Journal of Agricultural and Crop Research
Vol. 6(3), pp. 53-62, August 2018
ISSN: 2384-731X
Research Paper

Response of different maize (*Zea mays* L.) genotypes on yield under deficit irrigation in southern region of Bangladesh

Md. Mahmudul Hasan Khan[1*] • Anjan Kumar Das[1] • Shekh Shamsul Alam Kamar[1] • Razi Uddin[1] • Golam Morshed Rokon[2] • Md. Atikuzzamman[2] • Md. Nasir Uddin[3]

[1]Regional Agricultural Research Station, Bangladesh Agricultural Research Institute, Rahmatpur, Barisal, Bangladesh.
[2]CIMMYT, Barisal Hub, Bangladesh.
[3]UAO, DAE, MoA, Barisal, Bangladesh.

*****Corresponding author. E-mail: mhasan.bari12@gmail.com. Tel: +8801673167908.

Accepted 5th August, 2018

Abstract. This study was conducted at the Research field of Plant Breeding Division, Regional Agricultural Research Station (RARS), Bangladesh Agricultural Research Institute (BARI), Rahmatpur, Barisal, Bangladesh during the period from November, 2016 to April, 2017 to screen out the hybrid maize varieties under moisture deficit condition. There were two factors: (1) five irrigation treatments – I_1: Full irrigation at initial,vegetative stage, silking and grain filling stage (20-25 DAS and 50-60 DAS,75-80 DAS and 110-120 DAS), I_2: Full irrigation at initial stage (20-25 DAS), I_3: 50% irrigation both at initial and vegetative stage (20-25 DAS and 50-60 DAS) and I_4: 75% irrigation both at initial and vegetative stage and silking stage (20-25 DAS,50-60 DAS and 75-80 DAS), I_5: 50% irrigation at initial,vegetative stage, silking, and grain filling stage (20-25 DAS and 50-60 DAS,75-80 DAS and 110-120 DAS) and (2) five maize varieties, viz. V_1: BARI hybrid maize 9 (BHM−9), V_2: BARI hybrid maize 5 (BHM−5), V_3: BARI hybrid maize 7 (BHM−7), V_4: NK40 and V_5: Pacific 984. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. There was no significant ($\alpha = 0.05$) effect of irrigation and significant effect of varietal treatments on the grain yield of maize. The treatment I_1 produced the highest grain yield of 11.87 t/ha and I_5 (50% irrigation at initial, vegetative, silking and grain filling (20-25 DAS, 50-60 DAS, 75-80 DAS and 110-120 DAS) stages) produced the lowest yield of 11.02 t/ha. The treatment V_4 (NK-40) produced the highest grain yield of 15.03 t/ha and V_2 (BHM-5) produced the lowest yield of 5.99 t/ha.

Keywords: Maize (*Zea mays* L.), genotypes, deficit, irrigation, yield.

NTRODUCTION

Maize (*Zea mays* L.) is one of the main cereal crops in Bangladesh. The total area under maize cultivation in 2015-2016 was 0.39 million hectares with estimated production of maize was about 23.61 metric tons. Maize is a versatile crop due to its multifarious uses as feeds, food and industrial raw material. Every part of the maize plant is useful. In Bangladesh, a shortage of cooking oil has reached alarming proportions. Moreover, most of the available cooking oil is not of high nutritional value. Production and use of maize oil could help alleviate this situation, and the by-products of oil extraction can also be used in bakery products. Animal feed in the country is severely deficient due to the lack of an organized feed industry and non-availability of grazing land. Thus, maize could play an important role as animal feed and fodder fed as stover, green fodder or as silage. One of the important attributes of maize is that even after the cobs are harvested the remaining plant can be utilized as fodder. Thus maize would provide food for humans and feed for the livestock from the same planting and with the same input costs (Agricultural diary, 2017). Maize (*Zea mays* L.) belongs to the family Gramineae and is one of the most important photo-insensitive, cross pollinated cereal crops; it ranks 3rd in acreage and production in Bangladesh. Its growth in recent years has increased faster than any other crop in Bangladesh, probably due to its year round production, higher yield and less susceptible to high temperature and other natural hazards. The intensive efforts of researchers, seed producing agencies, breeders and extension agents in association with international cooperation from institute like CIMMYT have made it possible to take the crop to the farmers' door step of Bangladesh. The total area under maize cultivation in 2014-2015 was 3.95 lakh hectares with estimated production of maize was about 27.59 lakh metric tons (Agricultural diary, 2017).

Maize is being cultivated all over the world but the yield of maize is low in Bangladesh as compared to the other maize growing countries like China, Europe and India. Maize is also an excellent poultry feed. Yellow maize provides an additional advantage since it contains the fat soluble vitamin-A precursor, carotene, needed to promote normal growth in animals. At present poultry farmers are importing 2500 tons of maize grain per year for the poultry industry, thus expending valuable foreign exchange (Agricultural diary, 2017). No doubt, maize production in the country would reduce the drain of foreign exchange and at the same time contribute to the growth of the poultry industry. Mature, dried maize stalks can also be used as a fuel for cooking in the rural areas. Electricity and natural gas are not available in most parts of the country, and the rural population has been living with a serious shortage of fuel for cooking as well as for other essential needs such as processing of paddy. What is more alarming is the fact that this energy shortage is likely 'to worsen in the coming decades with increasing population pressure. In such a situation maize stalks and husks could serve as fuel in the countryside. In the long-run, maize can also be used for ethanol production as a substitute for petroleum based fuel (Year book, 2015). Maize can be grown all year round in Bangladesh and can therefore be fitted in the gap between the main cropping seasons without affecting the major crops. It can be harvested as fodder within 50 days of planting, as green cobs within 60-80 days and as grain within 100-130 days of planting. This flexibility allows the crop to fit easily into the cropping pattern. Another advantage of maize is its capacity to germinate under varying conditions. Maize can be dibbled in the flood prone areas as soon as flood water recedes without waiting for the soil to dry, at a time when no other crop would grow. Maize can be grown in these areas under no tillage and with minimum inputs. This type of land totals around 2 million ha (Year book, 2015). In the winter season in some cases, maize may compete with wheat, pulses, oil seeds and other rabi crops. Pulses, oil seeds, onion, garlic and potatoes can be intercropped with maize. Careful planning can also reduce the competition between maize and wheat since availability of land in the winter is not a problem. Maize can be grown in Bangladesh with other crops in several combinations. Patterns and possible associations of maize with other crops in Bangladesh are shown below: Its grain has high nutritive value containing 66.2% starch. 11.1% protein, 7.12% oil and 1.5% minerals. Moreover, 100 g maize grains contain 90 mg carotene, 1.8 mg niacin, 0.8 mg thiamin and 0.1 mg riboflavin (Chowdhury and Islam, 1993). Maize oil is used as the best quality edible oil. Green parts of the plant and grain are used as the feed of livestock and poultry. Stover and dry leaves are used as good fuel (Ahmed, 1994). The important industrial use of maize includes in the manufacture of starch and other products such as glucose, high fructose sugar, maize oil, alcohols, baby foods and breakfast cereals (Kristov, 1995). This crop has much higher grain protein content than our staple food rice. In Bangladesh the cultivation of maize was started in the late 19th century but the cultivation has started to gain the momentum as requirements of maize grain are being increased as poultry industry in Bangladesh (BBS, 2015). Loamy soil with nearly neutral pH is most suitable for production of maize. It can be grown all the year round in Bangladesh, and fitted in the gap between the main cropping seasons without affecting the major crops. It can also be grown in flood prone areas under no tillage, and with no inputs (Efferson, 1982). With its multipurpose properties, it will undoubtedly play a vital role in reducing the food shortage around the world, especially in Bangladesh. Maize being the highest yielding crop among cereal has high potential tor growing in the world as well as Bangladesh. Development of maize varieties having high yields within the shortage time may go a long way to supplement food and fodder shortage in Bangladesh. Yield is a complex character which is dependent on a number of agronomic characters and is highly influenced by many genetic and environmental factors (Joarder *et al*., 1978).

In Bangladesh, maize is being cultivated for a long time, but still it is a minor crop. Periodic attempts were made previously to accelerate maize production. During the last decade, maize has gained an increasingly important attention by the government. This is mainly due to its huge demand for poultry feed industries, fodder and fuel. From maize, 0.55 Mt of fodder and 0.27 Mt of fuel were produced (Ahmed, 1994). So, the researchers, government and farmers have to give more emphasis on maize cultivation. Expanding populations with greater food and energy needs are increasing demand for greater global maize (*Zea mays* L.) production. Unfortunately, environmental limitations such as temperature and drought continue to restrain maize production levels as they have in earlier decades and in many areas this is predicted to worsen with changing climates. Periodic moisture deficit

Table 1. List of maize genotypes with source used in this experiment.

Sl. no.		Variety/ Line
01.	V_1	BARI Hybrid Maize 9
02.	V_2	BARI Hybrid Maize 5
03.	V_3	BARI Hybrid Maize 7
04.	V_4	NK40
05.	V_5	Pacific 984

condition is caused by irregular rainfall, accentuated by low water holding capacity of tropical soils, as well as poor cultural practices and lack of appropriate varieties used by farmers, often causes maize crop losses (Klocke *et al*., 2004). Developing cultivars of maize that can perform well under heat and drought is an important goal throughout the world. Unfortunately, maize researchers and breeders have found that drought tolerance is a complex trait making the search for appropriate selection traits, breeding and screening methods difficult. An initial focus solely on yield stability under time points of water stress has so far resulted in incremental progress. Consequently, this has led to a search for secondary traits. In the case of maize these would ideally be identifiable in inbred lines and inherited to good yielding hybrids. These traits include but are not limited to, shortened anthesis-silking interval (ASI), delayed leaf senescence, increased rooting depth and density, hydraulic lift, high leaf number and short plant height, performance with limited available nitrogen, seedling vigor, and epicuticular wax. Many secondary trait screening methods are still costly when evaluating large numbers of genotypes in a breeding program. Technologies such as molecular markers for marker assisted selection and transgenic lines have been developed and provide another avenue to improve drought tolerance. However, for a trait as complex as drought, using the few identified genes mostly with small effects are unlikely to be a single solution in the near future. Alternatively, improvement in productivity of existing maize cultivars can be achieved through introgression of genes for drought tolerance. The initial step in utilizing germplasm is to screen for desirable characters, which can then be incorporated into existing cultivars. Drought tolerant (DT) maize germplasm can be assessed for DT capacity by evaluating them under well-watered and moisture deficit condition (Landi *et al*., 1995) using already identified traits that are directly or indirectly related to high grain yield under moisture deficit as index of selection in drought tolerant.

The objectives of this study are: 1) to screen out the most tolerant and most sensitive maize genotypes under moisture deficit condition, 2) to find out how the yield and yield contributing characters of different maize genotypes adopt to drought condition, 3) to compare the yield differences with deficit moisture condition.

MATERIALS AND METHODS

A field experiment was conducted at the Research Field of Plant Breeding Division, Regional Agricultural Research Station (RARS), Bangladesh Agricultural Research Institute (BARI), Rahmatpur, Barisal, Bangladesh during the period from November, 2016 to April, 2017 to screen out the hybrid maize varieties under moisture deficit condition. The experimental materials will consist of 5 diverse genotypes of maize. The experiment should be carried out in a Randomized Complete Block Design (RCBD) with three replications. The experimental field of Regional Agriculture Research Station, Rahmatpur, Barisal lies at the 22°42′ North latitude and 90°23′ East longitude at an altitude of 4 meter above the sea level. The experimental area is covered by Gangetic Tidal Floodplains and falls under Agro ecological Zone “AEZ–13”. The soil of the experimental land belongs to the Non-calcareous Grey Floodplain soils under the Ganges Tidal Alluvium tract. The land was saline, flat, well drained and above flood level. The soil was clay loam in texture having a pH value of 6.35 with moderate organic matter content. The annual rainfall ranges from 1780 to 1875 mm, most of which occurs from May to August and the rainfall is scanty from November, 2016 to April, 2017. Low temperature and plenty of sunshine prevail in the Rabi season (BARI, 2005-06) In order to maintain good yield in maize, it should be grown in rotation with legumes and green manures to improve and maintain soil health. In Bangladesh conditions, maize is grown in the pattern of maize/green manure or legume crop/transplanted rice. Heavy application of nitrogenous fertilizer before or at the time of planting prior to the monsoon may lead to heavy losses by leaching. First top dressing is at sowing and the 2s top dressing at knee height, with a possible third at tassel emergence. Potassium, zinc and sulphur should be applied at the time of final land preparation if these are required. In Bangladesh recommended rates are 80-120 kg/ha nitrogen, 60 kg/ha P_20_5 and 30-40 kg/ha K_20, 5 kg/ha Zinc and 20 kg/ha Sluphate /ha and 5-7 tons/ha of cow dung.

Materials of the experiment

Table 1 shows the list of maize genotypes with source used in this experiment.

Layout and design of experiment

The experiment carried out in a Randomized Complete Block Design (RCBD) with three replications. The experiment consisted of two factors irrigation and maize variety. Irrigation had 5 levels or treatment. The irrigation treatments were:

I_1 = Full irrigation at initial,vegetative stage,silking and grain filling stage (20-25 DAS and 50-60 DAS, 75-80 DAS and 110-120 DAS)
I_2 = Full irrigation at initial stage (20-25 DAS)
I_3 = 50% irrigation both at initial and vegetative stage (20-25 DAS and 50-60 DAS)
I_4 = 75% irrigation both at initial and vegetative stage and silking stage (20-25 DAS, 50-60 DAS and 75-80 DAS)
I_5 = 50% irrigation at initial,vegetative stage, silking, and grain filling stage (20-25 DAS and 50-60 DAS,75-80 DAS and 110-120 DAS)

For sowing the seeds, 5 to 6 cm deep furrows were made by using tine hand rakes at a spacing of 60 cm. The seeds were sown on 25 November 2016 at a depth of 5 to 6 cm, and 2 seeds were dropped per hill. The seed to seed distance was 25 cm.

Intensive care was taken during growth period for the adequate growth and development of the crop. Different genotypes matured at different times. So harvesting was completed by 5 May, 2017. Ten plants were collected from each plot by uprooting for data collection. The plants were bundled and tagged separately for each plot. Data were recorded from ten randomly selected plants/row from each experimental unit for all studied characters on yield contributing traits viz. Days to 50% tasseling, days to 50% silking, days to maturity, plant height, ear height, number of seed rows per cob, number of seeds per row, number of seeds per cob, thousand grain weight and yield (g/plant). The grains were separated from the shell by using a maize sheller. The grains were cleaned and dried in the sun at 14% (by weight) moisture content. Then the weight of the grains was taken by using a balance. The weight of the grain of collected samples was converted into yield per hectare for each plot. The collected sample plants were dried in the sun at 14% (by weight) moisture content. After proper sun drying hundred grain weights (g) were weighed by using balance. The weight of dried plants was taken by a balance. The weight of cover of cobs and shell was also taken by using a balance. Then the value was converted into yield per hectare for each plot. Harvest index (HI) is the ration between the grain yield and biological or biomass yield. The biological yield is the sum total of the grain and straw yields. The HI is expressed as:

$$\text{Harvest Index (HI) \%} = \frac{\text{Grain yield}}{\text{Biological Yield}} \times 100$$

The water use of a crop field is generally described in terms of field water use efficiency (FWUE), which is the ratio of the crop yield to the total amount of water used in the field during the entire growing period of the crop. The FWUE demonstrates the productivity of water in producing crop yield.FWUE for maize was calculated by:

$$\text{FWUE} = \frac{\text{Y}}{\text{WU}}$$

Where,

FWUE = field water use efficiency, kg $ha^{-1}cm^{-1}$
WU = seasonal water use in the crop fieldcm
Y = grain yield, kg ha^{-1}

The collected data were analyzed using MSTAT statistical package and the mean differences were adjusted by LSD.

RESULTS AND DISCUSSION

The experiment was conducted to screen out the most tolerant hybrid maize variety through analyzing the effect of deficit moisture on growth and yield characters of maize to expand irrigated agriculture with limited water resources. Among the means to survive the consequences of water scarcity and yet to sustain higher crop production under irrigated agriculture with decreasing share of water, deficient irrigation programs are highly valued and their adoption is widely promoted. The results obtained in the experiment have been presented, interpreted and discussed in this chapter under relevant headings and sub-headings with necessary tables. The effects of different irrigation levels, varieties on maize cultivation have been elaborated.

Effect of irrigation and variety on yield and yield parameters

The plant heights although varied to some extent but there were no significant difference among the irrigation treatments. But in case of variety treatment, it can be observed that the treatments were significant. Maize is very sensitive to water stress. Barrett and Skogerboe (1978) and Pandey *et al*. (2000) reported that water stress can effect growth, development and physiological processes of maize plants, which reduce biomass yield. Jama and Ottman (1993) noted that the maize needs for the highest water amount is during the flowering period. Because of this, one of the most important factors that can limit crop production is availability of water. If water stress can be avoided during silking and early ear development, high yield could be expected. Craciun and Craclum (1994) in his study on the effect of different irrigation water levels on grain yield, yield components and some quality parameters of silage maize (*Zea mays)* in Marmara Region of Turkey found that yield components such as plant height, ear length, the number of row per ear, the number of grain per row, the number of grain per ear and the number of ear per plant of maize grown under different levels of irrigation and quality parameters including 1000 grain weight, hectoliter weight, crude protein and crude oil in.

Plant height

The mean plant heights for different irrigation and variety

Table 2. Component of water requirement and water productivity in different treatments.

Irrigation treatment	Amount of total irrigation (cm)	Effective rainfall (cm)	Soil moisture contribution (cm)	Total water use (cm)	Water productivity (kg/m^3)
I_1	71.86	4.17	16.68	92.71	1.60
I_2	21.59	4.17	16.68	42.44	3.38
I_3	19.05	4.17	16.68	39.88	3.63
I_4	26.28	4.17	16.68	47.13	3.06
I_5	37.93	4.17	16.68	58.78	2.34

treatments are listed in Table 4. The highest plant height of 174.8 cm was obtained at I_1 (farmer practice) and the lowest was 163.2 cm at I_2 (Full irrigation at initial stage, 20-25 DAS). In case of variety treatments, the highest plant height of 214.2 cm was obtained at V_1 (BHM-9) and the lowest was 138.4 cm at V_3 (BHM-7) (Table 5). In similar experiments (Pandey *et al*., 2000), plant heights were reported to be higher with full irrigation (100% ETc or Epan = 1) and slightly deficit irrigation throughout the crop growing season, which agrees with the results of the current study.

Cob length and perimeter

The irrigation treatments did not exert significant influence on the length and perimeter of cobs (Tables 4). Among all treatments, the highest cob length of 17.89 cm was obtained at I_1 (farmer practice) and the lowest of 17.27 cm was obtained at I_2 (Full irrigation at initial stage, 20-25 DAS). In case of cob perimeter, the highest value of 4.717 cm was at I_4 (75% irrigation at initial, vegetative stage and silking (20-25 DAS, 50-60 DAS and 75-80 DAS) stages) and the lowest value of 4.705 cm was at I_2 (Full irrigation at initial stage, 20-25 DAS) (Table 4). On the other side, variety treatments were statistically significant on the length and perimeter of cobs (Tables 3). The highest cob length of 20.16 cm was obtained at V_5 (Pacific-984) and the lowest of 14.63 cm was obtained at V_2 (BHM-5). The highest cob perimeter of 5.442 cm was found at V_4 (NK-40) and the lowest of 3.917 cm was found at V_2 (BHM-5) (Table 5). BHM-9 and pacific-984 was adjacent to the highest value.

Abrecht and Carberry (1993) found that data obtained from two cobs study showed that cob length was significantly affected by irrigation levels ($p < 0.01$). The higher cob length values were obtained from treatments I125 and I100 (20.6 cm in both irrigation levels), while the shortest cob length (16.0 cm) was obtained from treatment I0. Because the cob length affects the number of grain per cob, it is accepted as one of the most important yield components that affects the grain yield. Their findings showed that when the irrigation levels decreased, the cob length decreased too. This result is consistent with the results of Bandyopadhyay and Mallik (1996). They showed that cob length was affected by different irrigation water levels (12.8 to 18.8 cm) and reported that the cob length decreased with decreasing water application. Cosculleula and Faci (1992) noted that full irrigation during total crop growing season increased the cob length, but deficit irrigation at different phenological stages decreased it. In a similar study, Lanza *et al*. (1980) reported values varying between 16.4 and 20.5 for cob length in relation to irrigation water levels.

Number of grains per cob

The highest number of grains per cob (416.0) was obtained at I_4 (75% irrigation at initial, vegetative stage and silking (20-25 DAS, 50-60 DAS and 75-80 DAS) stages) and the lowest (402.0) was at I_2 (Full irrigation at initial stage, 20-25 DAS) (Table 4). The irrigation treatments were not significant. The variety treatments exert significant difference among the treatments. The highest number of grains per cob (605.0) was obtained at V_1 (BHM-9) and the lowest (181.0) was at V_2 (BHM-5) (Table 5).

Prasad and Prasad (1989) found that the number of rows per cob was statistically affected by different irrigation water amounts. Results revealed that the higher number of row per cob was found in irrigated treatments whereas the lowest was found in non-irrigated plants. Results are similar with those of Dai *et al*. (1990). In a study carried out by Bryant *et al*. (1992) under the ecological conditions of Iran, the number of row per cob varied between 12.4 and 14.1. This result was lower than ours because of different cultivar and ecological conditions. Similar findings are reported by Cosculleula and Faci (1992) who stated that the lowest number of row per cob was obtained from non-irrigated plots. Differences between irrigation treatments were significant for the number of grain per row. Results showed that the number of grain per row increased as irrigation water amount increased up to I75 level. Results were similar with those of Claassen and Shaw (1970) who reported that the water stress decreased the number of grain per row at silking stage. The values of number of grain per row obtained in this study are in agreement with those of other resources on maize (Doorenbos and Kassam, 1979). Significant differences between irrigation treatments

Table 3. Analysis of variances for different yield contributing traits of Maize.

Source of variation	d.f	Plant height (cm)	Cob length (cm)	Cob diameter (cm)	No of grain per cob	Shell wt (g)	Cover wt (g)	Straw wt (g)	Grain yield (t/ha)	Biological yield (t/ha)	Harvest index (%)	100 grain wt (g)
Replication	2	224.235	0.247	0.011	256.995	1.665	0.374	1.133	0.694	0.308	15.201	3.321
Irrigation (Factor-A)	4	582.313	1.025	0.003	634.252	0.125	0.110	0.039	2.191	2.371	5.614	0.686
Variety (Factor-B)	4	14036.185*	107.552*	7.830*	555885.375*	23.752*	3.049*	156.950*	514.660*	1616.850*	426.460*	146.668*
AB	16	306.529*	0.747*	0.004*	928.416*	0.040*	0.060*	0.049*	1.636*	1.725*	5.086*	0.578*
Error	48	241.483	0.154	0.007	991.753	0.313	0.088	0.104	2.958	3.741	8.154	1.203

Table 4. Yield and yield parameters under different irrigation treatments.

Treatment	Plant height (cm)	Length of cob (cm)	Cob perimeter (cm)	No. of grain/cob	100-grain wt (g)	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	HI (%)
I_1	174.8	17.89	4.691	411	37.33	11.87	14.37	32.87	42.47
I_2	163.2	17.27	4.705	402	36.94	11.49	14.84	33.27	43.15
I_3	168.8	17.83	4.707	403	37.05	11.57	14.47	32.98	42.54
I_4	169.7	17.61	4.717	416	36.8	11.55	14.44	33.24	42.16
I_5	170.4	17.43	4.681	412	37.23	11.02	13.78	32.29	41.48
LSD	28.7	1.379	0.136	51.23	1.784	2.798	2.798	3.147	4.646
Mean	169.38	17.606	4.700	408.8	37.07	11.5	14.38	32.93	42.36
SE(±)	0.479	0.030	0.001	0.699	0.024	0.035	0.044	0.045	0.070
SD	4.154	0.262	0.014	6.058	0.214	0.306	0.381	0.396	0.608
Minimum	163.2	17.27	4.681	402	36.8	11.02	13.78	32.29	41.48
Maximum	174.8	17.89	4.717	416	37.33	11.87	14.84	33.27	43.15
CV (%)	9.07	2.23	1.73	7.7	2.96	11.96	2.69	5.87	6.74
Level of significance	NS	NS	NS	NS	NS	NS	NS	NS	NS

were found in terms of the number of grains per cob for combined data of two cobs. The highest numbers of grain per cob were obtained from I125 and I100 irrigation water amounts, whereas the lowest number of grain per cob was obtained from non-irrigated treatment. The number of grain per cob is related with the cob length, the number of row per cob and the number of grain per row. It was seen that the number of grain per cob increased like the number of grain per row, as the amount of irrigation water was increased. The cob length, the number of rows per cob and the number of grains per row gave the highest values when there was no deficit irrigation (I125 and I100 irrigation levels). Denmead and Shaw (1960) also reported that deficit irrigation decreased the number of grain per ear, which was in agreement with our findings. The effect of different irrigation water amounts were statistically important for the number of ear per plant of silage maize. The numbers of cob per plant varied between 0.89 and 0.65 number per plant. The higher number of cob per plant were obtained from I125, I100, I75, I50 and I25 treatments, which were statistically similar (0.89, 0.88, 0.88, 0.86 and 0.83, respectively), while the lowest value was determined at non-irrigated plots (0.65). The soil water stress affected the cob number per plant. Pandey *et al*. (2000) reported that water deficit decreased the cob number per unit area. Results are similar with those of Hanks (1974) who reported the stress of water affected the cob number of per plant.

100-grain weight

The 100-grain weight of maize was statistically similar for different irrigation treatments (Table 3). The highest 100-grain weight (37.33 g) was obtained at I_1 (farmer practice) and the lowest (36.80 g) was obtained at I_4 (75% irrigation at initial, vegetative stage and silking (20-25 DAS, 50-60 DAS and 75-80 DAS) stages) (Table 4). But the results were observed very nobly among the irrigation treatments. On the other side, the 100-grain weight of maize was statistically significant for different variety treatments. The highest 100-grain weight (39.24 g) was obtained at V_5 (Pacific-984) and the lowest (31.99 g) was obtained at V_2 (BHM-5) (Table 5). Lyle and Bordovsky (1995) in his study found that the effect of different irrigation water amount was statistically important for the 1,000 grain weight of maize for combined data of two years. As shown Table 4, the highest 1,000 grain weights were obtained from satisfactory irrigation while the lowest 1,000 grain weight was obtained from non-irrigated plots. As a result, 1,000 grain weight increased as the amount of irrigation water increased. Results were in agreement with the results of Petrunin (1966). They reported that when the amount of water decreased, both the 1,000 grain weight and grain yield were decreased. Similarly, Hossain (2009) reported that the application of deficit irrigation on maize at the flowering period decreased the 1,000 grain. Thakur (1980) also stated that the irrigations during milk maturation period increased the 1,000 grain weight.

Grain yield

The treatment I_1 produced the highest grain yield of 11.87 t/ha and I_5 (50% irrigation at initial, vegetative, silking and grain filling (20-25 DAS, 50-60 DAS, 75-80 DAS and 110-120 DAS) stages) produced the lowest yield of 11.02 t/ha (Table 4). The treatment V_4 (NK-40) produced the highest grain yield of 15.03 t/ha and V_2 (BHM-5) produced the lowest yield of 5.99 t/ha (Table 5). However, irrigation treatments had no significant effect but the variety treatments had significant effect on the production of grain yield of maize.

Downey (1971) found that the effect of different irrigation water amount was statistically important for grain yield per hectare for combined data of two years. In general, there was a close relationship between irrigation and grain yield. The relationship was mainly quadratic due to excessive irrigation. Quadratic relationships between grain yield and irrigation were also reported by Silva *et al*. (1992). Huang *et al*. (1999) found that there was a linear relationship between grain yield and seasonal irrigation water amount. The differences among the relationships reported by different researchers are due to different experimental conditions, seasonal rainfall amounts and distribution (Follett *et al*., 1978). In this study, the highest grain yield was obtained in satisfactory soil moisture during the growing period, while the lowest yield was obtained from treatment non irrigated plots. The results for the two years can be summarized by stating that a producer would have obtained the highest grain yield using full irrigation (1.00 × Epan) or slightly excessive irrigation (1.25 × Epan). These results are consistent with findings of Pandey *et al*. (2000), who showed that grain yield was affected by irrigation water amount.

Straw yield

Although irrigation played a positive role in increasing the straw yield of maize, its effect was insignificant (Table 3). The straw yield under various irrigation treatments ranged from 13.78 to 14.84 t/ha. Treatment I_2 (Full irrigation at initial stage, 20-25 DAS) produced the highest straw yield (14.84 t/ha) and I_5 (50% irrigation at initial, vegetative, silking and grain filling (20-25 DAS, 50-60 DAS, 75-80 DAS and 110-120 DAS) stages) produced the lowest (13.78 t/ha) yield (Table 4). Treatment V_5 (pacific-984) produced the highest straw yield (14.77 t/ha) and V_2 produced the lowest (8.459 t/ha) yield (Table 5). Variety treatments had significant effect on the production of straw yield of maize.

Biological yield

No significant variation was observed in the biological yield of maize among the irrigation treatments (Table 3). The highest biological yield (33.27 t/ha) was obtained at I_2 (Full irrigation at initial stage, 20-25 DAS) and the lowest (32.29 t/ ha) was in I_5 (50% irrigation at initial, vegetative, silking and grain filling (20-25 DAS, 50-60 DAS, 75-80 DAS and 110-120 DAS) stages) (Table 4). But the variety treatments had significant effect on biological yield. The highest biological yield (40.95 t/ha) was obtained from V_5 (pacific-984) and the lowest (21.50 t/ha) was at V_3 (BHM-7) (Table 5).

Table 5. Yield and yield parameters under different variety treatments.

Treatment	Plant height (cm)	Length of cob (cm)	Cob perimeter (cm)	No. of grain/ cob	100-grain wt (g)	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	HI (%)
V_1	214.2	19.52	5.112	605	39.11	12.43	14.76	40.18	44.7
V_2	147	14.63	3.917	181	31.99	5.99	8.459	21.62	34.6
V_3	138.4	14.8	3.93	234	36.09	6.81	8.582	21.5	39.6
V_4	170.6	18.93	5.442	456	38.93	15.03	13.52	40.4	48.33
V_5	186.7	20.16	5.101	568	39.24	14.12	14.77	40.95	44.56
LSD	28.7	1.37	0.13	51.23	1.78	2.79	0.5247	3.147	4.64
Mean	171.38	17.60	4.70	408.8	37.07	10.876	12.01	32.93	42.35
SE(±)	3.53	0.30	0.08	22.24	0.36	0.485	0.37	1.19	0.61
SD	30.62	2.67	0.72	192.68	3.12	4.201	3.233	10.38	5.33
Minimum	138.4	14.63	3.917	181	31.99	5.99	8.45	21.5	34.6
Maximum	214.2	20.16	5.442	605	39.24	15.03	14.77	40.95	48.33
CV (%)	9.07	2.23	1.73	7.7	2.96	11.96	2.69	5.87	6.74
F-Test	*	*	*	*	*	*	*	*	*

Harvest index

As compared in Table 4 and 5, the irrigation treatments did not exert any significant influence on the harvest index (HI) but the variety treatments had significant influence. Treatment I_2 (Full irrigation at initial stage, 20-25 DAS) provided the highest HI (43.15%) and I_5 (50% irrigation at initial, vegetative, silking and grain filling (20-25 DAS, 50-60 DAS, 75-80DAS and 110-120 DAS) stages) provided the lowest HI (41.48%) (Table 4). Treatment V_4 (NK-40) provided the highest HI (48.33%) and V_2 (BHM-5) provided the lowest HI (34.60%) (Table 5).

Water requirement and water use efficiency

The total water use during the whole season and the water productivity that represents the productivity of water in producing crop yields. The highest water productivity for grain production, WP (3.63 kg/m^3), was obtained at I_3 (50% irrigation both at initial and vegetative; 20-25 DAS and 50-60 DAS stages) and the lowest (1.60 kg/m^3) was obtained at I_1 (Farmer practice) (Table 2). Water productivity decreased with increasing quantity of applied irrigation. Karsau find that irrigation water use efficiency (IWUE) values varied from 1.11 to 1.72 kg m^{-3}, which are similar to reported values from 1.51 to 2.48 kg m^{-3} by Bharati *et al*. (1997) and up to 1.62 kg m^{-3} reported by Sridhar and Singh (1989). Differences in the rainfall during growing seasons could be the cause of small differences in the results of IWUE values because the amount of rainfall affects the amount of irrigation water applied. In this study, irrigation water use efficiency increased with decreasing irrigation water applied. In regions where water scarcity exists, irrigation managers should adopt the deficit irrigation approach to achieve sustainable crop production.

Figure 1 shows that the comparison of irrigation water applied including rainfall and irrigation water applied without rainfall with grain yield. There was a big deflection between water applied including rainfall and without rainfall. Figure 2 shows that there was some early rainfall in November and a huge rainfall before monsoon. That early rainfall was good for crops like maize, because it minimizes the production cost and helps to fill the grain properly. But for this kind of experiment, this huge rainfall effects directly to the crop yield. So the difference of grain yield was not observed properly between the stress treatments.

CONCLUSION

Most yield attributes of maize were significantly affected by different maize varieties but not

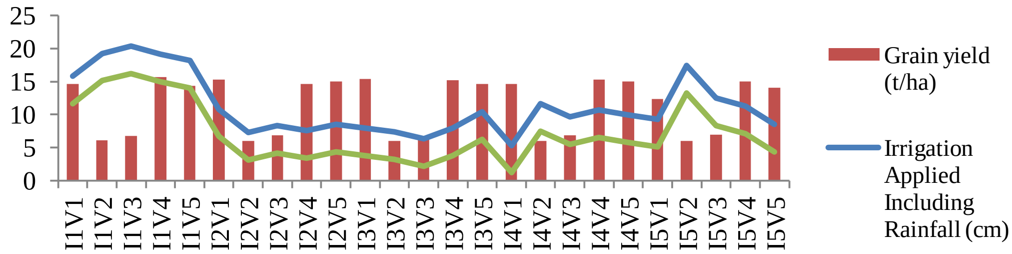

Figure 1. Component of water requirement and water productivity in different treatments.

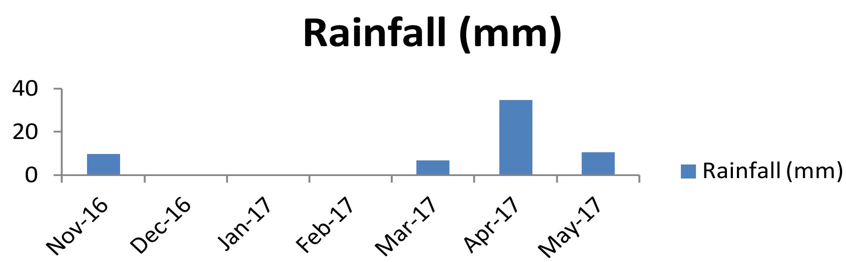

Figure 2. Rainfall pattern in Barisal district at Rabi Season.

significantly affected by irrigation treatments. The highest grain yield was 11.87 t ha^{-1} in I_1 (Full irrigation at initial, vegetative stage, silking and grain filling stage (20-25 DAS and 50-60 DAS, 75-80 DAS and 110-120 DAS) and the lowest was 11.02 t ha^{-1} in I_5 (50% irrigation at initial, vegetative stage, silking, and grain filling stage (20-25 DAS and 50-60 DAS,75-80 DAS and 110-120 DAS) NK-40 (V_4) produced the highest grain yield of 15.02 t ha^{-1} and BHM−5 (V_2) produced the lowest of 5.99 t ha^{-1}. These yields were however different. The water productivity/water use efficiency was the highest (3.63 kg/m^3), was obtained at I_3 and the lowest (1.60 kg/m^3) was obtained at I_1 in irrigation treatments.

REFERENCES

Abrecht DG, Carberry PS (1993). The influence of water deficit prior to tassel initiation on maize growth, development and yield. Field Crop Res. 31(1-2):55-69.

Ahmed F (1994). Maize Production Technology (in Bengali). Published by International Fertilizer Development Center, Consultant of the Ministry of Agriculture., Bangladesh pp. 13-15.

Bandyopadhyay PK, Mallik S (1996). Irrigation requirement of winter maize under shallow water table condition in Damodar Valley irrigation command area. J. Indian Soc. Soil Sci. 44(4):616-620.

Barrett JWH, Skogerboe GV (1978). Effect of irrigation regime on maize yields. J. Irrig. Drain. Div. 104:179-194.

BARI (Bangladesh Agricultural Research Institute) (2005−2006). Maize and Barley Improvement and Development of Hybrid Maize Res. Project in Bangladesh, BARI, Joydebpur, Gazipur-1701, August, (2006):86-93.

BBS (Bangladesh Bureau of Statistics). (2015). Yearbook of Agricultural statistics, Statistical Division, Ministry of Planning, Govt. of the People's Republic of Bangladesh (27):91-92.

Bharati A, Vadivelu KK, Umarani R (1997). Effect of irrigation management and nitrogen fertilization on seed yield, recovery and sowing quality of maize. Madras Agric. J. 84(1):33-36.

Bryant KJ, Benson VW, Kiniry JR, Williams JR, Lacewe lIRD (1992). Simulating corn yield response to irrigation timings: validation of the epic model. J. Prod. Agric. 5:237-242.

Chowdhury MK, Islam MA (1993). Production and uses of maize (in Bengali). Pub.by On Farm Res. Div. Bangladesh Agric. Res. Inst., Jaydebpur, Gazipur, Bangladesh. pp. 1-189.

Claassen MM, Shaw RH (1970). Water deficit effects on corn. II. Grain components. Agron. J. 62:652-655.

Cosculleula F, Faci JM (1992). Determination of the maize (*Zea mays* L.) yield function in respect of water using a line source sprinkler. Investigation Agraria, Production Protection Vegetables.7(2):169-194.

Craciun I, Craclum M (1994). Irrigated maize response under limited water supply. Romanian Agric. Res. 1:57−61.

Dai JY, Gu WL, Shen XY, Qi H, Zheng B, Cai SF (1990). Effect of drought on the development and yield of maize at different growth stages. J. Shenyang Agric. Univ. 21(3):181-185.

Denmead OT, Shaw RH (1960). The effects of soil moisture stress at different stages of growth on the development and yield of corn. Agron. J. 52:272-274.

Doorenbos J, Kassam AH (1979). Yield response to water. FAO Irrigation and Drainage Paper no. 33, FAO, Rome, Italy**,** 193.

Downey LA (1971). Effect of gypsum and drought stress on maize (*Zea mays* L.). I. Growth, light absorption and yield. Agron. J. 63:569-572.

Efferson S (1982). The yield–water relation and its utilization in practice. Resteniev "Dni" Nauki. 32(5):55-57.

Follett RF, Benz LC, Doering EJ, Reichman GA (1978). Yield response of corn to irrigation on sandy soils. Agron. J. 70(5):823-828.

Hanks RJ (1974). Model for predicting plant yield as influenced by water use. Agron. J. 66:660-664.

Hossain MS (2009). Effect of deficit irrigation on yield and water productivity of maize. M.S Thesis (Agric. Eng.) Department of Irrigation and Water Management. pp. 26-38.

Huang GH, Feng SY, Zhan WH, Wang G, Ziu ZG, Wu HQ (1999). Coupling effects of water and fertilizer on maize yield with drip irrigation. J. China Agric. Univ. 4(6):48-52.

Jama AO, Ottman MJ (1993). Timing of the first irrigation in corn and water stress conditioning. Agron. J. 85:1159-1164.

Joarder SK, Johnson RR, Boyer JS (1978). Dry matter production and translocation in maize subjected to drought during grain fill. Agron. J. 70:678-682.

Klocke NL, Schneekloth JP, Melvin S, Clark R, Payero JO (2004). Field scale limited irrigation scenarios for water policy strategies.

Appl. Eng. Agric. 20:623-631.
Kristov I (1995). Yield response to soil moisture level changes during individual stages of maize development. Pochvoznanie Agrokhimiya Khologiya. 30:74-75.
Landi DL, Patil SM, Jiotode DJ, Darangeg SO (1995). Effect of irrigation levels and row spacing on yield of rabi maize (*Zea mays* L.). J. Soil Grops. 8:95-97.
Lanza F, Rizzo V, Scarascia MEV, Bari DI, Losavio N (1980). Grain maize in the southern Italy: Effects of irrigation. Annali dell" Inst. Sperimentale Agron.11:167-179.
Lyle WM, Bordovsky JP (1995). Low energy precision application (LEPA) corn irrigation with limited water supplies. ASAE.38(2):455-462.
Pandey RK, Maranville JW, Chetina MM (2000). Deficit irrigation and nitrogen effects on maize production. J. Agric. Water Manag. 64(1):15-27.
Petrunin VM (1966). The effect of irrigation on the grain quality and yields of maize. Field Crop Abst. 20(1):34-38.
Prasad TN, Prasad UK (1989). Effect of irrigation pattern of sowing and intercrop on the growth, yield and water use efficiency of winter maize. Ann. Agric. Res. 10(2):139-144.
Silva DDDA, Loureiroo BT, Bernado S, Galvao JD (1992). Effects of water levels and nitrogen rates on line sprinkler irrigated maize. Revista Ceres. 39(222):91-104.
Sridhar V, Singh RA (1989). Effect of irrigation levels on growth of rabi maize. Annals Plant Physiol. 3(2):212-212.
Thakur C (1980). Scientific Crop Production. Food Crops. Metropolian Book Co., New Delhi. 1:145-185.

http://www.sciencewebpublishing.net/jacr