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EFFECTS OF TILLAGE, MULCH AND IRRIGATION ON MAIZE (*Zea mays* L.) YIELD IN DROUGHT PRONE AREA

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Abstract

The experiment was conducted to study the effect of tillage, mulch and irrigation on soil moisture, yield and yield attributes of hybrid maize (var. BARI Hybrid Maize-6). Two tillage practices (minimum tillage and conventional tillage), two levels of mulches (no mulch and rice straw mulch @ 3 t ha^{-1}) and three irrigation frequencies (one irrigation at 32 days after sowing (DAS), two irrigations at 32 and 55 DAS and three irrigations at 32, 55 and 85 DAS were used as treatment variables. Twelve treatment combinations were assigned in a split-split plot design with three replications. Minimum tillage and mulch conserved more moisture than conventional tillage with no mulch in both years. Minimum tillage and mulch (rice straw) as well as irrigation at 32, 55 and 85 DAS gave higher grain yield than conventional tillage with no mulch and any level of irrigation. Results revealed that application of straw mulch along with three irrigations and any kind of tillage practice might be a suitable combination for obtaining higher yield of maize in drought prone area.

Keywords: Drought, Maize yield, Minimum tillage, Straw mulch

Introduction

Maize, the third most important cereal crop after rice and wheat in Bangladesh, is being grown mostly in the rabi season all over Bangladesh. The present momentum is revolutionary due by far but not limited to high yield potential and extent of diversified usage *viz.* ever-expanding poultry feed market, important ingredients of cattle feed and fish feed, mixing with wheat flour for making bread and many others. With the advancement of time, the production area reached at 202,000 ha in 2009-2010 (BBS, 2014) where it was 10,000 ha in 1995, 137,000 ha in 2005-2006 (Hasan *et al.,* 2007) and the production was approximately 2.5 million tons in 2009-2010 (BBS, 2014). Maize production in Bangladesh increased significantly from 1,954,000 in 2011 to 4,700,000 t in 2020 rising at an increasing annual rate (a maximum of 17.1% in 2019 which then decreased to 14.6% in 2020) (BBS, 2021). The yield is now stagnated at around 6.5 t ha^{-1} (BBS, 2016 and AIS, 2014) in the ecologically unfavourable areas but the average yield was targeted by the government at 8.5 t ha^{-1} by 2030. Nevertheless, in the year 2015-2016, the production of maize could meet only around 65% of the national maize demand for poultry and other feeds.

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The traditional cropping system of the Chapainawabganj area has been T. Aman rice grown in the Kharif-II season (June/July-Oct/Nov) followed by fallow. Now rice-based intensive cropping systems are followed in this area. However, most of the area remains fallow during moisture deficiency periods due to deficiency of soil moisture for unavailability of groundwater and attenuated recharging of groundwater. Though coverage of irrigation and rain-fed rabi cropping have been increased, around 40-50 % of the HBT keeps on fallow after the harvest of T. Aman rice (BBS, 2016). Accordingly, maize crop in rice–maize systems in South Asia and Bangladesh is put forward to grow in the fallow period rather than rice-rice system because of increased yield, profit potential and efficient water use (Gathala *et al.*, 2013). The repeated current practice of growing transplanted rice through puddling and maize with conventional tillage degrades soil structure, delays maize sowing and reduces its yield potential, increases energy and labour requirements, ultimately leading to high production costs. Conservation agriculture (CA)-based tillage and crop establishment options may hold the potential to overcome such problems (Gathala *et al.,* 2013; Alam, 2018; Bell *et al.*, 2019). The development of conservation tillage practices for dry land (drought-prone) crop production has been and will be a dynamic process. Conservation agriculture can increase infiltration and reduce runoff and evaporation compared to conventional tillage and zero tillage with mulching and irrigation (Salahin, 2017; Islam, 2016). Mulching conserves soil water in a season with long periods without rain. Consequently, more soil water is conserved enabling crops to grow during short-term dry periods (Alam *et al*., 2014). Tillage and residue mulching management may significantly affect crop yields during years of poor rainfall distribution (Johnston and Hoyt, 1999).

The northwestern districts namely Rajshahi, Dinajpur, Rangpur, Bogura and Pabna are particularly drought-prone and receive only 127 mm of rainfall annually (Gathala *et al.*, 2013). About 5.73 m ha of the problem soils of Bangladesh is subjected to moderate and/or severe drought (Khan *et al.*, 2008). The impact of drought spreads disproportionately amongst different regions of Bangladesh. This is an expensive operation that cannot be deployed regularly in dry land farming. Mulch ameliorated the hydrothermal regime of the soil, improved the vegetative and flowering performance and significantly increased the fruit yield over bare ground (Agele *et al.,* 2000). No-till without or with little mulch is not a sustainable practice. Almost all environmental benefits of minimum tillage are due to the mulch cover at the soil surface. Minimum tillage should out-yield tilled crops in areas where drought stress is a problem due to the water conserved by the mulch cover (Agronomy Guide, 2007-2008). To cope with the challenge to feed the large population of Bangladesh, the extent of drought-prone areas and their according importance must add new momentum to the planning in getting food-self-sufficiency. Therefore, this study was undertaken to develop an appropriate tillage method, mulching and irrigation frequency for retention of soil moisture and productivity of maize in drought prone areas.

Materials and Methods

The experiment was conducted at Horticulture Centre, Chapainawabganj under Soil Science Division, BARI, during rabi season of 2011-2012 and 2012-2013. The geographical position of the experimental site was 24º35" N latitude and 88º16" E longitude. The site belongs to Agroecological Zone -11 having Calcareous Dark Grey Floodplain soils with some Calcareous Brown Floodplain soils under sub-group Typic Haplaquepts and the order Inceptisols. The climate is generally marked by high temperature (6.2°C in January to 42.9°C in June), considerable humidity and moderate rainfall (137 ± 323 mm). The hot season commences early in March and continues till the late of July. The maximum and minimum temperature during the crop growing period was 6.2 °C in January and 40.5°C in May in 2011-2012 and 6.5°C in January and 41.2°C in May in 2012-2013. The crop received 261.5 mm and 255.3 mm of total rainfall during the crop season of 2011-2012 and 2012-2013, respectively. Most of the rainfall received during the growing seasons occurred in May (harvesting time) (Alam, 2018). The detailed information about the physico-chemical characteristics of soils studied is presented in Tables 1a and 1b.

Soil moisture, bulk density and particle density were determined by the gravimetric method, core sampler and pycnometer method (Karim *et al.*, 1988). Soil pH (1: 2.5, soil: water) was measured using a glass electrode pH meter (Ghosh, 1983); available P and organic C were measured by Olsen and wet oxidation method according to Jackson, (1973). Total N, available S, and Ca were determined by micro-Kjeldahl method, turbid metric method and complex metric method, respectively (Page *et al.*, 1989). Exchangeable K and Mg were measured using NH_4OAC extraction method and particle size distribution was determined according to Black, (1965). Available Zn, Cu, Fe and Mn were determined by using diethylene triamine pentaacetic acid (DTPA) extraction method (Lindsay and Norvell, 1978). Soil field capacity was measured using pressure plate apparatus.

Twelve treatment combinations comprised two tillage practices *viz.* minimum tillage (a furrow was made by furrow opener), conventional tillage (tillage was done by three passes of a power tiller); two levels of mulching viz. no mulch and rice straw mulch @ 5 t ha^{-1} and three irrigation frequencies viz. one irrigation at 32 days after sowing (DAS), two irrigations at 32 and 55 DAS and three irrigations at 32, 55 and 85 DAS. The experiment was assigned in a split-split plot design with three replications where tillage practices were allocated in the main plot, mulch levels were in the sub-plot and irrigation was in the sub-sub plot. The unit plot size was 9.0 m × 6.0 m. Seeds of maize (var. BARI Hybrid Maize-6) were sown on 24 and 26 December 2011 and 2012, respectively maintaining 75 cm × 25 cm spacing. A fertilizer dose of 255 kg N, 55 kg P, 100 kg K, 40 kg S and 1 kg B ha^{-1} were applied in form of urea, triple superphosphate, muriate of potash, gypsum and borate, respectively. In addition, cowdung was applied at the rate of 5 t ha^{-1}. One-third of nitrogen and other fertilizers were applied at the time of final land preparation and the remaining nitrogen was applied in two equal splits at 30 and 55 DAS. All intercultural operations such as weeding, earthing up, fertilizer application etc. were done as and when required. The crop was harvested on 5 & 8 May 2012 and 2013, respectively. The seeds were sun-dried and weighed. Data on yield and yield contributing characters were taken. Data that were collected were subjected to analysis of variance and Duncan's Multiple Range Test (DMRT) was used for mean separation (Gomez and Gomez, 1984).

Table 1. Physico-chemical characteristics of experimental soils at Chapainawabganj

1a) Physical properties of soil

Soil depth (cm)	Bulk density ($g\ cm^{-3}$)	Particle density ($g\ cm^{-3}$)	Porosity (%)	Field capacity (%)	Textural class
0-15	1.45	2.54	42.91	33.42	Clay loam

1b) Chemical properties of soil

Soil depth (cm)	pH	OM	Total N	Ca	Mg	K	P	S	B	Cu	Fe	Mn	Zn
		%		meq 100 g^{-1}			μg g^{-1}						
0-15	7.2	1.32	0.063	11	2.52	0.10	12	13	0.2	1.6	58	10	2.2
Critical level				2.0	0.8	0.2	14	14	0.2	1	10	5	2

Results and Discussion

Effects of tillage on soil moisture

Tillage practices resulted in varied soil moisture on different days of sowing (Fig. 1 and 2). Conventional and minimum tillage failed to show significant differences among them in soil moisture content in any of the growing seasons. The changing of soil moisture pattern was almost similar in both the years. The highest soil moisture was observed in 2012-2013. It was observed that minimum tillage contained slightly higher moisture than conventional tillage over the years.

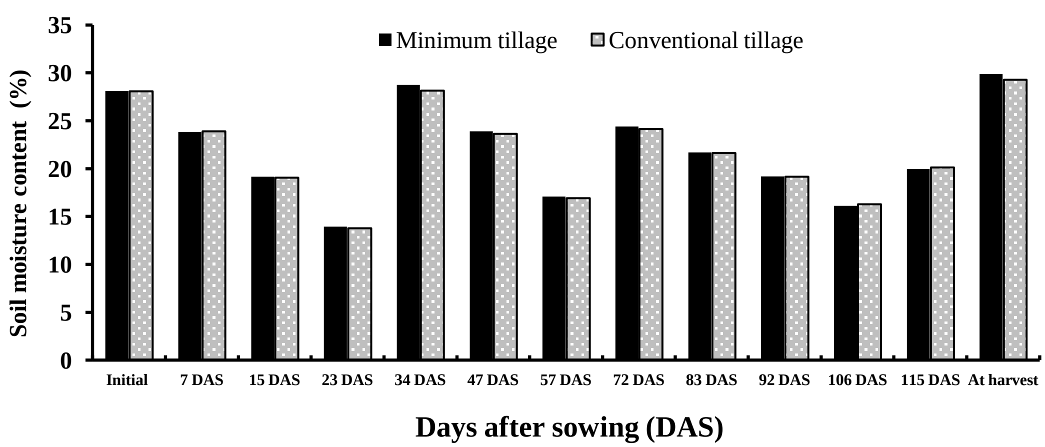

Fig. 1. Effects of tillage practices on soil moisture content at different days of sowing (2011-2012)

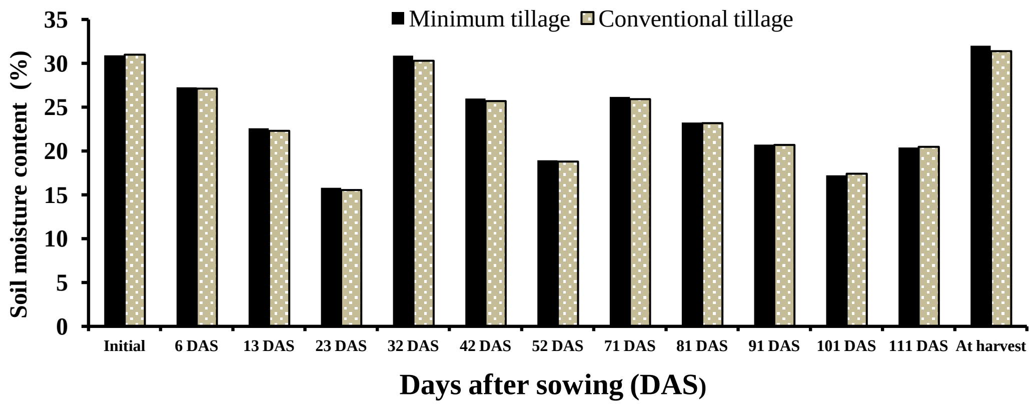

Fig. 2. Effects of tillage practices on soil moisture content at different days of sowing (2012-2013)

Effect of mulch on soil moisture

Mulching practices showed varied soil moisture retained in the soil on different days of sowing in both the years (Figs. 3 and 4). Significantly higher soil moisture retention occurred through mulching than no mulch. Fig. 3 and 4 revealed that comparatively higher soil moisture during 2012-2013 was observed than in 2011-2012. Yang *et al.* (2006) cited that the straw mulch is effective in conserving soil water and maintaining the microbial environment favorable for their activities. Mulch conserves soil moisture and prevents soil moisture from flowing back to the surface (Bu *et al.*, 2002).

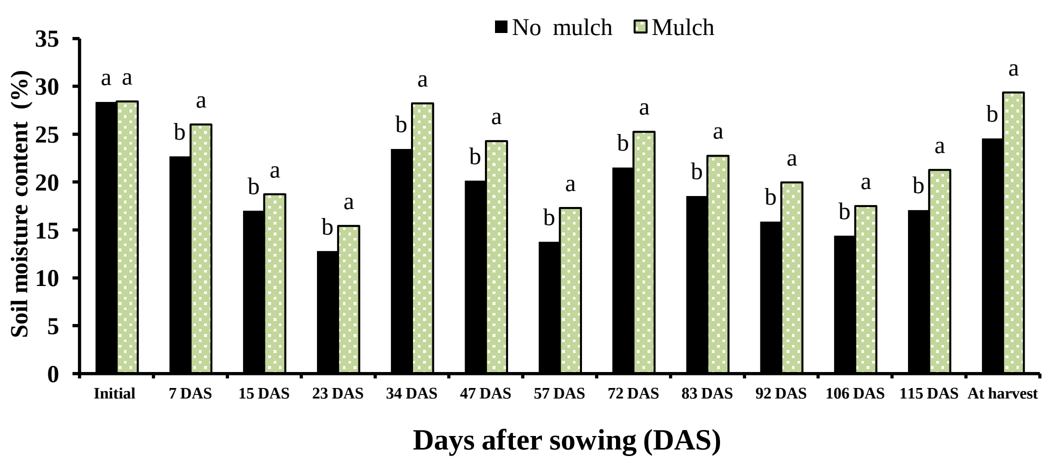

Fig. 3. Effects of mulching on soil moisture content at different days of sowing (2011-2012)

Effects of irrigation on soil moisture

Irrigation practices showed a variation in soil moisture retention over cropping seasons in both 2011-2012 and 2012-2013 (Figs. 5 and 6). From sowing up to 23 February, there was no variation in soil moisture retention due to irrigation water application but significant changing occurred among irrigation practices from 9 March to 23 April.

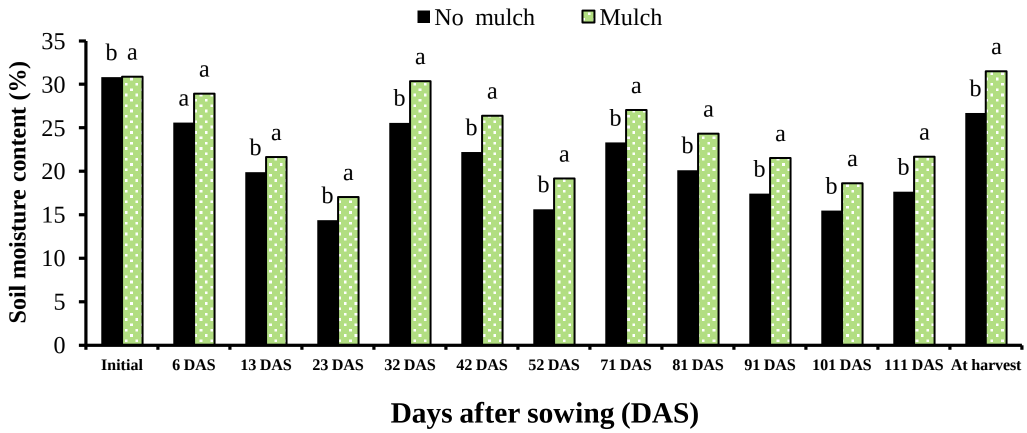

Fig. 4. Effects of mulching on soil moisture content at different days of sowing (2012-2013)

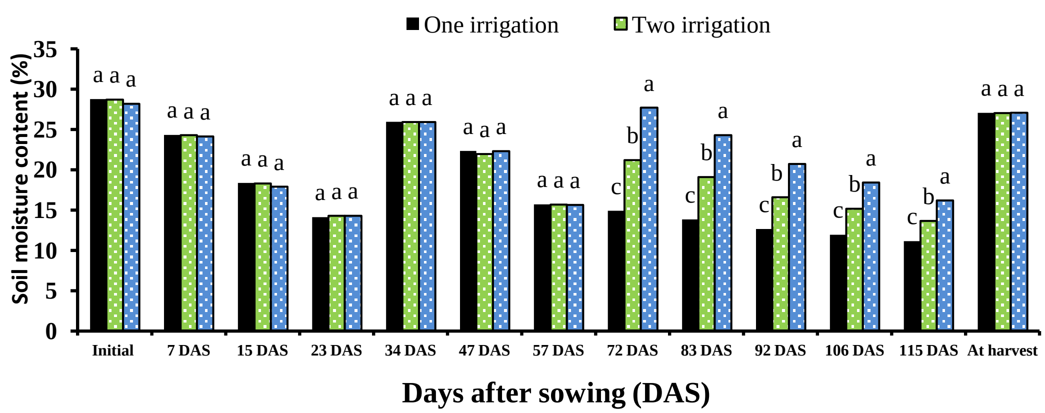

Fig. 5. Effects of irrigation on soil moisture at different days of sowing (2011-2012)

At the final date of sampling, soil moisture was similar to irrigation practices during the maize growing season in 2011-2012. As irrigation was applied on 23 February for all irrigation practices, the variation started getting visible from the date. The increase in moisture condition in three irrigation practices followed by two irrigation practices was for the increased number of irrigation applied at the different intervals while one irrigation treatment only received irrigation on 23 February (Figs. 5 and 6).

Effects of tillage practices on yield contributing characters and yield of maize

Tillage practices showed significant influence on cob length and grain yield of maize. Plant height, cob diameter and 100-seed weight were not found significant due to tillage practices (Table 2). Minimum tillage produced larger cob (15.1 cm) and higher grain yield (5.41 t ha^{-1}) than conventional tillage which produced smaller cob (14.7 cm) and lower grain yield (5.41 t ha^{-1}). The increased yield in minimum tillage can be attributed to the higher availability of nutrients with increased soil moisture status (Busari *et al.,* 2015).

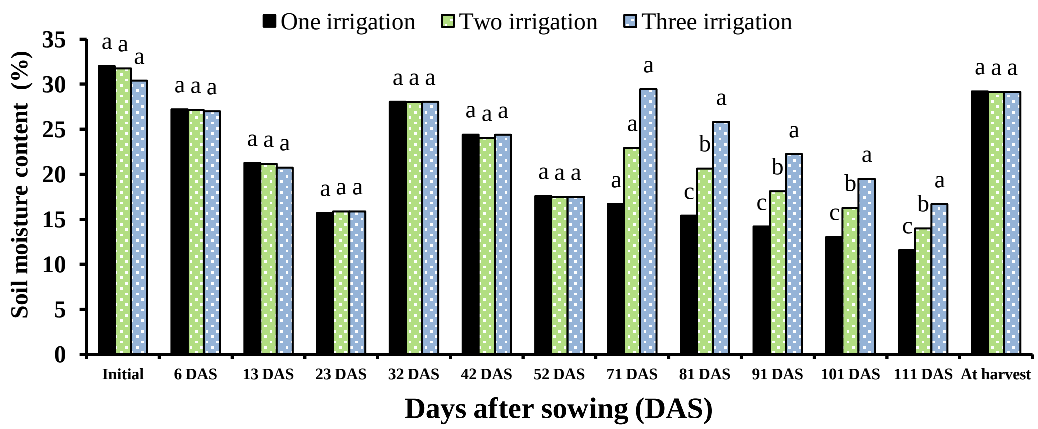

Fig. 6. Effects of irrigation on soil moisture at different days of sowing (2012-2013)

Effects of mulching on yield contributing characters and yield of maize

The application of mulch had a significant effect on the yield and yield attributes of maize (Table 2). Mulching practice gave higher plant height, longer cob with higher cob diameter, number of grains cob^{-1}, 100 seed weight and grain yield than that of under no mulch practice. Mulch practices conserved higher moisture over the growing season. The increased moisture in mulch practice would make nutrients available and continue the in-season turnover of the nutrients over the season of maize growth (Bu *et al.,* 2002).

Effects of irrigation on yield contributing characters and yield of maize

Irrigation frequency showed significant differences in yield and yield attributes of maize (Table 2). Three times irrigation at 32, 55 and 85 DAS performed better than double at 32 and 55 DAS and single irrigation at 32 DAS and the trends showed as three irrigations > two irrigations > single irrigation. The results are in agreement with Amin *et al.,* (2015) who stated that the irrigation frequency had a clear-cut effect on the total dry matter weight and grain yield of maize. Kara and Biber, (2008) also reported that the yield of maize increased significantly due to the application of irrigation.

Table 2. Effects of tillage, mulch and irrigation practices on the yield contributing characters and yield of maize (pooled data)

Treatment	Plant height (cm)	Cob length (cm)	Cob diameter (cm)	Grains cob^{-1} (nos.)	100-seed weight (g)	Grain yield ($t\ ha^{-1}$)
Tillage practice						
Minimum tillage	159	15.1 a	3.6	312	29.0	5.41 a
Conventional tillage	144	14.7 b	3.4	268	28.3	4.97 b
$LSD_{0.05}$	NS	0.3	NS	NS	NS	0.21
Mulching						
Mulch	167 a	16.2 a	3.7 a	373 a	29.7 a	6.07 a
No Mulch	135 b	13.7 b	3.3 b	207 b	27.7 b	4.32 b
$LSD_{0.05}$	20.9	1.9	0.14	37	1.5	0.30
Irrigation frequency						
One irrigation	120 c	13.5 b	3.3 b	217 c	27.5 c	3.01 c
Two irrigation	148 b	14.2 b	3.4 b	274 b	28.4 b	5.50 b
Three irrigation	185 a	17.1 a	3.9 a	379 a	30.1 a	7.07 a
$LSD_{0.05}$	4.4	1.2	0.2	22	0.5	0.45
CV (%)	13.6	6.9	5.8	14.9	8.9	9.6

NS = Not significant, Means followed by same letter (s) in a column do not differ significantly at 5% level of significance

Combined effects of tillage and mulch on the grain yield of maize

The tillage method and mulching combination noted significant variation in the grain yield of maize (Fig. 7). Both the tillage practices with mulching gave the maximum yield relative to both tillage practices without mulching. The yield increased due to the application of mulch with MT and mulch with CT was 1.41 and 2.08 t ha^{-1} which was about 30 % and 53 %, respectively over no mulch irrespective of tillage methods. Tillage method and mulching combination kept the surface layer wetter that exchanged water uptake with increasing vegetative growth, grains cob^{-1} and 100-grain weight and ultimately increased yield. Similar results were obtained by Khurshid *et al.* (2006) who stated that the integrated use of tillage and mulch were beneficial in improving the growth and yield of maize.

Combined effects of tillage and irrigation on the yield contributing characters and yield of maize

The combined effects of tillage and irrigation frequency were found to be significant for plant height, cob length, the number of grains cob^{-1} and grain yield of maize with an exception to cob diameter and 100-grain weight (Table 3). Minimum tillage with 3 irrigations produced the tallest plant (194 cm) which was statistically identical to conventional tillage with 3 irrigations. The shortest plant (118 cm) was obtained from lower levels of irrigation irrespective of tillage methods. Both tillage practices with 3 irrigations gave the longest cob (17.7 cm) and conventional tillage with single irrigation produced the shortest cob (13.0 cm). Minimum tillage with 3 irrigations gave the maximum number of grains cob^{-1} (419) and it was statistically different from all other treatment combinations. The highest grain yield (7.49 t ha^{-1}) of maize was obtained from minimum tillage with 3 irrigations which was similar to conventional tillage with 3 irrigations. Minimum tillage with 2 irrigations and conventional tillage with 2 irrigations gave statistically identical yields. The lowest yield (2.85 t ha^{-1}) was obtained from minimum and conventional tillage with single irrigation. Minimum tillage practices conserved more soil moisture, especially after several days of irrigation water application when crops undergo moisture stress. By retaining increased moisture, it might help increase root growth (Newell and Wilhelm, 1987) and acquire more nutrients from the rhizospheric zone (Alam *et al.*, 2014).

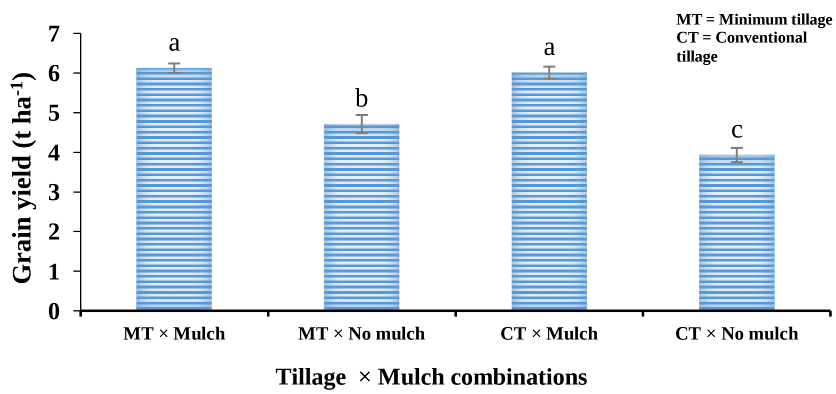

Fig. 7. Effects of tillage and mulching combination on the grain yield of maize (average of two years). Vertical bars represent standard errors of mean (±).

Table 3. Combined effects of tillage and irrigation on the yield contributing characters and yield of maize (pooled data)

Interaction of tillage × irrigation	Plant height (cm)	Cob length (cm)	Cob diameter (cm)	Grains cob^{-1} (nos.)	100-grain weight (g)	Grain yield (t ha^{-1})
MT × 1 irrigation	123 de	14.1 bc	3.5	221 d	28.0	3.18 c
MT × 2 irrigation	159 bc	13.7 bc	3.5	298 c	28.6	5.58 b
MT × 3 irrigation	194 a	17.7 a	3.9	419 a	30.6	7.49 a
CT × 1 irrigation	118 e	13.0 c	3.2	213 d	27.1	2.85 c
CT × 2 irrigation	137 cd	14.7 b	3.3	293 c	28.3	5.43 b
CT × 3 irrigation	177 ab	16.4 a	3.8	340 b	29.7	6.64 a
$LSD_{0.05}$	6.3	1.7	NS	32	NS	1.02
CV (%)	13.6	5.4	4.3	11.7	6.7	7.6

NS = Not significant, Means followed by same letter (s) in a column do not differ significantly at 5% level of significance

Combined effects of mulch and irrigation on the yield contributing characters and yield of maize

The combination of mulch and irrigation exerted a significant influence on plant height, cob length, a number of grains cob^{-1} and grain yield of maize. Cob diameter and 100 grain weight were not found significant due to mulching and irrigation (Table 4). All the yield parameters performed the best in the mulch with 3 irrigations combination compared to other combinations. Significantly the highest grain yield (8.28 t ha^{-1}) was obtained from mulch with 3 irrigations and the lowest (3.53 t ha^{-1}) from no mulch with single irrigation. The results showed that higher maize yield in this drought-prone region may be achieved by using a proper combination of mulch and irrigation. Similar results were obtained by Gill *et al.*, (1996) in a semi-arid sub-tropical monsoon region, Ludhiana, India.

Table 4. Combined effects of mulch and irrigation on the yield contributing characters and yield of maize (pooled data)

Interaction of tillage × irrigation	Plant height (cm)	Cob length (cm)	Cob diameter (cm)	Grains cob^{-1} (nos.)	100 grain weight (g)	Grain yield (t ha^{-1})
Mulch × 1 irrigation	125 cd	14.1 bc	3.5	291 c	28.6	3.73 e
Mulch × 2 irrigation	166 b	15.4 b	3.5	373 b	29.4	6.19 b
Mulch × 3 irrigation	211 a	19.2 a	4.2	456 a	31.0	8.28 a
No mulch × 1 irrigation	116 d	13.1 c	3.2	143 e	28.6	3.53 e
No mulch × 2 irrigation	130 c	13.0 c	3.3	176 d	27.5	4.81 d
No mulch × 3 irrigation	159 b	15.0 b	3.5	303 c	29.2	5.85 c
$LSD_{0.05}$	6.3	1.7	NS	32	NS	0.85
CV (%)	10.8	6.9	5.1	13.7	7.2	9.4

NS = Not significant, Means followed by same letter (s) in a column do not differ significantly at 5% level of significance

Conclusion

Results revealed that mulching under both tillage practices performed better in terms of moisture conservation than the tillage practices without mulches. Hence, the climate-related water stress may be successfully managed by minimum tillage along with three times irrigation at 32, 55 and 85 DAS and mulch @ 5 t ha^{-1} for obtaining a higher yield of maize.

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Conflicts of Interest

The authors declare no conflicts of interest regarding publication of this paper.

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