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Growth and yield of three hybrid maize varieties under different irrigation levels

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The response of three hybrid maize (*Zea mays L.*) varieties on five irrigation levels was evaluated in an experiment at Bangladesh Agricultural University, Mymensingh. The experiment included two factors – irrigation and maize variety. The Irrigation treatments/levels were I_o (no irrigation), I_1 (irrigation at IW (irrigation water need)/CPE (cumulative pan evaporation) = 0.4), I_2 (IW/CPE = 0.6), I_3 (IW/CPE = 0.8) and I_4 (IW/CPE = 1.0). The maize varieties were V_1 (BARI Hybrid Maize 5, BHM-5), V_2 (BARI Hybrid Maize 7, BHM-7) and V_3 (Pacific 984). The experiment was laid out in a split-plot design with irrigation in the main plots and variety in the sub-plots; there were three replications of the treatments. The size of the main plot was 7.0 m × 4.5 m and that of the sub-plot was 2.0 m × 4.5 m. Treatment I_4 produced the highest (9.30 t ha^{-1}) and I_o produced the lowest (7.62 t ha^{-1}) grain yield. V_3 (Pacific 984) produced the highest (8.60 t ha^{-1}) and V_2 (BHM-7) produced the lowest (7.31 t ha^{-1}) grain yield. The grain yield, however, did not vary significantly (p = 0.05) due to the effects of irrigations and varieties. The treatment combination I_4V_3 produced the highest (9.31 t ha^{-1}) and I_oV_2 produced the lowest (6.34 t ha^{-1}) grain yield. The interaction effects of irrigations and varieties on the grain yield were significant. Water use efficiency (WUE) for grain and biomass productions differed significantly among the irrigation treatments but insignificantly among the varieties. The interaction effects of the two factors on WUE were also significant. The highest WUE was obtained under the maximum water stressed treatment (I_o) and the lowest WUE was under maximum watered treatment.

Keywords: maize, variety, irrigation, interaction, growth and yield

Introduction

Many parts of the world now suffer from the growing scarcity of water available for agriculture. The reasons can range from drought and desertification to climate change and climate variability, water pollution, over-

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use of water and poor water management practices. As the water available for agriculture becomes limited, it is necessary to increase water productivity for better agricultural production by using limited water. Worldwide 70% of water use is for agriculture, with a much higher figure (85%) in low and middle income countries, where agriculture is a major economic sector (World Bank, 1992). The Food and Agriculture Organization (FAO, 2002) predicts a net expansion of irrigated land of some 45 million hectares in 93 developing countries (for a total of 242 million hectares in 2030) and projects that agricultural water withdrawals will increase by, approximately, 14% during 2000 – 2030 to meet food demand. Besides increasing water use efficiency by proper use of water, it is also important to identify some alternative crops, which can be adapted in adverse conditions, such as under water stress condition.

Maize is a multipurpose crop, which can supply food, feed and fuel in relatively large quantities as compared to other cereal crops. It is also used for manufacturing starch, corn flakes alcohol, salad oil, soap, varnishes, paints, printing and similar products (Ahmed, 1994). Its grain has high nutritive value (Thakur, 1980; Chowdhury and Islam, 1993). Compared to other crops, the acreage of maize has expanded rapidly. A major shift in global cereal demand is underway and, by 2020, demand for maize in developing countries is expected to exceed demand for both wheat and rice (Pingali and Pandey, 2001). Over the past 40 years, the global total area under maize has increased by 40% while production has doubled (Huang *et al*., 2006). So, it can be inferred that maize is on the way of its increased popularity.

In Bangladesh, maize being one of the high yielding cereal crops may be accepted as a third cereal crop. Yield potential of maize is very high, almost two times higher than rice and wheat; 8 to 9 t ha^{-1} is most commonly attained yield in many countries as against an average of 5.5 to 6.5 t ha^{-1} in Bangladesh. Now-a-days, maize has become an important cash crop in Bangladesh and farmers have become more interested to cultivate hybrid maize. Several seed companies import hybrid maize seeds and 70% of seed demand is met up through imported seeds (Banik *et al*., 2009). Maize is grown in Bangladesh during the driest months when rainfall is inadequate. But, proper growth and development of maize needs adequate soil moisture in the root zone. Inadequate water supply results in soil and plant water deficits, which reduce maize yield (Gordon *et al*., 1995). In relation to the yield, proper time and sufficient irrigation need to be realized in irrigation scheduling for the most effective use of available water in optimizing maize production. Shaozhong and Minggang (1993) identified the heading to milking stage of maize as the most sensitive period to water stress that has ultimate negative impact on grain yield. The objectives of this study were: (i) to investigate the effects of five irrigation regimes on yield and yield contributing attributes of maize, (ii) to identify the interaction effects of irrigation levels and maize varieties on yield and yield contributing attributes of maize, and (ii) to evaluate water productivity of maize under different irrigation levels and maize varieties.

Materials and Methods

Site description

The experiment was done at the Experimental Farm of Bangladesh Agricultural University, Mymensingh, during December 2010 to May 2011 to evaluate the response of five irrigation regimes and crop varieties on the yield and yield contributing attributes of maize. The field, a medium high land, belongs to the Old Brahmaputra Floodplain having non-calcarious Dark Grey Floodplain soil (FAO and UNDP, 1988). The soil was silt loam with pH varying from 5.75 to 6.42. The climate was subtropical with above-average rainfall of 242 cm. The temperature varied from moderately low in winter to moderately high in summer. There was 5.9 cm rainfall in three events during the period of experiment.

Treatments and design of experiment

The experiment was comprised of two factors – irrigation and maize variety. Irrigation was applied based on IW/CPE ratio; IW is irrigation water applied and CPE is cumulative pan evaporation. The irrigation treatments were: I_o = (no irrigation, control), I_1 = IW/CPE = 0.4, I_2 = IW/CPE = 0.6, I_3 = IW/CPE = 0.8 and I_4 = IW/CPE = 1.0. Irrigation was applied at 43, 63 and 83 days after sowing (DAS); 43, 63 and 83 DAS were the stages when a plant, on average, contained 3 – 5, 8 – 10 and 20 – 22 leaves, respectively. The crop varieties were V_1 (BARI Hybrid Maize-5, BHM-5), V_2 (BARI Hybrid Maize-7, BHM-7) and V_3 (Pacific 984).

The field was ploughed with a tractor and leveled with a disc harrow. It was divided into three blocks with spacing of 1.5 m between the adjacent blocks. The blocks contained three replications of the treatments. Each block was divided into 5 main plots having 1.5 m buffer space between the adjacent plots. Each main plot was again divided into 3 sub-plots each of size 4.5 m × 2 m. The buffer space between two adjacent sub-plots was 50 cm. A 15-cm high ridge was constructed around each sub-plot to retain irrigation water. Irrigation treatments were assigned in the main plots and the varieties were distributed in the sub-plots. Recommended dose of urea (500 kg ha^{-1}), triple super phosphate

(TSP, 250 kg ha^{-1}), muriate of potash (MP, 200 kg ha^{-1}), gypsum (240 kg ha^{-1}), zinc sulphate (10 kg ha^{-1}) and boric acid (5 kg ha^{-1}) were applied in the field. One-third of urea and whole of the other fertilizers were applied at the time of final land preparation. The rest two-third of urea was applied at 45 and 85 days after sowing (DAS). Maize seeds were sown on 25 December 2010 at a depth of 5 to 6 cm by manually dropping 2 to 3 seeds per hill. Within the row, seed to seed distance was 25 cm and row to row distance was 75 cm. Thinning was done at 35 DAS keeping only one healthy plant per hill. Weeds were controlled by uprooting them manually.

Data recording

After thinning, twenty plants were randomly selected in each plot and tagged for data collection on plant height, number of cobs per plant, number of grains per cob, cob length, and straw and grain yields. The matured crop was harvested on 8 May 2011. The cobs were cleaned, dried and shelled by a maize sheller. The grains were dried at 12% moisture content for calculating yield. Harvest index (HI) was calculated by the ratio grain yield to biological yield. The biological yield was calculated by the sum of straw and grain yields. The data were analyzed using analysis of variance (ANOVA) technique with MSTAT-C package and the mean differences were adjusted by Duncan's Multiple Range Test (Gomez and Gomez, 1984).

Results and discussion

Plant height

Treatment I_4 produced the tallest plants (123.9 cm) and I_o produced the shortest ones (96.0 cm) (Table 1). Quaye et al. (2009) also obtained increased plant height with increased application of water. In case of varieties (Table 2), V_2 produced the tallest plants (118.1 cm) and V_3 produced the shortest ones (106.5 cm). Both irrigation and maize variety however exerted only insignificant ($p = 0.05$) influence on plant height (Tables 1 and 2). It was noted that due to 5.9 cm rainfall during the experiment, full water stress could not be imposed in the control treatment. This fact influenced all the crop attributes in the control treatment. Considering interaction effects of irrigation and variety, the plant heights were significantly different among different treatment combinations (Table 3). The tallest plants (140.3 cm) were obtained under I_4V_2 and the shortest plants (85.4 cm) were under I_0V_1 (Tables 3).

Number of cobs per plant

As compared in Tables 1 and 2, the number of cobs per plant differed insignificantly both under the irrigation and varietal treatments. Treatment I_1 produced the highest number of cobs (1.07) per plant and I_3 produced the lowest number of cobs (0.93) per plant. In case of varieties, the highest number of cobs (1.09) per plant was obtained under V_1 and the lowest number (0.89) was obtained under V_2. The treatment combination I_1V_1 produced the highest number of cobs (1.17) per plant and I_3V_2 produced the lowest number (0.77) of cobs per plant (Table 3).

Cob length

Both irrigation and maize variety exerted insignificant influences on cob length (Tables 1 and 2). The maximum watered plots (I_4) produced the longest cobs (17.78 cm) and the maximum water stressed plots (I_o) produced the shortest cobs (16.39 cm). On the maize varieties, V_3 provided the longest cobs (17.67 cm) and V_2 provided the shortest cobs (16.78 cm). Niazuddin et al. (2002) and Gab-Alla et al. (1995) also reported similar effects of water regimes on the cob length of maize. The combined effects of irrigations and varieties however caused significant differences in cob length (Table 3).

Number of grains per cob

The effects of irrigation and varietal treatments on the number of grains per cob were insignificant. The highest number of grains per cob (547) was obtained under I_4 and the lowest number (509) was obtained under I_3. V_3 provided the highest number (552) of grains per cob while V_1 provided the lowest (510) number of grains per cob. The treatment combination I_4V_3 produced the highest number of grains per cob (585) while I_3V_1 produced the lowest (485) number of grains per cob. There were significant differences among the number of grains per cob under the combined effects of irrigation and varietal treatments (Table 3).

100-seed weight

The highest 100-seed weight of 32.18 g was obtained under I_1 and the lowest of 30.59 g was obtained under I_3. For the three maize varieties, the highest 100-seed weight (31.24 g) was obtained under V_3 while the lowest (30.60 g) was obtained under V_1. The 100-seed weight under both irrigation and varietal treatments were identical. These results were in agreement with the findings of Hossain et al. (2009). Considering interaction effects between the irrigation and maize variety, there were significant differences in 100-seed weights among different treatment combinations. The highest 100-seed weight of 33.18 g and the lowest of 29.05 g were obtained under the treatment combinations I_1V_2 and I_0V_1, respectively (Table 3).

Straw yield

Treatment I_4 helped producing the highest straw yield (10.58 t ha^{-1}) while the most stressed treatment, I_o, produced the lowest (8.32 t ha^{-1}) yield, both yields were however statistically similar (Tables 4 and 5). The straw yield was the utmost (9.12 t ha^{-1}) for V_1 and the least (8.35 t ha^{-1}) for V_2. The maize varieties also did not significantly influence the straw yield. The interaction effects of irrigation and maize variety however employed significant influences on the straw yield. The highest (10.69 t ha^{-1}) and lowest (5.26 t ha^{-1}) straw yields were obtained under I_1V_3 and I_4V_2, respectively (Tables 6).

Grain yield

The irrigation and varietal treatments exerted insignificant influences on the grain yield of maize. The highest grain yield (8.57 t ha^{-1}) was obtained under I_3 and the lowest (7.62 t ha^{-1}) was obtained under I_0. These results were in agreement with those of Talukder et al. (1999), Niazuddin et al. (2002) and Hossain et al. (2009). An increasing trend in grain yield was observed due to the lowering of water stress (Table 4). V_3 provided the highest grain yield (8.60 t ha^{-1}) and V_2 provided the lowest (7.31 t ha^{-1}) yield. The interaction effects between the irrigation and maize variety revealed that the highest grain yield (9.31 t ha^{-1}) was obtained under the treatment combination I_4V_3 and the lowest (6.34 t ha^{-1}) was under I_0V_2. The grain yields varied significantly due to the interaction effects of irrigation and maize variety. Similar effect of water regimes and variety on the grain yield of maize was also reported by Hossain et al. (2009).

Harvest Index

The highest harvest index (55.89%) was obtained under I_4 and the lowest (50.87%) was obtained under I_3, both values were statistically identical. The three maize varieties also provided similar harvest indices (Table 5); V_3 provided the highest harvest index (52.16%) and V_2 provided its lowest (51.45%) value. The interaction effects of the irrigation and maize variety on harvest index were significant (Table 6). The highest harvest index (57.65%) was obtained under I_2V_3 and the lowest (46.20%) was obtained under I_3V_1.

Water use efficiency

The highest water use efficiencies for grain (7.64 kg ha^{-1} cm^{-1}) and biomass (14.98 kg ha^{-1} cm^{-1}) production were obtained under I_o. The lowest water use efficiencies for grain (2.67 kg ha^{-1} cm^{-1}) and biomass (4.93 kg ha^{-1} cm^{-1}) productions were obtained under I_4. The water use efficiency, WUE, for grain production differed significantly among the irrigation treatments (Table 4). Niazuddin et al. (2002) and Hossain et al. (2009) also reported comparable effects of irrigation treatments on WUE. The highest WUE for grain production (4.90 kg ha^{-1} cm^{-1}) was obtained under V_1 and the lowest (4.41 kg ha^{-1} cm^{-1}) was obtained under V_2. For biomass production, the highest (9.39 kg ha^{-1} cm^{-1}) and lowest (8.60 kg ha^{-1} cm^{-1}) water use efficiencies were obtained under V_1 and V_2, respectively. The water use efficiencies, both for grain and biomass productions, were however statistically identical. Considering the interaction effects, WUE varied significantly between the treatment combinations. The highest WUE for grain production (8.86 kg ha^{-1} cm^{-1}) was under I_oV_1 and the lowest (2.35 kg ha^{-1} cm^{-1}) was under I_4V_3. The highest (16.04 kg ha^{-1} cm^{-1}) and lowest (4.63 kg ha^{-1} cm^{-1}) water use efficiencies for biomass productions were also obtained under I_oV_1 and I_4V_3, respectively.

Table 1. Effects of water stress treatments on plant height, number of cobs per plant, cob length, number of grains per cob and 100-seed weight of maize

Irrigation	**Plant height (cm)**	**No. of cobs/plant**	**Cob length (cm)**	**No. of grains/cob**	**100-seed weight (g)**
I_0	96.0^A	0.93^A	17.10^A	537^A	31.03^A
I_1	121.7^A	1.07^A	16.91^A	529^A	32.18^A
I_2	111.6^A	1.01^A	16.39^A	526^A	31.17^A
I_3	111.8^A	0.93^A	17.58^A	509^A	30.59^A
I_4	123.9^A	0.96^A	17.78^A	547^A	31.33^A
$LSD_{0.05}$	26.93	0.24	1.45	70.60	2.65

Common letter(s) within the same column do not differ at 5% level of significance.

Table 2. Effects of varieties on plant height, number of cobs per plant, cob length, number of grains per cob and 100-seed weight of maize

Variety	Plant height (cm)	No. of cobs/plant	Cob length (cm)	No. of grains/cob	100- seed weight (g)
V_1	115.1^{A}	1.09^{A}	17.01^{A}	510^{A}	30.60^{A}
V_2	118.1^{A}	0.89^{A}	16.78^{A}	526^{A}	31.14^{A}
V_3	106.5^{A}	0.95^{A}	17.67^{A}	552^{A}	31.24^{A}
$LSD_{0.05}$	34.77	0.313	1.874	91.15	3.426

Common letter(s) within the same column do not differ at 5% level of significance.

Table 3. Interaction effects on plant height, number of cobs per plant, cob length, number of grains per cob and 100-seed weight of maize

Interaction	Plant height (cm)	No. of cobs/plant	Cob length (cm)	No. of grains/cob	100- seed wt. (g)
I_0V_1	85.4^{G}	1.10^{ABC}	16.80^{DEF}	514^{BCDE}	29.05^{E}
I_0V_2	106.5^{CDEF}	0.83^{FG}	16.61^{DEF}	540^{BC}	31.18^{BCD}
I_0V_3	99.07^{FG}	0.87^{EFG}	17.90^{ABC}	556^{AB}	32.64^{AB}
I_1V_1	116.8^{BCDE}	1.17^{A}	16.47^{EF}	486^{DE}	30.67^{CDE}
I_1V_2	130.4^{AB}	1.0^{BCDE}	17.14^{BCDE}	547^{ABC}	33.18^{A}
I_1V_3	118.1^{BCDE}	1.03^{ABCD}	17.11^{CDE}	553^{ABC}	32.69^{AB}
I_2V_1	125.3^{AB}	1.13^{AB}	16.95^{DE}	536^{BC}	31.02^{BCD}
I_2V_2	102.3^{EF}	1.0^{BCDE}	15.93^{F}	508^{CDE}	30.85^{CDE}
I_2V_3	107.2^{CDEF}	0.90^{DEFG}	16.27^{EF}	533^{BCD}	31.65^{ABCD}
I_3V_1	121.0^{BCD}	1.03^{ABCD}	16.76^{DEF}	485^{E}	30.01^{DE}
I_3V_2	123.1^{ABC}	0.77^{G}	17.50^{BCD}	508^{CDE}	32.61^{AB}
I_3V_3	91.46^{FG}	1.0^{BCDE}	18.48^{A}	533^{BCD}	29.15^{E}
I_4V_1	127.2^{AB}	1.03^{ABCD}	18.04^{AB}	529^{BCDE}	32.03^{ABC}
I_4V_2	140.3^{A}	0.87^{EFG}	16.70^{DEF}	526^{BCDE}	31.89^{ABC}
I_4V_3	104.4^{DEF}	0.97^{CDEF}	18.60^{A}	585^{A}	33.08^{DE}
$LSD_{0.05}$	15.55	0.139	0.838	40.76	1.532

Common letter(s) within the same column do not differ at 5% level of significance.

Table 4. Effects of water stress treatments on straw yield, grain yield, harvest index, water use efficiency of grain and biomass of maize

Irrigation	Straw yield ($t\ ha^{-1}$)	Grain yield ($t\ ha^{-1}$)	Harvest index (%)	WUE_g kg/ha/mm	WUE_b kg/ha/mm
I_0	8.32^{A}	7.62^{A}	51.06^{A}	7.64^{A}	14.98^{A}
I_1	9.19^{A}	8.18^{A}	52.15^{A}	5.82^{B}	11.11^{B}
I_2	8.86^{A}	8.19^{A}	52.21^{A}	4.15^{BC}	8.06^{C}
I_3	8.78^{A}	8.57^{A}	50.87^{A}	3.25^{C}	6.39^{CD}
I_4	10.58^{A}	8.30^{A}	55.89^{A}	2.67^{D}	4.93^{D}
$LSD_{0.05}$	2.61	2.12	11.52	0.082	2.311

Common letter(s) within the same column do not differ at 5% level of significance.

Table 5. Effects of varieties on straw yield, grain yield, harvest index, water use efficiency of grain and biomass of maize

Variety	Straw Yield (t ha^{-1})	Grain Yield (t ha^{-1})	Harvest index (%)	WUE_g kg/ha/mm	WUE_b kg/ha/mm
V_1	9.12^{A}	7.50^{A}	51.70^{A}	4.90^{A}	9.39^{A}
V_2	8.35^{A}	7.31^{A}	51.45^{A}	4.41^{A}	8.60^{A}
V_3	8.90^{A}	8.60^{A}	52.16^{A}	4.81^{A}	9.30^{A}
$LSD_{0.05}$	3.37	2.74	14.87	0.11	2.98

Common letter(s) within the same column do not differ at 5% level of significance.

Table 6. Interaction effects on straw yield, grain yield, harvest index and water use efficiency of grain and biomass of maize

Interaction	**Straw Yield (t ha^{-1})**	**Grain Yield (t ha^{-1})**	**Harvest index (%)**	**WUE_g kg/ha/cm**	**WUE_b kg/ha/mm**
I_0V_1	7.17^{BC}	8.84^{BCD}	55.71^{BCD}	8.86^{A}	16.04^{A}
I_0V_2	7.03^{CD}	6.34^{F}	47.33^{EF}	6.36^{AB}	13.40^{B}
I_0V_3	7.79^{BC}	7.69^{DE}	50.15^{BCDEF}	7.70^{AB}	15.51^{A}
I_1V_1	8.17^{ABC}	8.66^{BCDE}	51.49^{BCDEF}	5.49^{AB}	10.66^{C}
I_1V_2	8.22^{AB}	8.45^{BCDE}	50.49^{BCDEF}	5.35^{AB}	10.56^{C}
I_1V_3	10.69^{AB}	8.44^{A}	54.46^{BCDE}	6.61^{AB}	12.12^{B}
I_2V_1	9.79^{A}	9.05^{AB}	50.45^{BCDEF}	4.39^{AB}	8.69^{D}
I_2V_2	8.65^{A}	8.74^{BCD}	48.54^{CDEF}	4.03^{AB}	8.21^{DE}
I_2V_3	7.01^{BC}	8.75^{BCD}	57.65^{B}	4.05^{AB}	7.27^{EF}
I_3V_1	8.9^{ABC}	7.74^{CDE}	46.20^{F}	2.93^{B}	6.30^{FGH}
I_3V_2	7.22^{ABC}	9.15^{ABC}	56.16^{BC}	3.47^{AB}	6.28^{FGH}
I_3V_3	8.60^{ABC}	8.83^{BCD}	50.25^{BCDEF}	3.34^{AB}	6.60^{FG}
I_4V_1	7.50^{BC}	8.76^{BCD}	54.66^{BCDE}	2.82^{B}	5.24^{GHI}
I_4V_2	5.26^{D}	8.85^{BCD}	54.71^{A}	2.84^{B}	4.53^{I}
I_4V_3	6.34^{ABC}	9.31^{EF}	48.30^{DEF}	2.35^{B}	5.03^{HI}
$LSD_{0.05}$	1.507	1.224	6.652	0.0473	1.334

Common letter(s) within the same column do not differ at 5% level of significance.

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