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Research Paper

Effect of irrigation and mulch on maize yield (*Zea mays*) in southern areas of Bangladesh

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Abstract. This study was conducted at the farmer's field of Babugong Upazilla, Barisal to determine the effect of irrigation sequences and straw mulch on the yield of maize. The experiment consisted of two factors: irrigation and mulch. The irrigation treatments in the main plot as I_1 Farmer practice, I_2 One irrigation at 4 leaf stage, 1_3: Two irrigations each at 4 leaf stage and 8-10 leaf stage, and I_4: Three irrigations each at 4 leaf stages, 8-10 leaf stage and tasseling stage. The subplot treatments as M_1: No mulch, M_2: Mulch with 1 cm thickness, M_3: Mulch with 2 cm thickness, and M_4: Mulch with 3 cm thickness. The variety of test crop was BARI hybrid Maize-9. I_4 (Three irrigations each at 4 leaf stage, 8-10 leaf stage and tasseling stage) produced the highest plant height (274.3 cm) stating that plant height is directly proportional to water availability but the quantity must not exceed the optimal quantity. From two year observations, I_3M_3 (Two irrigations each at 4 leaf stage and 8-10 leaf stage with 2 cm thick mulch) produced the highest number of grain per cob and 100-grain weight. The highest grain yield and biological yield were also obtained from I_3M_3 over two years of observations. Among all treatments, I_3M_3 (Two irrigations each at 4 leaf stage and 8-10 leaf stage with 2 cm thick mulch) produced the highest BCR (1.70).

Keywords: Irrigation, leaf stages, mulch, maize, growth, grain yield, yield characters.

INTRODUCTION

Water is a major growth factor, which provides turgidity to the cells and tissues. Shortage of water in plants, thus, hampers turgidity of cells or tissues as well as the internal plant activities. This can seriously hamper the rate of transpiration through stomata and there by the crop evapotranspiration. Obviously, the yield of crop will go down as the yield of crop is directly proportional to crop the crop evapotranspiration. Water also helps to control soil and plant temperature. Crop production in Barisal region of Bangladesh is facing serious water shortage during drought season. About 15.7 million- acres of land is irrigated, which is not enough to fulfil the 35.72 million acre of irrigation requirements (BBS 2010), To meet this shortage, ground water is being withdrawing but its quality is, reportedly, not good. Moreover, pumping cost has increased due to increase in water rates, oil and electricity. At the same time, there have been evidences of declination in water level of the aquifer due to irrigation. Excessive water withdrawal should be protected and simultaneously means to increase water productivity to be devised. Among the management practices for increasing water productivity (WP) one of them is mulching. Any material spread on the surface of soil to protect it from raindrops, solar radiation or

evaporation is called mulch. Its purpose is any or all of the following: to conserve moisture, to improve the fertility and health of the soil, to reduce weed growth and to enhance the visual appeal of the area. Straw is commonly used as mulch. Straw mulching has potential for increasing soil water storage (Shanging and Unger, 2001). Mulch increased WP by 14% as compared with bare soil treatment (Tolk *et al*., 1999). It moderates soil temperature and increases water infiltration during intensive rain (Gajri *et al*., 1994). The yield increases are generally credited to increase in water content in the soil due to reduced evaporation. Mulch increased grain yield by 17 % and above ground biomass by 19% (Folk *et al*., 1999). Texture also directly affects water-holding capacity of a soil. Irrigated silty soil increased 29 to 74% higher yield when mulch was applied (Tisdall and Adam, 1986). Therefore, the effect of mulch on improvement of available water to plants in different textured soil can be modified. Mulch can decrease soil temperature and retain better root growth for corn in case of coarse textured soil and grain yield could be more in loamy sand than sandy loam soil (Gajri *et al*., 1994). Water productivity is the yield of dry matter as a function of the total water used to produce a crop. Yield and water use efficiency (WUE) can be increased by improving soil and water management practices, improving crop management and growing high yield, stress-tolerant and widely adapted cultivars.The interactive effects of irrigation and mulch managements need to be better understood to achieve these goals. Keeping these aspects in mind, an experiment was carried out to investigate the effect of straw mulch and irrigation on yield of maize and the soil moisture content and water productivity during the growing stages of maize.

MATERIALS AND METHODS

The experiment was conducted at the farmer's field of Babugong, Barisal during 25 November, 2015 to 12 April, 2016 to study the effects of straw mulch and irrigation management on the yield and water use of maize. The maize hybrid of BARI hybrid Maize 9 (BHM-9) was used in experiment. This hybrid variety is popular due to its high yield potential and stress tolerant characteristics. The recommended doses of urea, triple super phosphate, muriate of potash, gypsum, zinc sulphate, boric acid and cow dung at the rate of 500, 240, 180, 240, 10, 5 kg/ha and 6 t/ha, respectively, were applied. One-third of urea and the entire doses of other fertilizers were applied at the time of final land preparation. The rest two-thirds of urea was top dressed in two equal splits at 30 and 50 Days after sowing (DAS). The first weeding was done manually at 20 DAS and also the thinning was done on the same day keeping only one healthy plant per hill; the rest of the plants were uprooted carefully to avoid disturbance to the nearby plants. The subsequent weeding was done at 64 DAS during the growing season of the crop.

Experimental design

The experiment consisted of two factors: irrigation and mulch. Irrigation and mulch had four levels or treatments. Irrigation was scheduled based on the depth of water required. The irrigation treatments were allocated to the main plot and the mulches in the subplot. The irrigation and mulch treatments were:

Main plot: Irrigation (4)	Subplot: Mulch (4)
Farmer practice	No Mulch
One irrigation at 4 leaf stage	Mulch with 1.0 cm
Two irrigations at 4 leaf stage and 8-10 leaf stage	Mulch with 2.0 cm
Three irrigations at 4 leaf stage,8-1 0 leaf stage and tasseling stage	Mulch with 3.0 cm

Quantification and application of irrigation

Irrigation was applied based on the depth of water required. The procedure of calculating irrigation water is summarized below

$$d_{ir} = \sum_i^n \frac{(FC - RL_i) \times AS_i \times D_i}{10o} \quad (1)$$

d_{ir} = Depth of irrigation water to be applied within the one irrigation cycle (rnm),
FC = Mean soil moisture content at field capacity (%),
RL_i = Residual soil moisture level before each irrigation in the i^{th} layer of soil profile (%)
As_i = Apparent Specific Gravity of the i^{th} layer of soil,
D_i = Depth of the i^{th} layer of the soil profile within the root zone to be irrigated (mm),

Irrigation was applied by using power sprayer and no excess water was applied in the plots. In this case volume of water was measured by the following equation:

$V = a \times d$ (m^3)

Here,
V = Volume of water in m
a = Area of the plot in m^2
d = Depth of water applied (m)

The following data were collected from the sample plants: 1. Plant height, 2. Cob length, 3. Cob perimeter, 4. Number of grains per cob, 5. Grain yield, 6. Straw yield, 7. Hundred (I00)-grain weight.

Harvest index

Harvest index (HI) is the ratio of the grain yield and

Table 1. Growth and yield parameters under different irrigation treatments during 2014-15 and 2015-16.

Treatment	Plant height (cm)	Length of cob (cm)	Cob perimeter (cm)	No. of grain/ cob	100-grain wt (g)	Plant height (cm)	Length of cob (cm)	Cob perimeter (cm)	No. of grain/ cob	100-grain wt (g)
	2015-16					2014-15				
I_1	253.9	18.19	3.467	503	31.33	225.1	20.13	3.572	511	35.76
I_2	256.4	19.51	3.553	542	33.17	217.6	21.05	3.517	526	36.47
I_3	262.8	19.31	3.521	560	33.42	219.1	19.67	3.48	572	37.72
I_4	265.1	18.94	3.563	555	33.17	228.1	20.29	3.427	557	35.82
LSD	21.8	1.521	0.211	86.06	6.05	18.75	3.985	0.3848	79.49	5.481
CV (%)	5.9	5.63	4.2	11.2	12.98	5.84	13.6	7.62	10.16	10.42
F-Test	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

I_1 Farmer practice, I_2 One irrigation at 4 leaf stage, 1_3: Two irrigations each at 4 leaf stage and 8-10 leaf stage, and I_4: Three irrigations each at 4 leaf stages, 8-10 leaf stage and tasseling stage

biological / biomass yield. The biological yield is the sum of the grain and straw yields. The HI is expressed as:

$$\text{Harvest Index (HI)} = \frac{Grain\ yield}{Biological\ yield} \times 100 \quad (2)$$

Water productivity

The water use of a crop field is generally described in terms of water productivity (WP), 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 WP demonstrates the productivity of water in producing crop yield. WP for maize was calculated by:

$$\text{WP} = \frac{Y}{SWU} \quad (3)$$

Where,

WP = Water productivity, kg/m^3
Y = Grain yield, kg/m^2
SWU = Seasonal water use in the crop field, m

The WU was calculated by summing up the water applied in irrigation (taking into account the rainfall) and soil moisture contribution.

Data analysis

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

RESULTS AND DISCUSSION

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, mulches on maize cultivation have been elaborately discussed.

Effect of irrigation and mulch on growth and yield parameters

Plant height

The mean plant heights for different irrigation and mulch treatments during 2015-16 and 2014-15 are listed in Table 2, respectively. The highest plant height of 265.1 cm was obtained at 1_4 (3 irrigations) and the lowest was 253.9 cm at I_1 (farmer practice) during 2015-16. In case of mulch treatments during 2015-16, the highest plant height of 264.9 cm was obtained at M_1 (No mulch) and the lowest was 252.0 cm at M_2 (1 cm mulch). In case of irrigation and mulch treatments, it can be observed from two year data that the highest plant height was obtained from the same treatment. So it can be inferred that the plant height of maize was very much responsive to availability of water. No significant difference in plant height was observed among the water application techniques even though the watering was done at different growth stages.

Cob length and perimeter

The treatments did not exert significant influence on the length and perimeter of cobs (Tables 1 and 2). Among all treatments, the highest cob length of 19.51 cm was obtained from 1_2 (1 irrigation) and the lowest of 18.19 cm from I_1 (farmer practice) in 2015-2016. In case of cob perimeter, the highest value of 3.563 cm was obtained from 1_4 (3 irrigation) and the lowest value of 3467 cm from I_1 (farmer practice) in the same year.On the other

Table 2. Growth and yield parameters under different mulch treatments during 2014-15 and 2015-16.

Treatment	Plant height (cm)	Length of cob (cm)	Cob perimeter (cm)	No. of grain/ cob	100-grain wt (g)	Plant height (cm)	Length of cob (cm)	Cob perimeter (cm)	No. of grain/ cob	100-grain wt (g)
	2015-16					2014-15				
M1	264.9	18.89	3.454	519	31.67	226.4	19.14	3.408	526	34.69
M2	252	18.55	3.523	541.0	32.25	225.4	20.14	3.486	536	36.89
M3	259.4	19.18	3.514	541	34.17	222.3	20.31	3.578	555	37.47
M4	261.7	19.33	3.612	560	33	215.8	21.56	3.524	548	36.72
LSD	21.8	1.521	0.211	86.06	6.05	18.75	3.985	0.3848	79.49	5.481
CV (%)	5.9	5.63	4.2	11.2	12.98	5.84	13.6	7.62	10.16	10.42
F-Test	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

M_1: No mulch, M_2: Mulch with 1 cm thickness, M_3: Mulch with 2 cm thickness, and M4: Mulch with 3 cm thickness.

hand, the highest cob length (19.33 cm) was obtained from M_4 (3 cm mulch) and the lowest of 18.55 cm from M_2 (1 cm mulch) in 2015-2016. The highest cob perimeter 3.612 cm was found from M_4 (3cm mulch) and the lowest of 3.454 M_1 (No mulch) in the same study year. In 2014-2015, the highest value of cob length was obtained at same treatment as of 2015-2016 but the cob perimeter was different among irrigation treatments over years. In case of mulch treatment the results were the same as irrigation treatments.

Number of grains per cob

Treatment, 1_3 (2 irrigation) produced the highest number of grains per cob (560) and treatment, I_1 (Farmer practice) produced the lowest (503) grains per cob in 2015-2016. The highest number of grains per cob (560) was obtained with 3 cm mulch (M_4) and the lowest (519) with no mulch (M_1) in the same year. In case of irrigation treatments of the study year of 2014-2015, the highest number of grains per cob was observed from the same treatments as of 2015-2016 but dissimilar values were obtained in case of mulch treatments over the years of observations.

100-grain weight

The 100-grain weight of maize was statistically similar for different irrigation and mulch treatments (Tables 1 and 2). The highest 100-grain weight (33.42 g) was obtained from I_3 (2 irrigation) and the lowest (31.33 g) from I_1 (Farmer practice) in 2015-2016. On the other hand, the highest 100-grain weight (34.17 g) was obtained from M_3 (2 cm mulch) and the lowest (31.67 g) was obtained from M_1 (No mulch) in the same year. It was also observed that 100-grain weight was the highest at the same treatments for both irrigation and mulch treatments over the two year data.

Effect of irrigation and mulch on yield

Grain yield

In 2015-2016, the treatment 1_3 produced the highest grain yield of 8.784 t/ha and I_1 (farmer practice) produced the lowest yield of 7.797 t/ha. The treatment M_3 produced the highest grain yield of 8.916 t/ha and M_1 (no mulch) produced the lowest yield of 7.798 t/ha. However, irrigation treatments had no significant effect on the production of grain yield but the mulch treatments had significant effect on the production of grain yield of maize. The grain yield was obtained the highest from the same treatments in the study period of 2014-2015 for irrigated and mulched treatments.

Straw yield

Although irrigation played a positive role in increasing the straw yield of maize, its effect was insignificant (Tables 3 and 4). The straw yield under various irrigation treatments ranged from 7.090 to 8.415 t/ha. Treatment 1_2 (I irrigation) produced the highest straw yield (8.415 t/ha) and (farmer practice) produced the lowest (7.090 t/ha) yield. Treatment M_4 produced the highest yield (8.185 t/ha) and M_2 produced the lowest (7.539 t/ha) yield. From the two year data, it was observed that the irrigation treatments had variable results but the mulch treatments had produced the highest yield of straw from the same treatments.

Biological yield

No significant variation was observed in the biological yield of maize among the treatments. The highest biological yield (19.50 t/ha) was obtained from 1_3 (2 irrigations) and the lowest (17.45 t/ha) from I_1 (Tables 3 and 4). The highest biological yield (19.53 t/ha) was

Table 3. Yield of maize as affected by irrigation under different treatments during 2014-15 and 2015-16.

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)
	2015-16			2014-15		
I_1	7.797	7.09	17.45	6	10.42	16.4
I_2	8.358	8.415	19.41	6.32	9.718	18.6
I_3	8.784	8.082	19.5	6.68	9.994	19.09
I_4	8.139	8.047	18.84	6.48	8.498	18.69
LSD	1.078	2.3	3.233	1.387	2.942	4345
CV (%)	9.16	20.45	12.09	15.08	21.09	16.54
F-Test	NS	NS	NS	NS	NS	NS

I_1 Farmer practice, I_2 One irrigation at 4 leaf stage, 1_3: Two irrigations each at 4 leaf stage and 8-10 leaf stage, and I_4: Three irrigations each at 4 leaf stages, 8-10 leaf stage and tasseling stage

Table 4. Yield of maize as affected by mulch under different treatments during 2014-15 and 2015-16.

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)
	2015-16			2014-15		
M1	7.798	7.971	18.33	6.199	9.745	17.93
M2	7.961	7.539	18.08	6.351	8.864	17.47
M3	8.916	7.939	19.53	6.471	9.769	19.1
M4	8.403	8.185	19.25	6.455	10.25	18.28
LSD	1.078	2.3	3.233	1.387	2.942	4.345
CV (%)	9.16	20.45	12.09	15.08	21.09	16.54
F-Test	*	NS	NS	NS	NS	NS

M_1: No mulch, M_2: Mulch with 1 cm thickness, M_3: Mulch with 2 cm thickness, and M4: Mulch with 3 cm thickness.

obtained from M_3 (2 irrigations) and the lowest (18.08 t/ha) from M_2.The same treatments produced the highest biological yields over the study years.

Harvest index

It is observed from Tables 5 and 6 that the irrigation treatments did not exert any significant influence on the harvest index (HI). Treatment 1_3 (2 irrigations) provided the highest HI (44.96%) and I_1 (farmer practice) provided the lowest HI (43.31%). Treatment M_3 (2 cm mulch) provided the highest HI (45.58%) and M_1 (No mulch) provided the lowest HI (42.72%).

Interaction effect of irrigation and mulch on growth and yield parameters

Plant height

The interaction effect of irrigation and mulch on plant height of maize was significant (Table 7). The highest plant height of 274.3 cm was obtained from I_4M_1 (3 irrigations with no mulch) treatment and the lowest of 244.9 cm was obtained from I_1M_2 (Farmer practice with 1 cm mulch) treatment (2015-2016). In 2014-15, I_3M_1 (two irrigations with no mulch) produced the highest (237.3 cm) plant height. This indicates that the plant height is a function of the amount of applied water but not of mulch.

Cob length and perimeter

The interaction of irrigation and mulch exerted significant impact on the length and perimeter of cob (Table 7). The highest cob length (20.67 cm) was recorded from 1_2M_3 and the lowest (17.48 cm) from I_1M_3 (2015-2016). However, in 2014-15, the highest (22.79 cm) and the lowest (17.56 cm) values were recorded from I_4M_4 and 1_4M_1, respectively. So, the interactive effects of irrigation and mulch on cob length were not found prominent for a specific treatment. The highest perimeter of cob (3.827 cm) was obtained from 1_4M_4 and the lowest (3.407 cm) from I_1M_2. It could not build any similarity among treatments of cob length and perimeter over two year findings.

Number of grains per cob

The number of grain per cob significantly varied due to

Table 5. Harvest index (HI) and under different irrigation treatments during 2014-15 and 2015-16.

Treatment	HI (%) for 2015-16	HI (%) for 2015-16
I_1	43.31	34.01
I_2	44.82	35.97
I_3	44.96	35.17
I_4	43.52	36.66
LSD	5.472	6.85
CV (%)	8.71	13.38
F-Test	NS	NS

I_1 Farmer practice, I_2 One irrigation at 4 leaf stage, 1_3: Two irrigations each at 4 leaf stage and 8-10 leaf stage, and I_4: Three irrigations each at 4 leaf stages, 8-10 leaf stage and tasseling stage

Table 6. Harvest index (HI) and under different mulch treatments during 2014-15 and 2015-16.

Treatment	HI (%) for 2015-16	HI (%) for 2015-16
M1	42.72	34.63
M2	44.38	36.88
M3	45.58	35.52
M4	43.93	34.79
LSD	5.472	6.85
CV (%)	8.71	13.38
F-Test	NS	NS

M_1: No mulch, M_2: Mulch with 1 cm thickness, M_3: Mulch with 2 cm thickness, and M4: Mulch with 3 cm thickness.

Table 7. Growth and yield parameters of maize as affected by interaction effect of irrigation and mulch during 2014-15 and 2015-16.

Interaction	Plant height (cm)	Length of cob (cm)	Cob perimeter (cm)	No. of grain/ cob	100-grain wt (g)	Plant height (cm)	Length of cob (cm)	Cob perimeter (cm)	No. of grain/ cob	100-grain wt (g)
	2015-16					2014-15				
I_1M_1	262.5	17.57	3.54	520	29.33	220.5	18.98	3.55	538	37.44
I_1M_2	244.9	18.97	3.407	536	32	233	20.24	3.447	545	38.17
I_1M_3	256.4	17.48	3.41	438	31.33	225.7	20.15	3.71	600	39.42
I_1M_4	251.6	18.75	3.513	519	32.67	221.2	21.17	3.58	544	35.84
I_2M_1	259.2	18.95	3.59	461	34.33	221.3	20.22	3.14	510	36.21
I_2M_2	254.3	18.83	3.52	601	29.33	211.5	21.02	3.56	585	36.18
I_2M_3	265.9	20.67	3.563	570	34	222.5	21.89	3.633	578	37.17
I_2M_4	265.9	19.6	3.537	537	34	214.9	21.06	3.733	483	36.32
I_3M_1	263.5	19.62	3.517	535	34.67	237.3	19.81	3.43	524	36.27
I_3M_2	260.1	18.53	3.437	529	30.67	231.5	18.35	3.447	527	34.82
I_3M_3	256.9	19.57	3.56	616	36	204.2	19.31	3.443	615	40.71
I_3M_4	270.5	19.52	3.57	558	33.33	203.5	21.22	3.6	572	36.97
I_4M_1	274.3	19.43	3.447	557	30.67	226.2	17.56	3.51	533	36.95
I_4M_2	248.9	17.87	3.453	497	34.67	225.7	20.95	3.49	486	35.23
I_4M_3	258.5	19.01	3.523	597	32.67	236.7	19.87	3.523	534	35.75
I_4M_4	258.9	19.47	3.827	567	34.67	223.8	22.79	3.183	491	29.61
LSD	25.17	1.757	0.2436	99.38	6.986	9.374	1.992	0.1924	39.74	2.741
CV(%)	5.9	5.63	4.2	11.2	12.98	5.84	13.6	7.62	10.16	10.42
F-Test	*	*	*	*	NS	*	*	*	*	*

Table 8. Yield of maize as affected by interaction effect of irrigation and mulch during 2014-15 and 2015-16.

Interaction	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)
	2015-16			2014-15		
$I_1 M_1$	7.99	6.64	17.3	6.033	9.447	19.56
$I_1 M_2$	7.663	7.877	18.21	6.337	11.05	17.76
$I_1 M_3$	7.803	7.06	17.27	6.98	11.31	20.5
$I_1 M_4$	7.73	6.783	17.04	6.557	9.877	18.53
$I_2 M_1$	7.67	8.187	18.19	5.89	10.22	18.05
$I_2 M_2$	9.197	8.49	20.61	6.35	9.047	17.76
$I_2 M_3$	7.95	7.803	18.25	7.043	10.29	19.64
$I_2 M_4$	8.613	9.18	20.57	5.8	9.313	18.27
$I_3 M_1$	7.84	8.49	18.79	6.403	9.977	18.96
$I_3 M_2$	7.553	7.09	17.33	6.037	7.04	14.98
$I_3 M_3$	11.3	7.87	22.24	7.447	8.897	16.46
$I_3 M_4$	8.447	8.877	19.94	7.027	14.06	25.04
$I_4 M_1$	7.69	8.567	19.05	6.47	9.333	17.63
$I_4 M_2$	7.43	6.7	16.46	6.68	8.32	17.57
$I_4 M_3$	8.613	9.023	20.38	6.06	8.577	16.52
$I_4 M_4$	8.823	7.9	19.46	4.79	7.763	13.87
LSD	1.244	2.656	3.733	0.6937	1.471	2.173
CV(%)	9.16	20.45	12.09	15.08	21.09	16.54
F-Test	*	NS	*	*	*	*

the interaction effect of irrigation and mulch (Table 7). The highest number of grains per cob (616.0) was obtained from 1_3M_3 and the lowest number (438.0) was obtained from 1_1M_4 in 2015-16. A similar value was obtained from 1_3M_3 (615.0) in 2014-15 but the lowest value (483.0) in this season was obtained from 1_2M_4.

Hundred (100)-grains weight

The 100-grain weight was statistically similar due to the interactive effect of irrigation and mulch (Table 7). 1_3M_3 produced the highest 100-grain weight of 36 g and 1_4M_1 produced the lowest 100-grain weight of 30.67 g. The highest value was similar to treatment 1_3M_3 for this variable but the lowest value decreased with increasing water supply.

Interaction effect of irrigation and mulch on yield

Grain yield

The interaction effect of irrigation and mulch had significant effect on the grain yield of maize (Table 8). The highest grain yield of 11.30 t/ha was recorded from 1_3M_3 and the lowest of 7.430 t/ha was received from 1_4M_2. For this parameter, the values were the highest at the same treatment but lowest with increasing water supply over the two year data.

Straw yield

The interaction effect of irrigation and mulch on straw yield was not significant during 2015-16 but significant during 2014-15. The treatment combination 1_2M_4 produced the highest straw yield of 9.180 tan and 1_1M_1 produced the lowest yield of 6.640 t/ha. In this variable, there was no similarity among the treatments for highest and lowest value over the study years.

Biological yield

The biological yield varied significantly due to the interaction effect of irrigation and mulch (Table 8). The highest biological yield of 22.24 t/ha was recorded from 1_3M_3 and the lowest of 17.04 t/ha from 1_1M_4. For this parameter, the values were found the highest for the same treatment over the two year data.

Interaction effect of irrigation and mulch on harvest index

Harvest index

The harvest index significantly differed due to interactive effect of irrigation and mulch (Table 9). The highest harvest index (50.91%) was recorded from 1_3M_3 and the lowest (40.72%) from 1_4M_1.

Table 9. Harvest index (HI) of maize under the interaction of different mulches and irrigation treatment during 2014-15 and 2015-2016.

Interaction	HI (%) for 2015-16	HI (%) for 2015-16
$I_1 M_1$	46.34	33.84
$I_1 M_2$	42.35	32.64
$I_1 M_3$	45.24	34.16
$I_1 M_4$	45.34	35.39
$I_2 M_1$	42.15	32.77
$I_2 M_2$	45.09	35.72
$I_2 M_3$	43.94	36
$I_2 M_4$	42.04	39.41
$I_3 M_1$	41.66	35.11
$I_3 M_2$	44.82	40.86
$I_3 M_3$	50.91	35.61
$I_3 M_4$	42.46	29.11
$I_4 M_1$	40.72	36.79
$I_4 M_2$	45.26	38.3
$I_4 M_3$	42.22	36.32
$I_4 M_4$	45.88	35.24
LSD	6.318	3.425
CV(%)	8.71	13.38
F-Test	*	*

Table 10. Component of water requirement and water use efficiency in different treatments.

Irrigation treatment	Mulch treatment	Irrigation no	Amount of total irrigation (mm)	Effective rainfall (mm)	Soil moisture contribution (mm)	Total water use (mm)	Water productivity (kg/m^3)
I1	m1	1	41.52	52.04	29.904	123.47	6.47
I1	m2	1	39.88	52.04	29.904	121.82	6.29
I1	m3	1	54.71	52.04	29.904	136.65	5.71
I1	m4	1	49.75	52.04	29.904	131.69	5.87
I2	m1	2	159.37	52.04	23.184	234.59	3.27
I2	m2	2	152.48	52.04	23.184	227.70	4.04
I2	m3	2	137.96	52.04	23.184	213.18	3.73
I2	m4	2	165.74	52.04	23.184	240.96	3.57
I3	m1	3	340.47	52.04	16.3296	408.84	1.92
I3	m2	3	280.97	52.04	16.3296	349.34	2.16
I3	m3	3	285.41	52.04	16.3296	353.78	3.19
I3	m4	3	269.97	52.04	16.3296	338.34	2.5
I4	m1	4	503.61	52.04	10.64	566.29	1.36
I4	m2	4	563.37	52.04	10.64	626.05	1.19
I4	m3	4	421.03	52.04	10.64	483.71	1.78
I4	m4	4	510.62	52.04	10.64	573.30	1.54

Water requirement and water use efficiency

Table 10 represents 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 (WP) for grain production, (11.19 kg/m^3), was obtained from 1_1M_1 (1 irrigation with no mulch) and the lowest (1.36 kg/m^3) from 1_4M_1 (3 irrigation with no mulch). Water productivity decreased with increasing quantity of applied water and decreasing

Table 11. Cost effectiveness of different treatments and irrigations for maize cultivation.

Treatment	Land preparation (tk/ha)	Seed	Fertilizer (tk/ha)	Irrigation (tk/ha)	Straw (tk/ha)	Labor (tk/ha)	Total cost (tk/ha)
$I_1 M_1$	9375	50	28800	3200	-	20000	61425
$I_1 M_2$	9375	50	28800	3200	8335	15000	64760
$I_1 M_3$	9375	50	28800	3200	16667	12000	70092
$I_1 M_4$	9375	50	28800	3200	25000	11000	77425
$I_2 M_1$	9375	50	28800	400	-	20000	58625
$I_2 M_2$	9375	50	28800	400	8335	15000	61960
$I_2 M_3$	9375	50	28800	400	16667	12000	67292
$I_2 M_4$	9375	50	28800	400	25000	11000	74625
$I_3 M_1$	9375	50	28800	1000	-	20000	59225
$I_3 M_2$	9375	50	28800	1000	8335	15000	62560
$I_3 M_3$	9375	50	28800	1000	16667	12000	67892
$I_3 M_4$	9375	50	28800	1000	25000	11000	75225
$I_4 M_1$	9375	50	28800	1800	-	20000	60025
$I_4 M_2$	9375	50	28800	1800	8335	15000	63360
I_4M_3	9375	50	28800	1800	16667	12000	68692
$I_4 M_4$	9375	50	28800	1800	25000	11000	76025

Table 12. Benefit cost ratio at different treatment and irrigations interactions for maize cultivation.

Treatment	Total cost (tk/ha)	Total return (tk/ha)	BCR
$I_1 M_1$	61425	93511.5	1.52
$I_1 M_2$	64760	98223.5	1.52
$I_1 M_3$	70092	108190	1.54
$I_1 M_4$	77425	101633.5	1.31
$I_2 M_1$	58625	91295	1.56
$I_2 M_2$	61960	98425	1.59
$I_2 M_3$	67292	109166.5	1.62
$I_2 M_4$	74625	89900	1.2
$I_3 M_1$	59225	99246.5	1.68
$I_3 M_2$	62560	93573.5	1.5
$I_3 M_3$	67892	115428.5	1.7
$I_3 M_4$	75225	108918.5	1.45
$I_4 M_1$	60025	100285	1.67
$I_4 M_2$	63360	103540	1.63
I_4M_3	68692	93930	1.37
$I_4 M_4$	76025	74245	0.98

quantity of mulch.

Cost effectiveness

The cost effectiveness represents the cost analysis among the treatments to identify the most effect treatment that can be economically benefitted to the farmers. This parameter also detects the benefit cost ratio (BCR) within the treatments that can effortlessly catch out the best interactions. Tables 11 and 12 shows that among all treatments, 1_3M_3 (2 irrigation with 2 cm mulch) gave the highest BCR (1.70) and 1_4M_4(3 irrigation with 3 cm mulch) gave the lowest BCR (0.98). It was observed that BCR, under unique value, was not beneficial to the farmers because the cost was higher than the benefit.

CONCLUSION

From two years' experimental results, it was found that

farmers' practice, I_4 (three irrigations at 4 leaf stage, 8-10 leaf stage and tasseling stage) produced the highest plant height (274.3 cm), which indicated that the plant height was directly related to the amount of applied water. From two year observations, 1_3M_3 (two irrigations at 4 leaf stage and 8-10 leaf stage with 2 cm mulch) produced the highest number of grain per cob and 100-grain weight. The highest grain yield and biological yield 1_3M_3 over the study years. Among all the treatments, 1_3M_3 (two irrigations at 4 leaf stage and 8-10 leaf stage with 2 cm mulch) produced the highest BCR (1 .70). Thus, from this study it is revealed that two irrigations at 4 leaf stage and 8-10 leaf stage with 2 cm mulch are the best options for optimal yield of the selected maize hybrid of BARI hybrid Maize 9 (BHM-9).

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