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Regulated deficit irrigation scheduling for maize cultivation in North-western areas of Bangladesh

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Abstract

Drought is one of the major issues for agricultural production in north western part of Bangladesh. A field experiment was conducted at Agronomy Field Laboratory, Department of Agronomy and Agricultural Extension, University of Rajshahi, during the period from November 2015 to March 2016 to examine the effect of deficit irrigation regimes on growth, yield contributing characters and yield of Maize. Irrigation amounts were calculated based onpan evaporation (Epan). Five irrigation treatments *viz.* T_1 (irrigation equivalent to 0.5 Epan), T_2 (0.75 Epan), T_3 (1.0 Epan) and T_4 (1.25 Epan) was compared with standard irrigation or farmers practice as control (T_0). The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Considering crop growth, yield components and yield of maize it was found that and most of the cases highest performance was noted for control treatment which reduced gradually with the reduction of irrigation amount. The highest (5.62 t ha^{-1}) grain yield was observed in T_0 which was statistically identical to the treatment T_4 (5.42 t ha^{-1}) while it reduced significantly by 9.85%, 9.14%, and 12.5%for irrigation treatment T_3,T_2 and T_1 respectively. Considering water use efficiency (WUE), the value was lowest with control. Based on our result, it can be suggested that irrigation amount equivalent to 1.25 Epan can produce nearly same amount of maize yield with 14.42 % less water and increase WUE by 9.09%. Irrigation amount equivalent to 1.25 Epan would be the best practice for maize cultivation in drought affected North-western areas of Bangladesh.

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Introduction

Maize (*Zea mays* L.) is the world's third most important cereal crop after wheat and rice grown primarily for grain and secondly for fodder (Nelson, 2005). The crop has tremendous potential as one of the main sources of food for the rapidly increasing population. Maize is also an important food and feed crop being recognized relatively recently in Bangladesh and has gained an increasingly important attention by the government (Hasan *et al.*, 2008).Maize is a moderate water demanding crop in all stages of its physiological development and can achieve high yields when water and nutrients are not limiting (Traore *et al.*, 2000).However, irrigated agriculture is under pressure to cut down the amount of water use for crop production and at the same time to produce more crops with less water. As a step towards achieving the objective of more crops per drop of water, there is a need for irrigators to begin to adopt the use of techniques and practices that regulate water application to crops and minimize waste. Water shortage is one of the great challenges for agricultural production, particularly in the countries or regions with limited water and land resources. Bangladesh is a small developing country with rising population where water requirement has continued to increase in all sectors. North-Western part of Bangladesh is received lowest rainfall and now affected by water scarcity problems in agriculture and secured livelihood.

For the last few decades, Bangladesh is facing water related difficulties like river bed siltation, low water flow and a big dam made by neighboring country India. On the other hand Barind Tract has a different geographic character than other parts of Bangladesh. Its soil formation is also different. This northern part is 37 meter above the sea level. People in this area used to cultivate rice once a year, but now produce various crops round the year including maize. Recently, farmers are switching to maize cultivation in increasing numbers because of better prices of the cereal and high demand by feed and flour mills. Therefore, improved irrigation techniques are needed to increase the water use efficiency of maize.

Under conditions of scarce water supply and drought, deficit irrigation can lead to greater economic gain by maximizing water use efficiency. The term water use efficiency is used to describe the relation between crop yield and water use (Owesis and Zhang, 1999). The optimum scheduling of irrigation for specified level of deficit water supply is determined by evaluating the effect of missed irrigation on crop yield. Identifying growth stages of particular crops under local conditions of climate and soil fertility allows irrigation scheduling for maximum crop yield and most efficient use of scarce water resource. Irrigation scheduling is one of the important issues to maximize irrigation efficiencies by applying the exact amount of water needed to replenish the soil moisture to the desired level Hefner and Tracy, 1995. Nevertheless, in recent years there has been a wide range of proposed novel approaches to irrigation scheduling which have not yet been widely adopted; many of these are based on sensing the plant response to water deficits rather than sensing the soil moisture status directly. Deficit (or regulated deficit) irrigation is one of the most useful way for maximizing water use efficiency by producing higher yields per unit of irrigation water applied (Tekwa and Bwade, 2011, English MJ, 1990). Technique of pan evaporation for irrigation scheduling is extensively used by many researchers (Kang *et al.* 2010; Manal *et al.* 2007; Tariq and Usman2009; Kirda *et al.* 2005; Kumar and Khepar, 1980). Pan evaporation is a measurement that combines or integrates the effects of several climate elements: temperature, humidity, rain fall, drought dispersion, solar radiation, and wind. Evaporation is greatest on hot, windy, dry, sunny days; and is greatly reduced when clouds block the sun and when air is cool, calm, and humid. Pan evaporation measurements enable farmers and ranchers to understand how much water their crops will need.

Deficit irrigation scheduling of a crop using pan evaporation method has not been tested in Bangladesh. Therefore, this method might have greater potentials for increasing water use efficiency in maize and may play a revolutionary change in irrigation technology.

Therefore, objectives of the present research was to determine the irrigation water requirements and increase water use efficiency for maize cultivation in drought affected north-western parts of Bangladesh by pan-evaporation method.

Materials and methods

Plant materials and growth condition

The experiment was carried out at Agronomy Field Laboratory, Department of Agronomy and Agricultural Extension, University of Rajshahi, Rajshahi during the period from November 2015 to April 2016 to study on the effect of regulated deficit irrigation scheduling for maize cultivation in drought affected North-Western areas of Bangladesh. Maize variety ACI-3110, collected from ACI seed dealer was used in our experiment. Five irrigation treatments viz. T_1 (irrigation equivalent to 0.5 Epan), T_2 (irrigation equivalent to 0.75 Epan), T_3 (irrigation equivalent to 1.0 Epan) and T_4 (irrigation equivalent to 1.25 Epan) was compared with standard irrigation or farmers practice as control (T_0). The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The size of each unit plot was 5m×2m. To maintain proper moisture level in the plot according to treatments, 1.5 m gap within the plots and 2 m gap within the blocks were maintained (Fig.1) and each plot was irrigated separately. Except experimental treatments, other agronomic practices and managements were done as per standard manner.

Measurement of irrigation water requirement

Estimation of evaporation: It has been observed that there is a close relationship exists between the rate of water consumption by crops and the rate of evaporation from an evaporation pan. Standard pan evaporation meter was used for the measurement of pan evaporation (Fig. 2).

Calculation of irrigation water requirement

Irrigation water requirement was calculated on the basis of cumulative pan evaporation (CPE). The daily pan evaporation as measured from evaporation pan and rainfall from standard rain-gauge were measured. Pan evaporation was adjusted by using the following equation:

$$CPE = EV_p \times K_p$$

Where, EV_p= Pan evaporation and K_p= Pan co-efficient = 0.7 (Michael, 1985).

The desire amount of irrigation water was calculated by following relationships:

T1 = CPE × 0.50; T2 = CPE × 0.75 ; T3 = CPE × 1.0; T4 = CPE × 1.25

The calculated amount of water was applied by means of hose pipe from the sources. The outlet discharge was measured by volumetric method. The seasonal water was predicted by adding amount of applied irrigation water, the rainfall received during the season and soil moisture content.

$$WR = IW + \text{rainfall} \pm \text{Soil water contribution}$$

$$\text{Water productivity (WP)} = \frac{\text{Cropyield(t / ha)}}{\text{WR}}$$

WR = Water requirement.

Estimation of irrigation water

The irrigation water was applied to bring the soil moisture at field capacity within effective root zone depth. Soil moisture was determined before irrigation by digital moisture meter and gravimetric method. The normal depth of water to be applied was determined using the following equation:

$$d = \frac{Fc - Mci}{100} \times As \times D$$

Where, d = Depth of irrigation, mm; F_c = Field capacity of the soil, %; M_{ci} = Moisture content of the soil at the time of irrigation, %; As = Apparent specific gravity; D = Root zone depth, mm.

Soil water contribution

Soil moisture content at the time of sowing and harvesting were determined by gravimetric method to know the soil water contribution.

Gravimetric method for soil moisture calculation

Soil sample was collected from the field from several places which represents the whole field. It must be collected from 20 cm depth using Auger. Then in laboratory 17 experiment moisture content was determined using following equation. The soil was oven dried at 105°C for about 24 hours.

% moisture = $\{(W_2 – W_3) / (W_3-W_1)\} \times 100$

Where, W_1 = weight of can (gm); W_2 = weight of can + weight of soil sample (gm); W_3 = weight of can + weight of oven dry soil (gm).

Determination of effective rainfall

Effective rainfall is the rainfall that is available in the plant root zone, allows the plant to germinate or maintain its growth. In simple sense, effective rainfall means useful or utilizable rainfall (Michael, 1985). The term effective rainfall has been interpreted differently, not only by specialists in different field but also by different workers in the same field. From the point of view of the water requirement of crops, the Food and Agriculture Organization (FAO) of the United Nations (Dastane, 1985) has defined the annual or seasonal effective rainfall as that part of the total annual or seasonal rainfall, which is useful directly and/or indirectly for crop production at the site where it falls, but without pumping. According to Nakagawa (1975), rainfall becomes effective if the daily amount is > 1cm and < 8 cm. However, effective rainfall was estimated using the USDA Soil Conservation Methods given:

$P_{effective} = P_{total}(125 - 0.2\ P_{total})/125$....................(i) for $P_{total} < 250$ mm

$P_{effective} = (125 + 0.1\ P_{total})$ .... (ii) for $P_{total} > 250$ mm

Where, $P_{effective}$ = effective rainfall, mm; P_{total} = total rainfall, mm.

However, this effective rainfall is an approximation.

Effective R – rainfall using FAO method: Re = 0.8 R – 25 if R > 75 mm/month; Re = 0.6 R – 10 if R > 75 mm/month.

Determination of crop water requirement (WR)

The water requirement for maize was computed by adding the applied irrigation water, effective rainfall during the growing season and contribution of moisture from the soil. Mathematically, water requirement was calculated by the following relationship according to Michael, (1985) and this value was considered as traditional or farmers irrigation rate (T_0).

$$\mathrm{WR} = \mathrm{IR} + \mathrm{ER} + \sum_{i=1}^{n} \frac{MSi - Mhi}{100} AiDi$$

Where, WR = seasonal water requirement, cm; IR = total irrigation water applied, cm; ER = seasonal effective rainfall, cm; Msi = moisture content at sowing in the i^{th} layer of the soil, %;Mhi = moisture content at sowing in the h^{th} layer of the soil, %; Ai = bulk density of the i^{th} layer of the soil, g cm^{-3};Di = depth of the i^{th} layer of the soil within the root zone, cm and n = number of soil layers in the root zone.

Relative water content (RWC)

Relative water content (RWC) was measured on fully expanded leaf according to Schonfeld *et al.* (1988) thus:

RWC (%) = {(fresh weight – dry weight)/(turgid weight – dry weight)} × 100.

Soil moisture content (SMC)

Following formula was used to calculate soil moisture content:

$$\text{Soil Moisture content} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Dry weight}} \times 100$$

Crop growth, yield components and yield

Different growth parameters (Plant height, Leaf area) were measured on randomly selected tagged plants at 30, 60, 90, 120 and 140 days after sowing (days after sowing). Yield components and yield was measured after harvest.

Grain yield was determined by harvesting the crops grown in two square meter area at the center of each plot. Biological yield was calculated by summation of grain yield and st over yield for each unit plot and then converted into t ha^{-1}.

Biological yield= Grain yield + Stover yield.

Harvest index (%) was calculated with the following formula:

Harvest index (%) = Grain yield/Biological yield × 100.

Statistical analysis

The collected data were analyzed statistically following the analysis of variance (ANOVA) technique and the mean differences were adjudged with Duncan's Multiple Range Test (DMRT) using the statistical computer package program, STATVIEW.

Results

Plant height

No significant effect was observed in plant height within different irrigation treatments at early growth stages (30 or 60 days after sowing) but it differed significantly at 90, 120 and 140 days after sowing (Table 1). At 90 days after sowing, plant height was found highest (172.69cm) in T_o or control irrigation which reduced slightly by 2.4, 4.0 and 6.7% for irrigation at T_4 (1.25 Epan), T_3 (1.0 Epan) and T_2 (0.75 Epan), respectively but significantly by 8.9% for lowest irrigation treatment or T_1 (0.5Epan).

At 120 days after sowing, plants were found tallest (214.28cm) in T_o or control irrigation treatment which reduced slightly in T_4but significantly by 4.5%,6.7% and 8.5% at T_3,T_2 andT_1 respectively (Table 1).

Table 1. Effect of deficit irrigation on plant height of maize

Treatment irrigation	Days after sowing				
	30	60	90	120	140
To	62.42	104.84	172.69a	214.28a	240.25a
T1	64.92	115.12	157.26b	195.94c	218.83c
T2	62.93	110.51	161.01ab	199.79bc	225.50b
T3	63.53	110.67	165.76ab	204.49b	231.00b
T4	64.74	111.62	168.43ab	212.60a	240.08a
LS	NS	NS	*	*	*
CV (%)	4.59	5.58	4.82	3.96	3.94

In a column, figures bearing dissimilar letter (s) differed significantly as per DMRT.LS =level of significance; * = 5% level of significance; NS = Non-Significant; CV= Co-efficient of variation, T_1= irrigation equivalent to 0.5 Epan; T_2 = irrigation equivalent to 0.75 Epan; T_3 = irrigation equivalent to 1.0Epan; T_4 = irrigation equivalent to 1.25 Epan; T_o = standard irrigation.

At 140 days after sowing, plant height was found highest (240.25cm) in T_o or control irrigation treatment which declined slightly for $T_4$and significantly by3.8%, 6.13% and 8.9% for irrigation at T_3, T_2 and T_1, respectively (Table 1).

This result indicates that irrigation water equivalent to 1.25 E pan might be sufficient for maize growth in this area. Maize is a moderately drought resistance crop (Islam *et al.,* 2011), although crop growth reduced slightly for less drought condition but severely under high drought. Ayotamuno *et al.* (2007) also reported that slight reduction of water had no remarkable effect on plant height but it makes significant difference if more water reductionis occurred.

Leaf area index (LAI)

No significant difference was found in leaf area index at 30 days after sowing. At 60 days after sowing, significant difference in leaf area index was observed within different irrigation treatments. The highest leaf area index (5.21) was observed in T_4 which was statistically similar (5.08 and 5.05) to T_o or control and T_3. The leaf area index significantly reduced by 9.42% and 12.21%under irrigation treatment T_2 and T_1respectively compared with control (Table 2). At 90 days after sowing, significant difference in leaf area index was also observed following different irrigation treatments. The highest leaf area index (4.48) was observed in the treatment T_4 which was almost similar with T_o or control.

The leaf area index significantly reduced by 5.95%, 11.9 % and 12%in the treatment T_3, T_2 and T_1respectively (Table 2). During our observation (30 and 60 and 90 days after sowing), it was found that maize crop performs best considering LAI under irrigation equivalent to 1.25 Epan. This highest value was similar to T_0 or control, even in irrigation equivalent to 1.0 Epan (T_3), less LAI reduction was observed. This result indicates that maize plant can tolerate medium drought and lack of proper irrigation instruction, farmers might be applying more water than crop need. During our observation LAI was found maximum at 60 days after sowing, which is also supported by Patel *et al.* (2006).

Table 2. Effect of deficit irrigation on leaf area index (LAI), total dry matter production (TDM) and crop growth rate (CGR) of maize

Irrigation	Leaf area index (LAI)			Total dry matter (TDM) gm^{-2}			Crop growth rate (CGR)gm^{-2} day^{-1}	
	30days after sowing	60 days after sowing	90 days after sowing	30 days after sowing	60 days after sowing	90 days after sowing	30-60 days after sowing	60-90 days after sowing
T_0	1.06	5.08a	4.41a	44.36	150.25a	461.12a	3.53a	10.36a
T_1	1.13	4.45b	3.88c	40.56	124.35c	368.25c	2.79c	8.13c
T_2	1.07	4.60b	3.89c	41.13	130.76bc	405.32b	2.98bc	9.15bc
T_3	1.14	5.05a	4.15b	41.57	137.07b	437.62a	3.18ab	10.01ab
T_4	1.11	5.21a	4.48a	43.90	149.07a	463.59a	3.50a	10.48a
CV (%)	6.44	7.09	6.51	7.70	8.10	9.25	10.80	10.72

In a column, figures bearing similar letter (s) or without letter are identical and those having dissimilar letter (s) differed significantly as per DMRT. LS= Level of significance, * = 5% level of significance, NS = Non-Significant; CV= Co-efficient of variation; T_1= irrigation equivalent to 0.5 Epan; T_2 = irrigation equivalent to 0.75 Epan; T_3 = irrigation equivalent to 1.0Epan; T_4 = irrigation equivalent to 1.25 Epan; T_0 = standard irrigation.

Total dry matter (TDM) production

Total dry matter (TDM) production differed significantly within different irrigation treatments at 60 and 90days after sowing (Table 2). At 30 days after sowing, highest (44.36gm^{-2}) TDM was observed in the treatment T_0 or control and lowest (40.56gm^{-2}) was found in treatment T_1. At 60 days after sowing, highest (150.25 gm^{-2}) TDM was found in control treatment (T_0) which reduced slightly (149.07 gm^2) in T_4but reduced significantly by 8.77%, 12.96 % and 17.23% for T_3, T_2 and T_1respectively. At 90 days after sowing, highest (463.59 gm^{-2}) TDM was observed in T_4 (1.25Epan) which was very close to T_0 or control (461.12gm^2). The TDM reduced slightly in the treatment T_3 significantly by 12.10% and 20.13% in the treatment T_2 and T_1 respectively. Similar result was reported by Abbas *et al.* (2005) and Patel *et al.* (2006), where a reduction in TDM was reported under less irrigation treatment.

Table 3. Effect of deficit irrigation on relative water content (RWC) in maize leaves.

Irrigation	RWC (%)	
	60 days after sowing	90 days after sowing
T_0	88.58a	86.22a
T_1	74.99c	76.80c
T_2	81.68b	79.98bc
T_3	81.07bc	82.19ab
T_4	87.06ab	85.63a
CV (%)	6.97	5.04

In a column, figures bearing similar letter (s) or without letter are identical and those having dissimilar letter (s) differed significantly (0.05) as per DMRT. RWC = Relative Water Contents in leaves; CV= Co-efficient of variation;T_1= irrigation equivalent to 0.5 Epan; T_2 = irrigation equivalent to 0.75 Epan; T_3 = irrigation equivalent to 1.0Epan; T_4 = irrigation equivalent to 1.25 Epan; T_0 = standard irrigation.

Crop growth rate (CGR)

Considering crop growth rate (CGR), the values were higher both in T_0 and T_4 at all observations (30-60 and 60-90 days after sowing). At 30-60 days after sowing, highest (3.53 gm^{-2} day^{-1}) crop growth rate was observed in T_0 or control treatment which was nearly similar (3.50$gm^{-2}day^{-1}$) to the treatment T_4 (1.25Epan).

Table 4. Effect of deficit irrigation on yield components and yield of maize.

Irrigation	Cob length (cm)	Number of rows cob^{-1}	Number of grains cob^{-1}	1000-grain weight (g)	Grain yield (t ha^{-1})	Stover yield(t ha^{-1})	Biological yield	Harvest Index (%)
T_0	19.75a	16.19a	450.31a	338.36a	5.6a	6.79	12.41	45.26ab
T_1	17.61c	12.98c	336.91c	317.06b	4.91c	6.77	1169	42.02d
T_2	18.22bc	14.22b	370.56bc	325.70ab	5.1b	6.52	11.63	43.91bc
T_3	19.31ab	15.14ab	406.92b	330.10ab	5.06b	6.58	11.65	43.50cd
T_4	19.95a	15.60a	455.06a	337.43a	5.42ab	6.44	11.86	45.71a
LS	*	*	*	*	*	NS	NS	*
CV (%)	6.03	8.53	12.45	3.48	6.72	4.21	4.47	3.54

In a column, figures bearing similar letter (s) or without letter are identical and those having dissimilar letter (s) differed significantly as per DMRT. * = 5% level of significance, NS = Non-Significant, CV= Co-efficient of variation; T_1= irrigation equivalent to 0.5 Epan; T_2 = irrigation equivalent to 0.75 Epan; T_3 = irrigation equivalent to 1.0Epan; T_4 = irrigation equivalent to 1.25 Epan; T_0 = standard irrigation.

The crop growth rate decreased slightly in T_3 but significantly by 15.35% and 20.87% in the treatment T_2 and T_1 respectively compared with control. At 60-90 days after sowing, highest (10.48 gm^{-2} day^{-1}) crop growth rate was observed in T_4 which was statistically similar with the treatment T_0 or control treatment (10.36gm^{-2} day^{-1}).

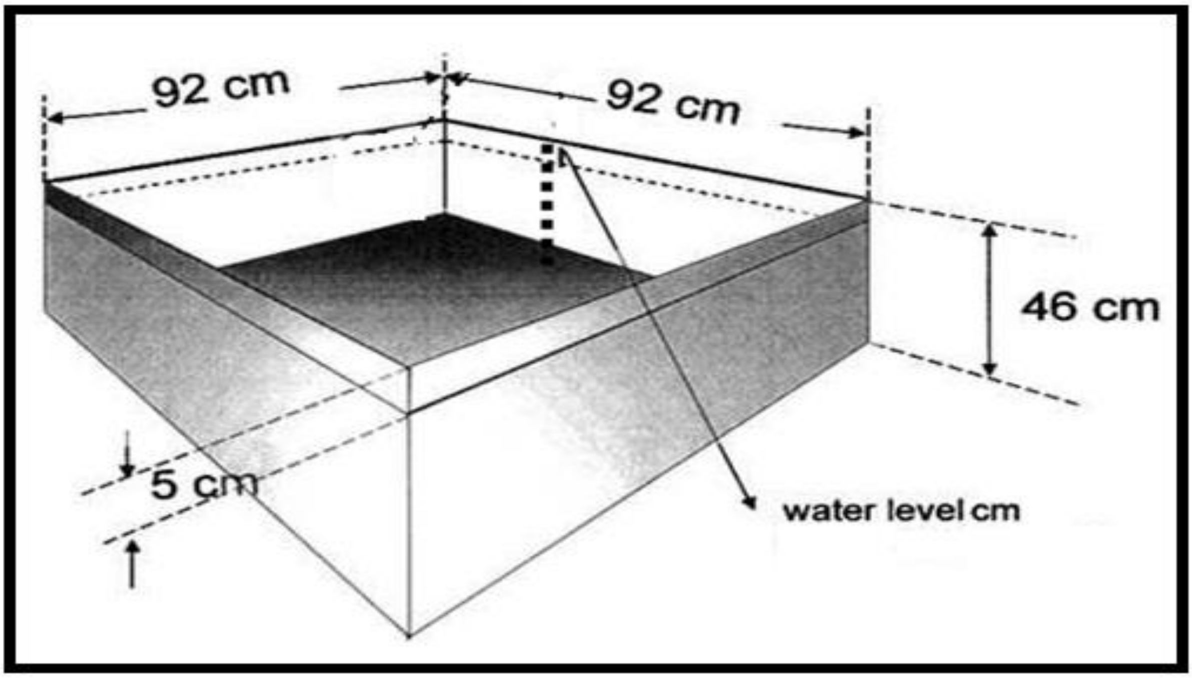

Fig. 1. Schematic diagram of evaporative pan.

The crop growth rate was slightly decreased in T_3 (1.0 Epan) but it significantly by 20.87% and 11.67% in T_2 (0.75 Epan) and T_1 (0.5 Epan) respectively compared with T_0 or control. Similar increased in CGR with increasing irrigation rate was also reported by several authors (Tekwa and Bwade, 2011; Manal *et al.*, 2007; Tariq, 2009; Patel *et al.,* 2006). Kristov (1995) found that water deficiency during the extremely critical growth stages such as tasseling, milk ripeness and maturity caused severe reduction in crop growth, yield and water use efficiency.

Relative water contents (RWC)

Significant difference in relative water contents (RWC) in maize leaf was observed during our observation (At 60 and 90 days after sowing) (Table 3).

At 60 days after sowing highest (88.58) relative water content was observed in T_0 or control irrigation treatment which was similar (87.06) to $T_4$and reduced significantly by 8.47%, 7.79% and15.34% in T_3, T_2 and T_1 respectively. At 90 days after sowing, highest (86.22) relative water content was also observed in T_0 or control which was nearly similar (85.63) with T_4.

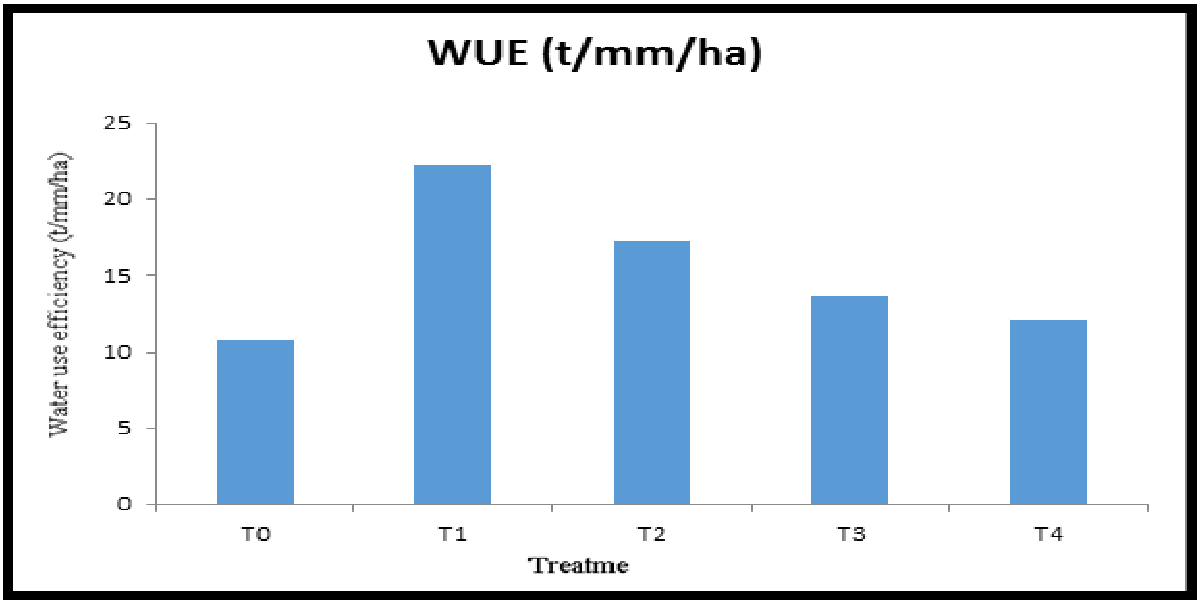

Fig. 2. Water use efficiency (WUE) of maize under deficit irrigation.

T_1= irrigation equivalent to 0.5 Epan; T_2 = irrigation equivalent to 0.75 Epan; T_3 = irrigation equivalent to 1.0Epan; T_4 = irrigation equivalent to 1.25 Epan; T_0 = standard irrigation.

The relative water content of leaf reduced slightly in T_3 but significantly by 7.23% and 10.91% in T_2 and T_1 respectively compared with T_0 or control. Effect of water stress on RWC (relative water content) has been investigated by several researchers. Alexieva *et al.* (2001) stated that relative water content is the main factor which caused growth reduction in response. During our observation, RWC was found to be reduced with reduction of irrigational water and also the effect correlated with the growth responses of maize plants.

Cob length

In cob length, remarkable difference was observed within different irrigation treatments (Table 4). Cob length was found highest (19.95cm) in the treatment T_4 (1.25 Epan), that was statistically identical (19.75 cm) with treatment T_0 or control.

The cob length reduced slightly for irrigation treatment T_3 (1.0 Epan) whereas it reduced significantly by7.7 % and10.8% for irrigation at T_2 (0.75 Epan) and T_1 (0.5 Epan) respectively compared to the treatment T_0 or control (Table 3). The results are in conformity with the findings of Hossain (2001).

Number of grains cob^{-1}

There was found remarkable effect of different irrigation treatment on number of rows cob^{-1} (Table 4). The highest (16.19) number of rows cob^{-1} was recorded in T_0 or control treatment which was nearly similar with the treatment T_4 (irrigation equivalent to 1.25 Epan). The number of rows cob^{-1} reduced slightly by 6.4% in the treatment T_3 (irrigation equivalent to 1.0Epan) whereas, it reduced significantly in the treatment T_2 (irrigation equivalent to 0.75 Epan) and T_1 (irrigation equivalent to 0.5 Epan) by 12.13% and 19.82% respectively compared to treatment T_0.

In addition to row number, number of grains was also counted and significant difference found in number of grains cob^{-1} due to different irrigation treatment (Table 4). The highest (455.06) number of grains cob^{-1} was observed in T_4 which was statistically identical to T_0 or control (450.31). The number of grains cob^{-1} reduced significantly by 9.63%, 17.70% and 25.25% in T_3, $T_2$and T_1 compared with T_0 or control. The findings resemble with the result obtained by Rajendar *et al.* (1996).

No significant difference found in 1000-grain weight with in the treatment except treatment T_1 (0.5 Epan). The highest (338.36 gm) value of 1000-grains weight was recorded in T_0or control treatment which was statistically identical (337.42gm) with T_4. The value of 1000-grains weight was slightly decreased in the treatment T_3 (1.0Epan) and T_2 (0.75 Epan) but it was significantly decreased by 6.29% in T_1 (0.5 Epan) (Table 4).

Grain yield

Different irrigation treatments showed significant effect in grain yield. The highest (5.62 t ha^{-1}) grain yield was observed in T_0 or control irrigation treatment which was statistically identical to T_4 (Table 4). The grain yield reduced significantly by 9.85%, 9.14%, and 12.5% for irrigation treatment T_3, T_2 and T_1 respectively compared with control or standard irrigation.

The result agreed with the findings of Patel *et al.* (2006), they reported that limited water supply in the growing season reduces maize yield. Kirda *et al.* (2005) also observed the reduction of grain yield under deficit irrigation treatments compared to full irrigation practice.

Stover yield

No significant effect was found in Stover yield within different irrigation treatments (Table 4). The highest Stover yield (6.79 t ha^{-1}) was found in the treatment T_0 or control treatment and lowest (6.44t ha^{-1}) was observed in treatment T_4 (1.25 Epan).

Biological yield

In term of biological yield, no remarkable effect found in biological yield due to different irrigation treatments (Table 4).

The highest (12.41ha^{-1}) biological yield was obtained in the treatment T_0 or control treatment and lowest (11.63ha^{-1}) biological yield was observed at treatment T_2 (0.75 Epan).

Harvest index

Different irrigation treatment had a significant influence on harvest index. The highest (45.71) harvest index was obtained in the treatment T_4 (1.25 Epan) which was nearly similar with the treatment T_0 or control treatment. The harvest index reduced slightly by 2.98% in the treatment T_2 (0.75Epan) and significantly decreased by 3.89% and 7.15%. In the treatment T_3 (1.0Epan) and T_1 (0.5Epan) respectively compared to treatment T_0 or control (Table 4).

Water use efficiency (WUE)

The maximum average water use efficiency (0.22) was obtained in T_1 and the minimum (0.11) was observed in T_0 or control irrigation treatment (Fig. 2). The water use efficiency increased slightly (9.09%) in T_4 (1.25 Epan) and significantly by 27.02%, 54.55% and 100% in T_3, $T_2$and T_1respectively compared to control (T_0).

Conclusion

From the experimental results we found that deficit irrigation had a significant effect on growth and yield contributing characters of maize. In most of the parameters eg. plant height, leaf area index (LAI), total dry matter (TDM), crop growth rate (CGR), relative water content of leaf (RWC), soil moisture content (SMC), cob length, number of rows cob^{-1}, number of grains per cob^{-1}, grain yield, harvest index showed highest result in the treatment T_0 or control treatment (Farmer's practice) and lowest result was observed in the treatment T_1 (irrigation equivalent to 0.5 Epan). As lower amount of water was applied in the treatment T_1 (0.5 Epan) most of the parameters became lower in the treatment T_1(0.5 Epan).Considering most of the yield contributing characters and yield performance of maize, it was observed that irrigation equivalent to 1.25 Epan can perform same as conventional irrigation amount.

Therefore, our recommendation also support 1.25Epan irrigation as it can produce nearly same amount of maize yield with 14.42% less water and increase WUE by 9.09%. So that, irrigation amount given at treatment T_4 i.e. equivalent to 1.25 Epan would be the best practice for maize cultivation in drought affected North-Western areas of Bangladesh.

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