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Growth and Physiological Responses of Maize to Deficit Irrigation

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Abstract

A field experiment was conducted at the Agronomy Field Laboratory, Department of Agronomy and Agricultural Extension, University of Rajshahi, from 2 December 2020 to 20 April 2021 to find out the effect of deficit irrigation schedule for maize measured based on panevaporation. The field experiment was set up using a split-plot experimental design including two maize varieties (Syngenta NH-7720 & Ishpahani Diamond) and four irrigation regimes viz. T_1 (irrigation based on125% of pan evaporation), T_2 (irrigation based on 100% of pan evaporation), T_3 (irrigation based on 75% of pan evaporation) and T_4 (irrigation based on 50% of pan evaporation). Considering different phyto-physiological responses and yield of maize, it was found that different irrigation regimes differed significantly. In most cases, the highest performance was noted for maximum irrigation treatment (T_1), which reduced gradually with the reduction of irrigation amount. The highest grain yield (13.82 t ha^{-1}) was observed in the treatment $T_{1,}$ which was statistically identical to the T_2 (12.02 t ha^{-1}). However, grain yield reduced significantly by 25.50% and 32.05% for T_3 and $T_{4,}$ respectively, but water use efficiency (WUE) was higher in T_4 (2.64 kg ha^{-1} cm^{-1}) and the lower (2.43 kg ha^{-1} cm^{-1}) in T_3. Although the maize varieties differ significantly, overall performance was good in V_2 (Ishpahani Diamond). The highest grain yield (13.897 t ha^{-1}) was obtained from the combination of V_2T_1, which was more or less similar to the combination of V_1T_2. Based on my result, it seemed that an irrigation amount equivalent to 100% of pan evaporation could produce nearly the same amount of maize yield with 25 % less irrigational water compared with T_1. So, it is suggested that an amount of irrigation equal to 100% of pan evaporation would be the best way to grow maize. This would give a good grain yield and allow less water to be used for irrigation, which is very helpful in the north-western parts of Bangladesh that are affected by drought.

Keywords: Panevaporation, Irrigation schedule and phytophysiological response.

Introduction

Innovative agricultural management techniques are required to meet future demand for food, feed, and fiber products while limiting detrimental effects on air, soil, and water quality. After rice and wheat, maize (*Zea mays* L.) is the third-most significant cereal crop farmed for grain and fodder (Nelson, 2005). It produces around 25% of the world's cereal production and 18% of the world's cereal acreage (Haque, 2010). This is mostly a result of the enormous demand for maize, especially in the chicken feed business. The demand for maize is anticipated to rise in the foreseeable future gradually. The production area and yield of maize are increasing day by day in Bangladesh (BARI, 2011). Factors like technological change, higher input usage, better pest management etc. have contributed to the increase in maize production (Gulati and Dixon, 2008).

Green cobs, roasted cobs, popped grains, and flour made from maize can all be eaten straight up (Ahmed, 2015). Its grain has a high nutritional value, with a starch content of 66.20 %, a protein content of 11.10 %, an oil content of 7.12 %, and mineral content of 1.50%. The pure 100g grain also contains 90g carotene, 1.80mg niacin, 0.90mg thiamine, and 0.10mg riboflavin (Chowdhury and Islam, 1993). Therefore, it would probably be possible to reduce food shortage if the peoples of Bangladesh include more maize in their diet. However, it is a crop with a higher yield and lower cost than wheat and rice. Therefore, a thorough plan is required to popularize and preserve the crop.

Water is vital for agriculture as it controls all the physiological processes during plant growth. So every crop needs to access adequate water during its different growth stages (Payero *et al.,* 2010). But, on the other hand, excess water may result in reduced crop yield, which is undesirable for agriculture (Evans *et al*., 2008). Therefore, irrigation is generally applied when adequate rainfall is unavailable to meet the total water requirement for potential crop production. But, in many cases, irrigators tend to over-irrigate when water and other irrigation equipment are adequate, believing it will increase crop yields. Still, unfortunately, instead of increasing crop production, it often results in plant disease, nutrient leaching and reduced pesticide effectiveness (Misra and pant, 1990). Moreover, wastage of water and energy increases production costs, ultimately minimizing benefits (Zhang and Oweis, 1999). Hence, proper irrigation scheduling is required for every crop to prevent the over-application of water in the field by determining the exact amount and timing for application (Jones, 2004).

The north-western part of Bangladesh receives the lowest rainfall and is now affected by water scarcity problems in agriculture and secure livelihood. For the last few decades, Bangladesh has faced water-related difficulties like river bed siltation, low water flow, and a big dam by neighbouring India. However, this area of Bangladesh is 37 meters above sea level. People in this region used to grow rice once a year, but now they grow various crops all year, including maize. Due to higher cereal prices and increased demand from feed and flour mills, farmers are transitioning to maize farming in greater numbers. Therefore, better irrigation methods are required to boost 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 correlation between crop productivity and water use is referred to as water use efficiency (Zhang and Owesis, 1998). Water use efficiency can be altered by raising the plant's water consumption or output. In this situation, deficit irrigation minimizes negative yield while reducing water use. However, due to the fact that drought tolerance varies greatly by growth stage, species, and cultivars, this strategy necessitates a detailed understanding of crop responsiveness to water. Therefore, the best irrigation scheduling for a given level of deficit water supply is established by examining the impact of missing irrigation on crop productivity. When irrigation is scheduled for optimum crop yield and the most effective use of limited water resources, crop growth stages under the local climate and soil fertility conditions can be identified. Irrigation scheduling is one of the crucial issues to maximize irrigation efficiencies by applying the exact amount of water needed to replenish the soil moisture to the desired level. This requires knowledge of crop water requirements and yield responses to water, the constraints specific to each irrigation method, the limitations relative to the irrigation water supply system and the financial and economic implications of the irrigation practice.

However, a variety of novel irrigation scheduling techniques have been presented in recent years that have not yet been generally implemented; many of these are based on sensing the plant response to water deficiencies rather than the actual state of the soil's moisture. Deficit (or regulated deficit) irrigation is one of the most useful ways to maximize water use efficiency by producing higher yields per unit of irrigation water applied (Tekwa and Bwade, 2011). Although yield may be reduced under deficit irrigation, the reduction in irrigation costs and the opportunity costs of water may more than compensate for the lower yield (Ali *et al*., 2007).

Many scholars, like Manal *et al*. (2007), Tariq (2009), Kang and Zhang (2011), etc., utilize the pan evaporation technique for irrigation scheduling. The impacts of numerous climate factors, including temperature, humidity, rain fall, drought dispersion, sun radiation, and wind, are combined or integrated into the assessment of pan evaporation. The present study aimed to investigate different phyto-physiological responses and yield of maize subjected to deficit irrigation

Materials and Methods

Plant materials and growth condition

The current study was conducted from December 2020 to April 2021 at the Agronomy Field Laboratory, Department of Agronomy and Agricultural Extension, University of Rajshahi, Rajshahi. Geographically the experimental field is located at 24°22'36" N latitude and 88°38'27"E longitude at an average altitude of 71 ft above sea level. The trial area's land was level, well-drained, and above flood stage (Medium high land). The soil had a pH of 8.4 and a sandy loam texture. The air temperature ranged from 6.1to 39.7 °C, and the mean temperature was 21.90 °C. Total rainfall was received 213mm on 12 rainy days. The maximum humidity was 92.15 %, and the minimum humidity was 27%.

The experiment consists of two maize varieties, i.e. V_1 (SYNGENTA NH-7720 maize) and V_2 (ISHPAHANI DIAMOND maize) and four irrigation frequencies, i.e. T_1= irrigation based on 125% of pan evaporation, T_2= irrigation based on 100% of pan evaporation, T_3 = irrigation based on 75% of pan evaporation and T_4= irrigation based on 50% of pan evaporation. The experiment was laid out in a split-plot experimental design with three replications, keeping the four irrigation frequencies in the main plots and two maize varieties in subplots. The size of each unit plot was 20 m^2 (5m×4m).

Calculation of irrigation water requirement

Irrigation water requirement was calculated based on cumulative pan evaporation (CPE). The daily pan evaporation was measured from the evaporation pan. Rainfall was also recorded from a standard rain gauge. Pan evaporation was adjusted by using the following equation:

$$CPE = EV_p \times K_p \quad \text{(i)}$$

Where,

EV_p= Pan evaporation and

K_p= Pan co-efficient = 0.7 (Michael, 1985)

The desired amount of irrigation water was calculated by the following relationships:

$T_1 = CPE \times 1.25$

$T_2 = CPE \times 1.0$

$T_3 = CPE \times 0.75$

$T_4 = CPE \times 0.50$

A hose pipe was used to apply the calculated amount of water from the sources. A volumetric measurement was made of the outlet discharge. The seasonal water was anticipated by combining the amount of irrigation water that was applied, the seasonal rainfall, and the soil moisture content.

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

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

WR = Water requirement

Soil water contribution

Gravimetric analysis was used to evaluate the soil moisture content during sowing and harvest to quantify the soil water contribution. Soil samples were collected from a depth of 20 cm with an auger. The moisture content was then calculated using the following equation after drying the samples at 105°C for 24 hours.

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

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 available in the plant root zone, allowing the plant to germinate or maintain its growth. Therefore, effective rainfall means useful or utilizable rainfall (Michael, 1985). However, the term effective rainfall has been interpreted differently, not only by specialists in different field but also by different workers in the same field. 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 as follows:

$P_{effective} = P_{total}(125 – 0.2\ P_{total})/125$……………(1) for P_{total}< 250 mm

$P_{effective} = (125 + 0.1\ P_{total})$ ………………......... (1) 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 the contribution of moisture from the soil. Mathematically, water requirement was calculated following the methods described by Michael, (1985), and this value was considered as traditional or farmers' irrigation rate (T_0).

$$WR = IR + ER + \sum_{i=1}^{n} \frac{MSi - Mhi}{100} AiDi \text{..(vi)}$$

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.

Crop cultivation and agronomic management

A power tiller was used to prepare the experimental field. The weeds and stubbles were removed to clean the land. Recommended doses of urea (540 kg ha^{-1}), triple Super phosphate (TSP) (240 kg ha^{-1}), muriate of potash (220kg ha^{-1}), gypsum (240kg ha^{-1}), zinc sulphate (15 kg ha^{-1}) and boric acid (5 kg ha^{-1}) was applied. One third of nitrogen as urea, whole triple super phosphate (TSP), muriate of potash (MP), zinc sulphate, and boric acid were applied at the time of final land preparation. The rest two –third of the urea was applied in two equal splits at 55 and 85 days after sowing(DAS).

Table 1. Number of irrigation and total depth of water applied under different treatments

Number of Irrigation	Depth of Irrigation Water Applied (mm)			
	1.25Epan	1.0Epan	0.75Epan	0.50Epan
	T_1	T_2	T_3	T_4
1stirrigation	150	120	90	60
2nd irrigation	200	160	120	80
Rainfall	213	213	213	213
Total	563	493	423	353

Two hybrid maize varieties Syngenta NH-7720and Ispahani Diamond Seeds were sown on 2 December 2020 in 65cm apart rows by hand drilling of a depth of 3-4 cm deep furrows with country plough. The seeds were sown continuously in the furrow at 30 kg ha^{-1}. Earthing up was done by spade at 25 DAS to prevent the lodging of plants.

The plots were irrigated two times (35 DAS and 80 DAS) as per experimental treatments during the growing period. Drainage was done when necessary by using drainage channels.

At maturity, the experimental crops were harvested plot-wise on 20 April 2021. Before harvesting, $2m^2$ plant samples were selected randomly and uprooted from each plant for data recording. The data of the different growth parameters of maize were collected from randomly selected five plants. 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 program STATVIEW.

Results and Discussions

Our study assessed the growth, yield, and yield-contributing traits of various maize varieties. At 120 DAS, V_2 had the largest leaf area (5792.36 cm^2), which was noticeably (10.96 %) greater than V_1. The effect of irrigation frequencies in the leaf area of maize was not statistically significant at 120 DAS (**Table 2)**. At 120 DAS, T_1 had the largest leaf area (6019.69 cm^2), which decreased slightly (4.7 %) in T_2, but dramatically (11.79 and 19.68 %, respectively) in T_3 and T_4. The interaction between varieties and irrigation frequencies significantly influenced the total leaf area (cm^2) (**Table 2**). At 120 DAS, combination of V_2 with T_1 produced the largest leaf area (6233.52 cm^2), whereas the interaction of V_1 with T4 created the smallest leaf area (4329.38 cm^2).

A significant difference in maize varieties' total dry matter (TDM) production was found during our observation **(Table 2)**. At 42 days after sowing, V_2 had the most TDM (16.55 g $plant^{-1}$), which was 38.38 % more than V_1. At 63 DAS, V_2 had the highest TDM (83.64 g $plant^{-1}$), which was 44.72 % more than V_1. At 84 days after sowing, V_2 had the highest TDM (184.53g $plant^{-1}$), which was 26.26 % more than V_1. At 105 DAS, V_2 had the most TDM (224.25g $plant^{-1}$), which was 31.21 % more than V_1. At 140 days after sowing, V_2 had the most TDM (257.779g $plant^{-1}$), which was 21.25 % more than V_1. It is clear from the results above that different maize types produced different amounts of total dry matter. Ispahani Diamond may be a more robust type of corn than Syngenta NH 7720. The majority of the time, different irrigation methods were shown to cause appreciable changes in maize's total dry matter (TDM) output **(Table 2)**. At 42 DAS, the highest TDM (22.96 g $plant^{-1}$) was observed in T_1, reduced by 28.51% in T_2 but significantly by 63.11 and 75.35% for T_3 and T_4, respectively. At 63 DAS, the highest TDM (106.9 g $plant^{-1}$) was observed in T_1, reduced by 30.30% in T_2 and significantly 50.95 and 75.43% in T_3 and T_4, respectively. At 84 DAS, the highest TDM (184.98 g $plant^{-1}$) was observed in T_1, reducing only 15.58% in T_2 but significantly by 31.06 and 45.63% in T_3 and T_4, respectively. At 105 DAS, the highest TDM (244.83 g $plant^{-1}$) was observed in T_1, reducing 18.10% in T_2 but significantly by 30.29 and 42.40% for T_3 and T_4, respectively. At 140 DAS, the highest TDM (275.61 g $plant^{-1}$) was observed in T_1, reducing only 10.73% in T_2 but significantly by 24.53 and 30.39% for T_3 and T_4, respectively. Significant effects in TDM were observed in the interaction between variety and irrigation frequency of maize **(Table 2).** At 42 DAS, the highest TDM (27 g $plant^{-1}$) was observed in V_2T_1, and the lowest value (4.58 g $plant^{-1}$) was observed in V_1T_4. At 63 DAS, the highest TDM (131.333 g $plant^{-1}$) was observed in V_2T_1, and the lowest value (17.17 g $plant^{-1}$) was observed in V_1T_4. At 84 DAS, the highest TDM (205.97 g $plant^{-1}$) was observed in V_2T_1, and the lowest value (80.5g $plant^{-1}$) was observed in V_1T_4. At 105 DAS, the highest TDM (269.67 g $plant^{-1}$) was observed in V_2T_1, and the lowest value (107.33 g $plant^{-1}$) was observed in V_1T_4. At 140 DAS, the highest TDM (311.56 g $plant^{-1}$) was observed in V_2T_1, and the lowest value (166.44 g $plant^{-1}$) was observed in V_1T_4. A reduction in total dry matter was detected under the treatment of less irrigation, as was reported by Abbas *et al.* (2005), Patil *et al*.

Table 2. Varietal differences, effect of irrigation frequecies and interaction effect on Leaf Area (LA), total dry matter (TDM) and crop growth rate (CGR) of maize at different day's after sowing (DAS).

Varieties	Leaf area (m^2)	Total Dry Matter (TDM) g plant^{-1}					Crop Growth Rate (CGR) g m^{-2} day^{-1}			
	120 DAS	42 DAS	63 DAS	84 DAS	105 DAS	140 DAS	21-42 DAS	43-63 DAS	64-84 DAS	84-105 DAS
V_1	5.15 b ±212.96	10.2 b ±2.31	46.23 b ±9.51	120.58 b ±11.78	154.25 b ±15.63	202.96 b ±11.29	6.18 b ±1.83	28.6 b ±5.80	59.01±2.3	26.85±5.82
V_2	5.79 a ±126.4	16.56 a±3.07	83.64 a ±12.92	163.53 a ±11.39	224.25 a ±15.23	257.78 a ±14.05	11.24 a ±2.46	53.25 a ±7.28	63.4±2.01	48.19±4.15
LS	0.01	0.05	0.01	0.01	0.01	0.01	0.05	0.01	NS	NS
Treatments										
T_1	6.01 a ±186.4	22.96 a ±4.41	106.9 a ±17.8	184.98 a ±13.53	244.83 a ±18.93	275.61 a±21.41	16.33a±3.63	66.62a±8.52	66.94 a±1.53	52.05±4.39
T_2	5.73 ab ±169.75	16.41ab ±3.67	74.15 ab ±14.59	156.15ab ±11.37	200.5 ab ±23.95	246.02ab±16.09	11.21 ab±2.87	45.82ab±8.73	64.33ab83	40.48±10.18
T_3	5.30 bc ±213.82	8.47bc ±1.6	52.43bc ±12.18	126.52bc ±15.85	170.67bc ±19.71	208.0bc±15.96	4.78bc±1.26	34.89bc±8.52	58.8bc±3.26	32.1±4.36
T_4	4.83 c ±264.54	5.66 c ±0.83	26.27 c ±5.95	100.57c ±13.65	141 c ±24.05	191.83 c±14.23	2.02c±0.53	16.36 c±4.06	54.75 c±3.27	25.48±9.08
LS	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	NS
Interaction										
V_1T_1	5.80 ±269.6abc	18.92±6.54abc	82.47±18.27 abc	164.0±13.96 abc	220.0±17.0abc	239.67±18.97 bc	12.82±5.34abc	50.44±9.32 b	66.22±2.47 ab	44.44±1.85 ab
V_1T_2	5.49 ±250.59abc	10.8±6.18 bcd	55.37±25.56bcde	138.8±16.72b cd	152.33±29.75cde	223.37±25.32 bcd	6.68±5.01 bcd	35.37±3.8b c	64.84±2.27 ab	30.4±3.89 bcd
V_1T_3	4.99 ±333.16 cd	6.5±3.58 cd	29.93±17.49 de	99.03±13.01 de	137.33±15.07 de	182.33±13.92 cd	3.35±2.86 cd	18.6±11.12 c	54.84±2.37 bc	21.3±8.92 cd
V_1T_4	4.32 ±358.61d	4.59±4.79 d	17.17±20.14 e	80.5±13.25 e	107.33±17.94 e	166.44±24.26 d	1.88±3.67 d	9.99±12.2 c	50.27±3.32 c	11.27±5.37 d
V_2T_1	6.23 ±235.31 a	27.0±1.06 a	131.33±8.6 a	205.97±18.22 a	269.67±24.96 a	311.56±16.87 a	19.83±1.18 a	82.8±5.99 a	67.67±2.54 a	59.66±7.03 a
V_2T_2	5.97 ±154.31 ab	22.03±2.8 ab	92.93±12.73 ab	173.5±13.0 ab	248.67±14.43 ab	268.67±18.18 ab	15.56±2.13 ab	56.27±7.88 b	63.94±5.62 ab	50.56±2.98 ab
V_2T_3	5.62 ±143.62abc	10.43±0.79bcd	74.93±4.91 bcd	154.0±14.66 bc	204±28.85 abcd	233.67±14.39 bc	6.31±0.60 bcd	51.19±3.27 b	62.75±3.33 ab	42.89±12.36 ab
V_2T_4	5.34 ±144.49 bc	6.73±1.37 cd	35.37±8.37 cde	120.63±17.71cde	174.67±30.44bcde	217.22±12.80 bcd	3.36±0.723 cd	22.73±5.61c	59.23±4.73abc	39.68±14.72abc
LS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV%	7.8	51.85	42.48	18.54	21.25	13.99	63.73	33.93	9.97	28.71

Mean values in a column having the same letters or without letter do not differ significantly as per Duncan's multiple range test (DMRT), NS= Non significant, CV= Co-efficient of variation, LS= Level of significant, DAS=Day's after sowing, V_1=Syngenta NH-7720, V_2= Ishpahani Diamond,T_1 = irrigation equivalent to 1.25 Epan, T_2= irrigation equivalent to 1.00 Epan, T_3 = irrigation equivalent to 0.75 Epan, T_4 = irrigation equivalent to 0.50 Epan.

(2006) and Viswanatha *et al.* (2000). These researchers all came to the same conclusion.

The result showed that the two maize varieties differed significantly in crop growth rate **(Table 2).** At 21-42 DAS, highest crop growth rate (11.24 g m^{-2} day^{-1}) was found in V_2, which was reduced significantly by 45% in V_1. At 43-63 DAS, highest crop growth rate (53.25 g m^{-2} day^{-1}) was found in V_2, which was significantly 46.28% higher than V_1. At 64-84 DAS, highest crop growth rate (63.4g m^{-2} day^{-1}) was found in V_2,and the lowest (59.01 g m^{-2}day^{-1}) was in V_1. At 85-105 DAS, the highest crop growth rate (48.19 g m^{-2} day^{-1}) was found in V_2,and the lowest (26.85 g m^{-2}day^{-1}) was in V_1.Deficit irrigation significantly affected crop growth at 21-42, 43-63, and 64-84 DAS but slightly in 85-105 DAS **(Table 2)**. At 21-42 DAS, the highest CGR (16.33 gm^{-2} day^{-1}) was observed in T_1,and it was reduced by 31.87, 70.71 and 87.62% for T_2, T_3 and T_4, respectively. At 43-63 DAS, the highest CGR (66.62 gm^{-2}day^{-1}) was observed in T_1, which was reduced by 31.22, 47.62 and 75.45% for T_2, T_3 and T_4, respectively. At 64-84 DAS, the highest CGR (66.944 gm^{-2}day^{-1}) was observed in T_1, which reduced only 3.91% in T_2 but significantly by 12.17 and 18.21% for T_3 and T_4, respectively. At 85-105 DAS, the highest CGR (50.05 gm^{-2} day^{-1}) was found in T_1, and the lowest (25.476 gm^{-2} day^{-1}) was obtained from T_4. Crop growth rate differed significantly due to interaction between varieties and irrigation frequencies **(Table 2).** At 21-42 DAS, the highest CGR (19.83 g m^{-2} day^{-1}) was observed in the combination of V_2T_1, and the lowest value (1.88 g m^{-2} day^{-1}) was obtained from V_1T_4. At 43-63 DAS, the highest CGR (82.80 g m^{-2} day^{-1}) was observed in the combination of V_2T_1, and the lowest value (9.99 g m^{-2} day^{-1}) was obtained from V_1T_4. At 64-84 DAS, the highest CGR (67.67 g m^{-2} day^{-1}) was observed in the combination of V_2T_1, and the lowest value (50.27 g m^{-2} day^{-1}) was obtained from V_1T_4. At 85-105 DAS, the highest CGR (59.66 g m^{-2}day^{-1}) was observed in the combination of V_2T_1, and the lowest value (11.27 g m^{-2} day^{-1}) was obtained from V_1T_4. However, it is said that CGR is decreased with the reduction of irrigation amount. This result is further supported by Wang *et al.* (2002), which proved that water deficiency retarded plant growth.

The crop growth rate is useful for the justification of different treatments (Hunt *et al*., 2002). This result is further supported by Patil *et al.* (2006), who reported that CGR increased with increasing irrigation rate. Total dry matter production is the critical component for CGR calculation. Thus CGR increases with the increase of TDM.

Significant differences in relative water contents (RWC) of leaf were found between two maize varieties. At 60 DAS, the highest RWC (78.38%) was observed in V_2, which was significantly 5.3% higher than that in V_1. At 80 DAS, the highest RWC (83.21%) was found in V_2, which was markedly reduced to 6.07% in V_1. At 100 DAS, the highest RWC (72.38%) was found in V_2, which was significantly lower at 3.88% in V_1**(Table-3)**. At 60 DAS, the highest RWC (80.26%) was observed in T_1, which reduced slightly by 3.08% in T_2 but significantly by 5.96 and 10.07% in T_3 and T_4, respectively. At 80 DAS, the highest RWC (85.26%) was observed

Table 3. Varietal differences, effect of irrigation frequencies and interaction effect on RWC, Canopy Cover (%) and Chlorophyll content (ChN_{spad}) of maize at different growth stages

Varieties	Relative water content (RWC)%			Canopy Cover (%)			Chlorophyll content (ChN_{SPAD})		
	60 (DAS)	80 (DAS)	100 (DAS)	63 (DAS)	84 (DAS)	105 (DAS)	60 (DAS)	90 (DAS)	120 (DAS)
V_1	74.22 b±1.37	78.16 b±1.46	69.57 b±0.65	68.3±3.88	75.19 b±0.95	79.8 b±1.33	44b±1.42	54.99 b±1.72	48.64 b±1.04
V_2	78.38 a±1.2	83.21 a±1.41	72.38 a±0.93	69.94±2.25	80.56 a±1.04	87.63 a±1.31	49.25 a±1.75	60.88 a±1.87	52.63 a±1.39
LS	0.05	0.01	0.01	NS	0.01	0.01	0.01	0.05	0.01
Treatments									
T_1	80.26 a±1.22	85.26 a±1.70	73.96 a±1.26	80.25 a±3.74	81.41 a±1.54	88.77 a±2.22	52.5 a±2.37	64.15 a±2.84	55.05 a±2.03
T_2	77.78ab±1.64	82.52ab±1.8	71.11 b±0.90	69.68b±3.37	78.43ab±1.65	83.92 b±2.08	47.5 ab±2.09	58.93 ab±1.85	51.25 ab±1.07
T_3	75.48bc±1.29	79.58bc±1.54	70.14 b±0.89	64.99 b±3.75	76.97 bc±1.63	82.33 b±2.33	44.33 bc±1.43	56.15 bc±1.39	49.1 bc±1.35
T_4	71.67 c±2.04	75.37 c±2.64	68.7 b±1.04	61.57 b±3.15	74.68 c±1.44	79.84 b±2.1	42.17 c±2.67	52.42 c±1.92	47.15 c±1.58
LS	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Interaction									
V_1T_1	78.73±1.31 ab	82.71±1.44 abc	71.87±0.66 b	86.80±3.60 a	78.40±0.95 bcd	84.74±1.84 bc	48.33±2.60 ab	59.77±2.84 ab	51.5±1.89 bc
V_1T_2	75.98±1.76 ab	79.92±2.2 bc	70.04±1.25 bc	67.33±4.74 b	75.7±1.75 cde	79.66±1.44 cd	45.0±2.31 bc	56.5±2.42 bc	47.6±1.29 bc
V_1T_3	75.75±1.60 bc	77.54±1.61 cd	68.99±0.86 bc	59.98±4.76 b	74.34±1.81 de	77.79±1.80 d	42.33±1.45 bc	54.37±2.28 bc	45.43±1.9 bc
V_1T_4	68.42±2.31 c	72.47±2.99 d	67.39±1.14 c	59.1±4.94 b	72.31±1.73 e	77.0±3.5 d	40.33±3.48 c	49.33±4.14 c	58.6±2.11 c
V_2T_1	81.78±1.85 a	87.8±2.43 a	76.05±1.77 a	73.69±3.77 ab	84.42±1.37 a	92.8±2.27 a	56.67±2.03 a	68.53±3.64 a	58.6±2.17 a
V_2T_2	79.58±2.66 ab	85.12±2.14 ab	72.17±1.19 b	72.03±5.37 b	81.16±1.75 ab	88.18±1.26 ab	50.00±3.21 ab	61.37±2.31 ab	52.47±1.61 b
V_2T_3	77.21±1.65 ab	81.63±2.1 abc	71.29±1.4b c	69.99±4.75 b	79.59±1.78 abc	86.86±1.85 ab	46.33±2.03 bc	57.93±1.18 bc	50.6±1.82 bc
V_2T_4	74.92±2.19 b	78.27±1.9 bcd	70.01±1.56 bc	64.04±4.36 b	77.06±1.32 bcde	82.68±1.32 bcd	44.00±1.73 bc	55.5±3.0 bc	48.87±2.25 bc
LS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV%	4.46	4.66	3.11	11.46	3.53	4.18	9.08	8.54	6.49

Mean values in a column having the same letters or without letter do not differ significantly as per Duncan's multiple range test (DMRT), NS= Non significant, CV= Co-efficient of variation, LS= Level of significant, DAS=Day's after sowing, V_1=Syngenta NH-7720, V_2= Ishpahani Diamond, T_1 = irrigation equivalent to 1.25 Epan, T_2= irrigation equivalent to 1.00 Epan, T_3 = irrigation equivalent to 0.75 Epan, T_4 = irrigation equivalent to 0.50 Epan.

in T_1 which was reduced slightly by 3.21% in T_2 but significantly 6.65 and 11.59% in T_3 and T_4, respectively. At 100 DAS, the highest RWC (73.963%) was observed in T_1, which was reduced significantly by 3.86, 5.16 and 7.11% in T_2, T_3 and T_4, respectively (**Table 3**). A significant interaction was found between varieties and irrigation frequencies in the RWC of maize leaf **(Table 3)**. At 60 DAS, the highest RWC (81.78%) was observed in the combination of V_2T_1, and the lowest value (68.42%) was obtained from V_1T_4. At 80 DAS, the highest RWC (87.80%) was observed in the combination of V_2T_1, and the lowest value (72.47%) was obtained from V_1T_4. At 100 DAS, the highest RWC (76.05%) was observed in the combination of V_2T_1, and the lowest value (67.39%) was obtained from V_1T_4.

During our observation, it was found that leaf RWC is positively correlated with irrigation levels. Similar findings were also reported in Parthasarathi *et al.*'s experiment (2013). They noticed that the relative water content of maize leaves considerably decreased as water stress increased.

Canopy cover (%) of maize varieties differ marginally at 63 DAS but significantly at 84 and 105 DAS **(Table 3)**. At 63 DAS, the maximum canopy cover (69.94%) was obtained in V_2 and the minimum (68.30%) in V_1. At 84 DAS, the maximum canopy cover (69.94%) was obtained in V_2, which was significantly 6.65% higher than V_1. At 105 DAS, the maximum canopy cover (87.63%) was obtained in V_2, which was significantly 8.92% higher than V_1. Canopy cover of maize showed statistically significant results due to different irrigation frequencies **(Table 3)**. At 63 DAS, maximum canopy cover (80.25%) was recorded in T_1, which reduced significantly by 13.16, 19.01 and 23.27 % in T_2, T_3 and T_4, respectively. At 84 DAS, the highest canopy cover (81.41%) was observed in T_1, which was reduced by 3.66% in T_2 but significantly by 5.45 and 8.26% for T_3 and T_4, respectively. At 105 DAS, maximum canopy cover (88.77%) was recorded in T_1, which was reduced significantly by 5.45, 7.25 and 10.05 % in T_2, T_3 and T_4, respectively. A significant interaction was found between varieties and irrigation frequencies in the canopy cover of maize **(Table 3)**. At 63 DAS, maximum canopy cover (86.80%) was found in the combination of V_1 with T_1 and the minimum (59.10%) was observed in V_1 with T_4. At 84 DAS, maximum canopy cover (84.42%) was found in the combination of V_2 with T_1 and the minimum (72.31%) was observed in V_1 with T_4. At 105 DAS, maximum canopy cover (92.97%) was found in the combination of V_2 with T_1 and the minimum (77.00%) was observed in V_1 with T_4.

Leaf chlorophyll content of maize varieties was measured on 60, 90 and 120 DAS and presented in (**Table 3**). The Chlorophyll content differed significantly within the maize varieties at all observations (60, 90 and 120 DAS). At 60 DAS, chlorophyll content was found maximum (49.25) in V_2, which was significantly (10.65%) higher than in V_1. At 90 DAS, chlorophyll content was found maximum (60.88) in V_2, which was significantly (5.89%) higher than in V_1. At 90 DAS, chlorophyll content was found maximum (52.63) in V_2, which was significantly (7.58%) higher than in V_1. Chlorophyll content of maize showed statistically significant results due to different irrigation frequencies **(Table 3)**. At 60 DAS, T_1 had the highest chlorophyll content (52.5), which decreased marginally in T_2 by 9.52 % but dramatically in T_3 and T_4 by 15.5 and 19.68 %, respectively. At 90 DAS, T_1 had the maximum chlorophyll content (64.15), which decreased marginally in T_2 (8.13 %), but

Table 4.Varietal differences, effect of irrigation frequecies and interaction effect on plant height, yield components and yield of maize

Varieties	Plant height (105 DAS)	Cob length (cm)	No. of grains cob^{-1}	1000 grain weight (g)	Grain yield (t ha^{-1})	Stover yield(t ha^{-1})	Biological yield (t ha^{-1})	Harvest index(%)
V1	215.58 b ±8.69	13.31b±0.34	370.63 b±12.55	243.83 b±7.4	10.55 b±0.69	10.77 b±0.92	21.31 b±1.69	49.68±0.59
V2	241.08 a ± 8.21	15.03 a±0.44	425.88 a±15.73	263.22 a±6.72	12.22 a±0.51	12.71 a±0.91	24.92 a±1.41	49.45±0.74
LS	0.05	0.01	0.01	0.05	0.05	0.05	0.05	NS
Treatments								
T1	253 a±10.37	15.63 a±0.74	441.64 a±25.99	279.19 a±6.92	13.82 a±0.81	15.53 a±1.09	29.34 a±1.84	47.16 ± 0.82
T2	241.17 ab±9.2	14.56 ab±0.48	417.08ab±16 .96	259 ab±7.83	12.04 ab±0.7	12.23ab±1.1	24.27 ab±1.8	49.86±1.04
T3	218.5 bc±11.74	13.67bc±0.4 2	379.42bc±18 .68	247.88 bc±8.19	10.29 bc±0.7	9.99 bc±0.7	20.28 bc±1.45	50.78±0.59
T4	200.67 c±10.15	12.83 c±0.38	354.86 c±13.62	228.01 c±8.05	9.39 c±0.68	9.17 c±0.57	18.98 c±1.24	50.44±0.63
LS	0.05	0.05	0.05	0.05	0.05	0.05	0.05	NS
Interaction								
V_1T_1	241.00±10.97a bc	14.37±0.85b cd	396.83±34.5 1bc	268.75±10.7 6ab	13.73±1.6a	15.03±1.77a	28.76±3.37a b	47.69±1.22b c
V_1T_2	230.67±10.97a bcd	13.78±0.64b cde	384.83±15.4 1bc	253.8±12.4b	11.11±0.99a bcd	10.36±0.73b c	21.47±1.72c d	51.65±0.533 a
V_1T_3	200.00±13.37c d	12.78±0.17d e	353.00±25.5 2c	236.42±10.6 1bc	8.94±0.64cd	8.92±1.04c	17.85±1.69d	50.28±1.20a b
V_1T4	190.00±19.35d	12.33±0.33e	347.83±22.9 4c	216.33±8.52 c	8.42±0.95d	8.75±1.04c	17.17±1.99d	49.08±0.37a bc
V_2T_1	265.00±16.46a	16.88±0.67a	486.44±21.9 4a	289.63±5.2a	13.89±0.7a	16.03±1.61a	29.92±2.3a	46.63±1.27c
V_2T_2	251.67±13.87a b	15.33±0.38a b	449.33±13.3 7ab	264.2±11.27 ab	12.97±0.88a b	14.11±1.53a b	27.07±2.34a bc	48.07±1.37c d
V_2T_3	237.00±13abc	14.56±0.29b c	405.83±12.7 0bc	259.35±9.56 ab	11.65±0.66a bc	11.07±0.65b c	22.71±1.32b cd	51.29±0.12a
V2T4	210.67±3.36bc d	13.33±0.60c de	361.89±18.7 7c	239.68±10.7 4bc	10.35±0.69b cd	9.63±0.61c	19.98±1.31d	51.81±0.08a
LS	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
CV%	10.26	6.58	9.34	6.84	14.6	17.77	15.77	3.25

Mean values in a column having the same letters or without letter do not differ significantly as per Duncan's multiple range test (DMRT), NS= Non significant, CV= Co-efficient of variation, LS= Level of significant, DAS=Day's after sowing, V1=Syngenta NH-7720, V2= Ishpahani Diamond,T1 = irrigation equivalent to 1.25 Epan, T2= irrigation equivalent to 1.00 Epan, T3 = irrigation equivalent to 0.75 Epan, T4 = irrigation equivalent to 0.50 Epan.

dramatically in T_3 and T_4 (12.47 and 11.73 %, respectively). At 120 DAS, T_1 had the highest chlorophyll content (52.5), which decreased marginally in T_2 (6.9 %), but dramatically in T_3 and T_4 (10.8 and 14.35 %, respectively). A significant interaction was found between varieties and irrigation frequencies in chlorophyll content **(Table 3)**. At 60 DAS, maximum chlorophyll content (56.67) was found in the combination of V_2 with $T_1$and the minimum (40.33) was observed in V_1 with T_4. At 90 DAS, maximum chlorophyll content (68.53) was found in the combination of V_2 with $T_1$and the minimum (49.33) was observed in V_1 with T_4. At 120 DAS, maximum chlorophyll content (58.6) was found in the combination of $V_2T_1$and V_1T_4, and the minimum (45.43) was observed in V_1 with T_3.

The plant height of two different maize varieties was measured105 days after sowing (DAS), as presented in (**Table 4**). The plant height has differed significantly at 105 DAS. At 105 DAS, the highest plant height (241.08 cm) was obtained in V_2, which was significantly 10.78% higher thanV_1. The variation in plant height of maize under different irrigation frequencies was statistically significant at 105 DAS (**Table 4**). At 105 DAS highest plant height (238.83 cm) was observed in T_1, which reduced only 7.7% in T_2 but significantly by 13.63 and 20.68% for T_3 and T_4, respectively. The variation in plant height of maize was statistically significant due to the interaction between varieties and irrigation frequencies at 105 DAS (Table 4). At 105 DAS, the tallest plant (245 cm) was obtained from V_2 with T_1, and the shortest plant (167.33) was observed in V1 with T4. According to several earlier reports (Sahu *et al*.2013, Hussaini *et al*.2001), comparable observations for maize crops were also made. Mugabe and Nyakatawa, (2000), who reported that crop growth declined when three-quarters and half of the water requirements were supplied, provided more support for similar findings.

Both maize varieties differed significantly in respect of cob length. The highest cob length (15.03 cm) was observed in V_2, which was significantly 11.4% higher than V_1. A significant difference in cob length of maize was observed for different irrigation frequencies **(Table 4)**. The highest cob length (15.63 cm) was recorded in T_1, which was reduced slightly (6.84%) in T_2 but significantly by 12.53 and 17.86% in T_3 and T_4,respectively. Significant interaction in cob length of maize was observed between varieties and irrigation frequencies **(Table 4)**. Maximum cob length (16.88 cm) was recorded in the combination of V_2 with T_1, and the minimum (12.33 cm) was found in V_1T_4.

A significant difference was found in the number of grains cob^{-1} between the two maize varieties. The highest number of grains cob^{-1} (425.88) was observed in V_2, which was significantly (12.98%) higher than V_1 **(Table 4)**. Significant differences in the number of grains cob^{-1}were observed for different irrigation frequencies **(Table 4)**. The maximum number of grains cob^{-1} (441.639) was recorded in T_1,which was reduced slightly (5.56%) in T_2 but significantly by 14.08 and 19.64% in T_3 and T_4, respectively. Significant interaction in the number of grains cob^{-1} was observed between maize varieties and irrigation frequencies **(Table 4)**. Maximum number of grains cob^{-1} (486.44) was found in the combination of V_2 with T_1, and the minimum (347.83) was found in the V_1 with T_4.

Varieties differ significantly in 1000 grains weight of maize. The highest1000 grains weight (263.22 g) was observed from V_2, which was significantly 7.36% higher than V_1 **(Table 4)**. Significant differences in 1000 grains weight were observed for different

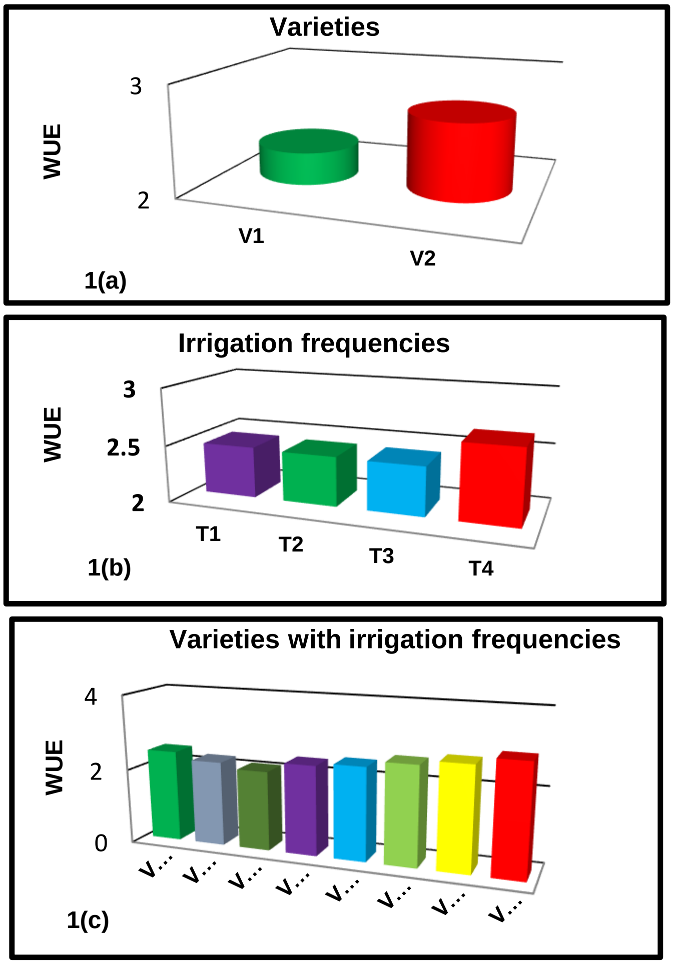

Figure 1. (a): Varietal differences in water use efficiency (WUE) of maize, (b): Effects of irrigation frequencies in water use efficiency (WUE) of maize,(c): Effects of interaction between variety and irrigation frequency in water use efficiency (WUE) of maize.
WUE= Water Use Efficiency, V_{1} = (Syngenta NH-7720), V_{2} = (Ishpahani Diamond), T_1 = irrigation equivalent to1.25 Epan, T_2 = irrigation equivalent to 1.00 Epan, T_3 = irrigation equivalent to 0.75 Epan, T_4 = irrigation equivalent to 0.50 Epan.

irrigation frequencies **(Table 4)**. The maximum 1000 grains weight (279.19g) was recorded in T_1, which was reduced slightly (7.23%) in T_2 but significantly by 11.21 and 18.33% in T_3 and T_4, respectively. Hochman *et al.* (1982) observed that water stress during grain growth was found to decrease grain size.A significant interaction between varieties and irrigation frequencies in 1000 grains weight of maize was observed**(Table 4)**. A maximum 1000 grains weight (289.63 g) was found in the combination of V_2 with $T_1$and the minimum (216.33 g) was observed in V_1 with T_4.

Both maize varieties differed significantly in grain yield. The highest grain yield (12.22 t ha^{-1}) was observed in V_2 (Ishpahani Diamond), which was significantly 13.64% higher than V_1 (Syngenta NH-7720) **(Table 4).** Grain yield showed significant differences due to different irrigation frequencies **(Table 4)**. The maximum grain yield (13.82 t ha^{-1}) was recorded in T_1, which was reduced slightly (12.87%) in T_2 but significantly by 25.50 and 32.05% in T_3 and T_4, respectively. A significant interaction of maize was found between varieties and irrigation frequencies in grain yield **(Table 4)**. Maximum grain yield (13.897 t ha^{-1}) was observed in the combination of V_2 with T_1, and minimum (8.421t ha^{-1}) was observed in V_2 with T_4. Although no remarkable differences in grain yield were observed between both maize varieties, it was slightly higher in V_2 (Ishpahani Diamond). These results are further supported by Bangladesh Agricultural Research Institute (BARI, 2015).
During our observations, it was discovered that a slight water reduction had no appreciable impact on maize production, while a severe water deficit resulted in a significant yield loss. Zhang *et al*. (2004), state that a severe soil water deficit (SWD) reduced maize grain yield. With increased irrigation frequency, maize output rose (Shivakumar *et al*. 2011; Salemi *et al*. 2011). The North China Plain's maize crop production decreased with decreasing irrigation quantities, Chen *et al.* (2009) found, whereas maximum yields were attained under completely irrigated conditions.
There were significant differences found between the two varieties in stover yield. Maximum stover yield (12.71 t ha^{-1}) was observed in V_2, which was significantly (15.27%) higher than in V_1 **(Table 4)**. Stover yield showed significant differences due to different irrigation frequencies **(Table 4)**. The maximum stover yield (15.53 t ha^{-1}) was recorded in T_1, which reduced (21.21%) in T_2 but significantly by 35.66 and 40.95% in T_3 and T_4, respectively. Significant interaction was found between varieties and irrigation frequencies on the stover yield of maize **(Table 4)**. The highest stover yield (16.03 t ha^{-1}) was observed in the combination of V_2 with T_1, and the lowest (8.75 t ha^{-1}) was in V_1 with T_4.
Significant differences were found between the two maize varieties in biological yield. Maximum biological yield (24.92 t ha^{-1}) was observed in V_2which was significantly (14.48%) higher than V_1 **(Table 4)**. Significant differences were observed in biological yield for different irrigation frequencies **(Table 4)**. The highest biological yield (29.34 t ha^{-1}) was recorded in T_1, which was reduced slightly (17.29%) in T_2 but significantly30.87 and 35.33% in T_3 and T_4, respectively. Significant interactions between varieties and irrigation frequencies were observed in the biological yield of maize **(Table 4)**. The highest biological yield (9.28t ha^{-1}) was observed in the combination of V_1 with T_1 and the lowest (8.07t ha^{-1}) in V_2 with T_4.
This result is further supported by Jia *et al*, (2014), who reported significant differences in biological yield among the different irrigation treatments.
Both maize varieties differed slightly in harvest index (HI). Maximum HI (49.48%) was observed in V_1, and the minimum (49.45%) was found in V_2, **(Table 4)**. The harvest index was not statistically significant at different irrigation frequencies**.** The maximum HI, (50.78%) was recorded in T_3,and the minimum (47.16%) was found in T_1 **(Table 4)**. A significant interaction was observed between varieties and irrigation frequencies in harvest index (HI), **(Table 4)**. The Maximum HI (51.81%) was observed in the combination of V_2 with and the minimum (46.63 %) in V_2 with T_1.
Both maize varieties differed slightly in water use efficiency (WUE). The highest WUE (2.69 kg ha^{-1} cm^{-1}) was observed in V_2 (Ishpahani Diamond), and V_1 (Syngenta NH-7720) showed the lowest result (2.29kg ha^{-1} cm^{-1}) **(Figure 1a).** No significant effects were observed in maize's water use efficiency (WUE) (**Figure 1b**). The maximum WUE (2.66 kg ha^{-1} cm^{-1}) was recorded in T_4 (irrigation equivalent to 0.50 Epan) and the minimum (2.43 kg ha^{-1} cm^{-1}) in T_3 (irrigation equivalent to 0.75 E_{pan}). No significant interaction was observed between varieties and irrigation frequencies in maize's water use efficiency (WUE) (**Figure 1c**). Maximum WUE (2.93 kg $ha^{-1}cm^{-1}$) was found in the combination of V_2 with T_4 and the minimum (2.11 kg $ha^{-1}cm^{-1}$) in $V_1$with T_3.
Kirda (2002) stated that with a 25% water deficit under deficit irrigation, WUE was 1.2 times that achieved under normal irrigation practice.

Conclusion

According to the observations made throughout these studies, V_2 (Ishpahani Diamond) showed better overall results than V_1 in the end (Syngenta NH-7720). The highest grain yield (12.22 t ha^{-1}) was obtained from V_2, and the lowest (10.55 t ha^{-1}) value was in V_2. The highest grain yield (13.82 t ha^{-1}) was observed in treatment T_1 (irrigation equivalent to 125 % E_{pan}), which was nearly identical to (12.04 t ha^{-1}) in treatment T_2 (irrigation equivalent to 100 % E_{pan}) by using 20.42 % less water. Therefore, T_2 (irrigation equivalent to 100 % E_{pan}) would be the best practice for maize cultivation, particularly in the drought-affected north-western areas of Bangladesh. The most effective interaction was observed in the combination of V_2 with T_1, where the grain yield was obtained at 13.89 tha^{-1}. Diminishing water resources and increasing food requirements need greater efficiency in water use both in rainfed and irrigated agriculture. If we get more or less the same amount of yield by applying less water, we should follow the deficit irrigation practices to save our future agriculture, the next generation, and our country.

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