the growth and the effects included shortened length, lower diameter and lower fresh weight and dry weight of ears and also decreased rate and duration of grain filling and finally results in lower grain yield (Song and Dai, 2000). So it needs too much attention to provide drought tolerant variety and proper irrigation facility to get maximum grain yield of maize as it has much adverse effects on its morphological and physiological processes. Therefore, the present study was undertaken to evaluate the morphological and yield performance of four maize varieties under non-irrigated water stress condition for identifying relatively drought tolerant variety.

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

MATERIALS AND METHODS

The experiment was conducted at the Research field of Crop Physiology and Ecology Department, HSTU, Dinajpur during the period of November 2007 to April 2008 in a split plot design with three replications. The unit plot size was 3m x 2m having a plot to plot and block to block distance of 0.75m and 1.0m, respectively. Two growing conditions- well watered condition (three irrigation levels) and water stress condition (no irrigation) were placed in the main plots as main plot treatments whereas four maize varieties (BARI maize-5, BARI maize-7, BARI Hybrid maize-2 and BARI Hybrid maize-5) were placed randomly in the sub-plots as sub-plot treatments. The experimental plots were fertilized with $N–P_2O_5–K_2O–S$ @ 138–96-90-27 kg/ha in the form of Urea, TSP, MP and Gypsum, respectively. At the time of final land preparation, cowdung was applied at the rate of 5 t/ha. The whole quantity of TSP, MP, gypsum and 1/3 of urea were given at the time of final land preparation. The remaining urea was top dressed in two equal splits: 1st at 40 days after sowing (DAS) and 2nd at 70 DAS. The seeds were sown in lines at 70 x 20 cm spacing. The seeds were placed at depth of approximately 2.5cm from the soil surface. After sowing slight irrigation with overhead sprinkler was given for uniform germination.

Number of green leaf at the dry silk stage, length of leaf blade, length of leaf sheath, leaf breadth, plant height, number of fertile cob per plant and single plant weight were recorded from five randomly selected plants from the middle of each plot to avoid border effect. Cob length, cob diameter, number of rows per cob, number of grain per cob, cob weight and grain weight per cob were recorded from five randomly selected cobs. Hundred well dried grains were counted manually for 100 grain weight. Grain yield was measured in t/ha after harvest of whole plot. Grain yield was adjusted to 12% moisture content.

Drought susceptibility index (S) was calculated for grain yield as described by Fisher and Maurer (1978).

$S = (I - Y/Y_P) / (1- X/X_P)$

Where,

Y = Grain yield of variety in a stress environment

Y_P = Grain yield of variety in a stress free environment.

X = Mean Y of all varieties

X_P = Mean Y_P, of all varieties

(S< 1.0, stress tolerant and S >1.0, stress susceptible.)

The data were analyzed by partitioning the total variance with the help of computer by using MSTAT program. The treatment means were compared using Duncun's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Plant height and single plant weight

The interaction effect of growing condition and maize varieties on plant height and single plant weight was significant (Table 1). Under well watered growing conditions, variety BARI hybrid maize-2 was statistically tallest (232 cm) than the other three varieties viz. BARI hybrid maize-5 (220cm), BARI maize-7 (200 cm) and BARI maize-5 (190 cm). Under non-irrigated water stress condition, all the varieties significantly reduced their height. But the reduction was lower in BARI maize-5 and BARI maize-7 (5.26 and 7.5%, respectively) than the varieties BARI hybrid maize-5 and BARI hybrid maize-2 (9.09 and 9.48%, respectively. The reduction in plant height under water stress condition was due to the negative effect of water stress on growth. Similar result was found by Dhillon *et al.* (1995) and Sain *et al.* (2001) in maize. They reported that water stress decreased plant height.

At well watered growing condition, BARI hybrid maize -2 showed the highest single plant weight (385g) followed by the other hybrid variety. BARI maize-5 attained statistically lowest single plant

Table 1. Plant height and single plant weight of maize as influenced by non-irrigated water stress condition

Variety	Growing conditions	Plant height		Single plant weight	
		Actual (cm)	Reduction (%)	Actual (g)	Reduction (%)
BARI hybrid maize -5	Well watered	220 b	9.09	378 b	8.73
	Water stress	200 d		345 d	
BARI hybrid maize -2	Well watered	232 a	9.48	385 a	11.69
	Water stress	210 c		340 e	
BARI maize -7	Well watered	200 d	7.50	370 c	13.52
	Water stress	185 f		320 f	
BARI maize -5	Well watered	190 e	5.26	340 e	12.35
	Water stress	180 g		298 g	
CV(%)		1.78	-	1.00	-

In a column, means followed by the same letter(s) did not differ significantly at 5% level by DMRT.

weight (340 g). Under non-irrigated water stress growing condition, all the varieties significantly reduced their single plant weight compared to well watered condition. But the reduction was lower in the varieties BARI hybrid maize-2 and BARI hybrid maize-5 (11.69 and 8.73%, respectively) than the other two varieties BARI maize-7 and BARI maize-5 (13.52 and 12.35%). Result from other studies like Galbiatti (2004) found that non-irrigated water stress condition had the negative effect on the growth of the maize plant which supports the result of the present study.

Leaf characteristics

Number of green leaf at dry silk stage, length of leaf sheath and length of leaf blade were influenced significantly by the interaction effect of growing conditions and maize varieties but the influence was not significant in case of leaf breadth (Table 2). Under well watered condition, BARI hybrid maize-2 had the highest number of green leaf at dry silk stage (11.80) than the other three varieties viz. BARI hybrid maize-5 (11.26), BARI maize-7 (10.60) and BARI maize-5 (9.80). These differences in number of green leaf at dry silk stage among the maize varieties were due to their genetic characters. Under non-irrigated water-stress condition all the varieties showed reduced number of green leaf at dry silk stage. The reduction was lowered in BARI maize -5 and BARI maize-7 (3.06 and 3.77% respectively) than the varieties BARI hybrid maize -2 and BARI hybrid maize -5 (9.75 and 11.19%). From the result it was found that water stress caused decrease in number of green leaf. Similar result was found by Desai and Singh (2001) in maize.

Under well watered growing condition, BARI hybrid maize -5 had the highest leaf sheath length (I5 cm) than the other three varieties viz. BARI hybrid maize -2 (14.20 cm), BARI maize-5 (13.80 cm) and BARI maize-7 (14.40 cm). Under non-irrigated water stress condition, the leaf sheath length was reduced in all the maize varieties. But the reduction was lower in BARI hybrid maize-2 and BARI hybrid maize-5 (8.45 and 11.13% respectively) than the varieties BARI maize -7 and BARI maize-5 (12.99 and 12.10%, respectively). From the result it was found that water stress caused decrease in leaf sheath length. This may be due to reduced vegetative development of the plants by non-irrigated water stress condition (Galbiatti, 2004).

BARI hybrid maize -2 had the highest length of leaf blade (90.86 cm) which was statistically identical with BARI hybrid maize -5. BARI maize-5 had the lowest value (83.66 cm) which was at par with BARI maize -7 under well watered condition. Under non-irrigated water stress condition, the length of leaf blade was reduced in all the maize varieties but their reduction was not significant. BARI maze-5 showed the lowest reduction (3.35%) whereas BARI maize-7 showed the highest reduction (5.28%). The reduction in BARI hybrid maize -2 and BARI hybrid maize-5 was 4.84% and 4.07%

Table 2. Leaf characteristics of maize as influenced by non-irrigated water stress condition

Variety	Growing conditions	No. of green leaf		Length of leaf sheath		Length of leaf blade		Leaf breadth	
		Actual No.	Reduction (%)	Actual (cm)	Reduction (%)	Actual (cm)	Reduction (%)	Actual (cm)	Reduction (%)
BARI hybrid maize -5	Well watered	11.26 ab	11.19	15.00 a	11.13	88.46 ab	4.07	11.00 a	1.55
	Water stress	10.00 ab		13.33 ac		84.86 cd		10.83 a	
BARI hybrid maize -2	Well watered	11.80 a	9.75	14.20 ab	8.45	90.86 a	4.84	11.20 a	1.79
	Water stress	10.65 ab		13.00 ac		86.46 ac		11.00 a	
BARI maize -7	Well watered	10.60 ab	3.78	14.40 ab	12.99	85.86 ad	5.28	10.43 a	2.88
	Water stress	10.20 ab		12.53 bc		81.33 cd		10.13 a	
BARI maize -5	Well watered	9.80 ab	3.06	13.80 ac	12.10	83.66 cd	3.35	10.20 a	2.65
	Water stress	9.50 b		12.13 c		80.86 d		9.93 a	
CV(%)		10.32	-	7.30	-	3.32	-	6.02	-

In a column, means followed by the same letter(s) did not differ significantly at 5% level by DMRT.

respectively. From the result it was found that water stress caused decrease in leaf blade length. This may due to the vegetative development of the plants were hampered by non-irrigated condition (Galbiatti, 2004).

Under well watered condition, BARI hybrid maize-2 had the highest leaf breadth (11.20 cm) whereas BARI maize-5 showed the lowest value (10.20cm). Under water stress condition, all the varieties showed reduction in leaf breadth. But the reduction was lower in BARI hybrid maize-5 and BARI hybrid maize-2 (1.55 and 1.79%, respectively) than BARI maize-7 and BARI maize-5 (2.88 and 2.65%, respectively). Galbiatti (2004) reported that non-irrigated water stress condition had the negative effect on the growth of the maize plant which supports the result of present research work.

Cob characteristics

The interaction effect of four maize varieties and growing conditions was significant for cob length, cob diameter and single cob weight (Table 3). Under well watered condition, BARI hybrid maize -2 had the highest cob length (19.21 cm) followed by BARI hybrid maize -5 (18.72 cm), under well watered growing condition and BARI maize -5 attained the lowest cob length (17.10 cm). All the varieties at non-irrigated water stress condition showed reduced cob length. But the reduction was lower in BARI maize -7 (7.66%) and BARI maize -5 (8.42%) than the other two varieties BARI hybrid maize-5 and BARI hybrid maize-2 (9.19 and 9.21%, respectively). Results from other studies like Song and Dai (2000), Desai and Singh (2001) in maize support the present study. They reported that water stress decreased cob length in maize.

Under well watered condition, BARI hybrid maize -2 had the highest cob diameter (4.52cm) which was at par with BARI hybrid maize -5 (4.50 cm), whereas BARI maize -5 attained the lowest cob diameter (3.80 cm). Under non-irrigated water stress condition, all In a column, means followed by the same letter(s) did not differ significantly at 5% level by DMRT.

The varieties showed reduction in their cob length. But the reduction was lower in BARI maize -7 and BARI maize -5 (8.54 and 7.89%, respectively), than those of BARI hybrid maize-5 and BARI hybrid maize-2 (13.33 and 9.29%, respectively). From the result it was found that water stress caused decrease in cob diameter in all the varieties. Similar result was found by Song and Dai (2000) in maize.

Under well watered growing condition, BARI hybrid maize -2 had significantly highest single cob weight (185.36 g) than the other three varieties. Non-irrigated water stress condition showed lower single cob weight for all the varieties compared to well watered condition. The reduction was lower in BARI hybrid maize -5 (3.70%), whereas BARI maize -5 had the highest reduction (5.76%). Celiz *et al.* (1995) and Reta Sanchez and Faz Contreras (1999) reported that water stress reduced the single cob weight in maize. These findings support the result of the present work.

Yield contributing characters

The combined effect of four maize varieties and growing conditions was significant for number of seeds per cob, weight of seed per cob and 100-seed weight though the effect was insignificant for number of fertile cobs per plant (Table 4). Under well watered condition, BARI maize -7 showed the highest number of fertile cobs per plant (1.20), whereas BARI maize -5 had the lowest value (1.13). Non-irrigated water stress condition reduced the number of fertile cobs per plant for all the varieties in different magnitude. But the reduction was lower in BARI hybrid maize -2 and BARI 11.50%, respectively). From the result it was found that number of fertile cobs per plant was decreased by water stress condition. Similar result was also found by Muhammad *et al.* (1997).

BARI hybrid maize -2 had the significantly highest number of seeds per cob (420) followed by the other hybrid variety BARI hybrid maize -5 (412), whereas BARI maize -5 showed the lowest value (390) which was at par with BARI maize -7 (400) under well watered condition. All the hybrid maize-5 (4.35 and 5.83%, respectively) than BARI maize-7 and BARI maize-5 (11.67 and

Table 3. Cob characteristics of maize as influenced by non-irrigated water stress condition

Variety	Growing conditions	Cob length		Cob diameter		Single cob weight	
		Actual (cm)	Reduc-tion (%)	Actual (cm)	Reduc-tion (%)	Actual (g)	Reduc -tion (%)
BARI hybrid maize -5	Well watered	18.72ab	9.19	4.50ab	13.33	178.60b	3.70
	Water stress	17.00ac		3.90cd		172.00bd	
BARI hybrid maize -2	Well watered	19.21a	9.21	4.52 a	9.29	185.36 a	5.48
	Water stress	17.44ac		4.10bc		175.20 b	
BARI maize -7	Well watered	17.50ac	7.66	4.10bc	8.54	174.66 b	5.42
	Water stress	16.16ac		3.75cd		165.20de	
BARI maize -5	Well watered	17.10ac	8.42	3.80cd	7.89	170.00bc	5.76
	Water stress	15.66c		3.50d		160.21 e	
CV(%)		6.97	-	5.61	-	2.16	

varieties under non-irrigated water stress condition showed reduction in their number of seeds per cob at different intensities. The reduction was lower in BARI hybrid maize -5 (9.23%), whereas BARI maize-5 had the highest reduction in the number of seeds per cob (11.03%). From the result it was found that water stress reduced the seeds number per cob. Similar statement was made by Guan *et al.* (1997), Muhammad *et al*. (1997) in maize.

Under well watered condition, BARI hybrid maize -2 had the highest weight of seed per cob (142.36 g) which was statistically similar to BARI hybrid maize-5 (140.47 g) and BARI maize-7 (130.86 g), whereas BARI maize-5 showed the lowest value (125.30 g). Under non-irrigated water stress condition, all the varieties showed significantly lower weight of seed per cob. But the reduction was lower in BARI hybrid maize-2 (15.24%) and BARI hybrid maize-5 had the highest reduction (17.70%). In the present study it was found that water stress caused decrease in weight of seed per cob. This was also supported by Udomprasert *et al.* (1999).

BARI hybrid maize-2 had the highest 100-seed weight (34.26 g) followed by BARI hybrid maize-5 (33.56g), whereas BARI maize-5 showed the lowest 100-seed weight (31.40 g) under well watered growing condition. At non-irrigated water stress condition, all the varieties showed reduction in their 100-seed weight. But the reduction was lower in BARI hybrid maize-5 and BARI hybrid maize-2 (7.03 and 8.06%, respectively) than BARI maize-5 and BARI maize-7 (10.19 and 11.30%, respectively). Results, from other studies like Muhammad *et al*. (1998) in maize varieties, found that 100-seed weight was significantly reduced by the water stress.

Grain yield and drought susceptibility index

Yield of four maize varieties at different growing conditions is presented Table 5. The interaction effects of varieties and growing conditions on grain yield was significant. Under well watered growing condition it was found that BARI hybrid maize-2 had significantly highest yield (7.00 t/ha) followed by BARI hybrid maize-5 (6.80 t /ha), whereas BARI maize-5 and BARI maize-7 showed the lowest grain yield (6.00 t/ha). Non-irrigated water stress condition showed reduction in grain yield for all the varieties in different magnitude. But the reduction was lower in two hybrid varieties viz. BARI hybrid maize-5 and BARI hybrid maize-2 (21.18 and 22.86%) than other varieties viz. BARI maize-7 and BARI maize-5 (25.00 and 28.33%). In this growing condition again BARI hybrid maize-2 attained the highest yield (5.40 t/ha), whereas BARI maize-5 had the lowest yield (4.30 t/ha).

Table 4. Yield contributing characters of maize as influenced by non-irrigated water stress condition

Variety	Growing conditions	No. of fertile cobs /plant		No. of seeds per cob		Weight of seed per cob		100-seed weight	
		Actual (No.)	Reduction (%)	Actual (No.)	Reduction (%)	Actual (g)	Reduction (%)	Actual (g)	Reduction (%)
BARI hybrid maize-5	Well watered	1.20 a	5.83	412 b	9.23	140.47 a	17.70	33.56 ab	7.03
	Water stress	1.13 a		374 d		115.60 cd		31.20 cd	
BARI hybrid maize-2	Well watered	1.15 a	4.35	420 a	9.29	142.36 a	15.24	34.26 a	8.06
	Water stress	1.10 a		381 d		120.66 bc		31.50 bd	
BARI maize-7	Well watered	1.20 a	11.63	400 c	11.00	130.86 ab	15.37	32.47 ab	11.30
	Water stress	1.06 a		356 e		110.75 de		28.80 cd	
BARI maize-5	Well watered	1.13 a	11.50	390 c	11.03	125.30 bc	15.78	31.40 cd	10.19
	Water stress	1.00 a		347 f		105.53 e		28.20 d	
CV(%)		11.70	-	1.05	-	4.21	-	4.34	-

In a column, means followed by the same letter(s) did not differ significantly at 5% level by DMRT.

Table 5. Grain yield and drought susceptibility index of maize as influenced by non-irrigated water stress condition

Variety	Growing conditions	Grain yield		Drought susceptibility index
		Actual (t/ha)	Reduction (%)	
BARI hybrid maize-5	Well watered	6.80 b	21.18	0.88
	Water stress	5.36 d		
BARI hybrid maize-2	Well watered	7.00 a	22.86	0.95
	Water stress	5.40 d		
BARI maize-7	Well watered	6.00 c	25.00	1.03
	Water stress	4.50 e		
BARI maize-5	Well watered	6.00 c	28.33	1.77
	Water stress	4.30 f		
CV(%)		1.78	-	-

In a column, means followed by the same letter(s) did not differ significantly at 5% level by DMRT.

According to drought susceptible index based on grain yield BARI hybrid maize-2 and BARI hybrid maize-5 were suggested as drought tolerant (S<1) and BARI maize-5 and BARI maize-7 were found as drought susceptible (S>1). From the result it was found that water stress reduced the yield. Results from other studies like Bergonci *et al.* (2001) and, Zamfir and Zamfir (1999) in maize varieties found that yield was significantly reduced by water stress. These findings support the results of the present study.

CONCLUSION

From the overall results it might be concluded that all the varieties showed better performance in the well-watered condition compared to the non-irrigated water stress condition. But the two hybrid varieties showed better performance over the other varieties under non-irrigated water stress condition. Based on the drought susceptibility index BARI hybrid maize-2 and BARI hybrid maize-5 were found as the drought tolerant and BARI maize-5 and BARI maize-7 were considered as drought susceptible.

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