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EFFECT OF MULCH, PLANTING TECHNIQUES AND INCREASED MAD LEVEL ON YIELD AND WATER PRODUCTIVITY OF MAIZE UNDER A SEMI-ARID ENVIRONMENT

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A field study was conducted to estimate the combined effects of delayed irrigations under increased Management Allowed Depletion (MAD) level and moisture conservation practices on the yield and water productivity of maize crop. The experiment was carried out at Water Management Research Center (WMRC), University of Agriculture, Jhang Road Faisalabad. Total eight treatments, including conventional ridge sowing (CRS) without mulch (CRS + no mulch), conventional ridge sowing with mulch (CRS + mulch), bed-furrow sowing (BFS) without mulch (BFS + no mulch), bed-furrow planting with mulch (BFS + mulch), bed-furrow planting without mulch and with 60% MAD (BFS + no mulch + 60% MAD), bed-furrow planting with mulch and 60% MAD (BFS + mulch + 60% MAD), bed-furrow planting without mulch and 70% MAD (BFS + no mulch + 70% MAD), bed-furrow planting with mulch and 70% MAD(BFS + mulch + 70% MAD) were randomly allocated in randomized complete block design (RCBD).Each treatment was further replicated thrice in order to reduce the experimental error. Results showed that BFS + mulch + 60% MAD treatment increased the grain yield by 23% to 25%, total dry matter (TDM) by 7% to 10%, plant height by 11% to 12% and harvest index by 16% to 19% as compared to CRS + no mulch treatment. Furthermore, BFS with 70% MAD under with and without mulch resulted a significant reduction in plant traits. Additionally, delayed irrigation application reduced the water use by maize due to decrease in application losses on BFS under wheat straw mulch. It is concluded that mulching in BFS could be beneficial to harvest maximum yield of maize under deficit as well as normal irrigation.
Keywords: Mulch, Planting techniques, Delayed irrigation, Water productivity.

INTRODUCTION

Globally, four billion people are facing water supply shortage severely (Mekonnen and Hoekstra, 2016). Moisture conservation practices can increase the sustainable yield and water productivity which could help to meet the food demands, estimated to increase up to 70-100% by 2050 (Boyer *et al.*,2013; Dinar *et al.*, 2019). Pakistan is facing water scarcity for the last few decades and has become most vulnerable country (8th rank) due to climatic changes. Its economy is mostly based on agriculture that is consuming almost 91.6% water resources (Ahmed, 2019). Approximately, 80-90% land areas are irrigated through unproductive irrigational water (Tiercelin and Vidal, 2006) which caused the salinity (Qadir *et al.*, 2014). Many farmers failed to adapt modern technologies like drip and sprinkler irrigation (Siyal, 2016), therefore, economical technologies which are easy to handle and functional should be introduced in under-developed countries. Delayed irrigation is effective and water saving practice to get sustainable production of crop yield, suitable for dry region and water scarce areas (Chartzoulakis and Bertaki, 2015; Chai *et al*., 2016), that reduces drought impacts (Stikić *et al.*, 2014), reduces salinity level on irrigated lands (Khamraev and Bezborodov, 2016) and conserves the soil moisture (Mellouli *et al.,* 2000). Evaporation rate directly affects the soil moisture level which can be decreased by monitoring the factors like capillary action, water vapor pressure (Li *et al.,* 2015) by using mulching technique. Mulching practices can alleviate the water shortage that reduces the vaporization from soil (Chukalla *et al.,* 2015; Rahman *et al.,* 2016; Chen *et al.,* 2019), increase production (Arash, 2013) and reduce the weed invasion (Kabir *et al.,* 2016; Nawaz *et al.,* 2017).

Yield is significantly reduced under delayed irrigation but water use efficiency increases (Fan *et al.*, 2019). Globally, maize is third most cultivated crop after wheat and rice. It is a short duration crop of about 100-110 days (Sun *et al.,* 2007 and Ahmad *et al.*, 2020), good source of nutrition (Shah *et al.,* 2016), source of fodder and feed for animals (Martinello and Giner, 2010).It is mostly cultivated in rain fed and irrigated regions (Siyal, 2009). It is cultivated on almost 1.1 million hectares land area and yields 3.313 million tons that produces 3264kg ha^{-1}average grain yield (Tahir *et al.*, 2009). Maize crop is cultivated in almost all provinces of Pakistan but mostly grown in Punjab and KPK (Tahir and Habib, 2013).Water scarcity affects maize productivity by affecting all other ecological parameters including decrease in size of leaf and height (Rengasamy *et al*., 2010). Maize crop is more sensitive at reproductive stages during tasseling, silking and grain filling as compared to vegetative stages under water deficit conditions (Salah *et al.*, 2010). Keeping in view above facts, the goal of this research was to investigate the impacts of mulching and water deficit in terms of delayed irrigations under increased MAD levels on water productivity and yield of maize.

MATERIALS AND METHODS

Experiment was conducted at the farms of Water Management Research Centre (WMRC), University of Agriculture, Faisalabad, during the Kharif period of 2017 and 2018 on maize crop. The site is located at 31˚North (longitude) and 73˚ E East (latitude) and 184m above sea level in the irrigated agricultural area of central Punjab, Pakistan (ASP, 2006). Extreme weather conditions are observed during summer and winter in Faisalabad. The maximum and minimum temperature in summer reached up to 50˚C and 27˚C. Winter maximum and minimum temperature was found to be 23˚C and 6˚C, respectively. Average annual rainfall was recorded about 439mm. Soil texture was found to be the sandy loam (Anjum, 2014).

The experiment involved a two years data (Kharif-2017 and Kharif-2018) in Randomized complete block design with eight treatments and three replicates. Maize crop was planted in two main plots with straw mulch and without mulch. Each plot was further divided into four sub-plots with ridge sowing with conventional irrigation and bed-furrow planting with three different (Management Allowed Depletion) MAD levels *i.e.*, 50, 60, and 70% MAD. Wheat straw was used as mulch. The eight treatments were T_1 = Conventional Ridge Sowing without Mulch (CRS + no mulch), T_2=Conventional Ridge Sowing with Mulch (CRS + mulch), T_3=Bed-Furrow planting without mulch (BFS + no mulch) and 50% MAD,T_4=Bed-Furrow planting with mulch and 50% MAD (BFS + mulch), T_5=Bed-Furrow planting without mulch and 60% MAD (BFS + no mulch + 60% MAD),T_6=Bed-Furrow planting with mulch and 60% MAD (BFS + mulch + 60% MAD) , T_7=Bed-Furrow planting without mulch and 70% MAD (BFS + no mulch + 70% MAD) and T_8=Bed-Furrow planting with mulch and 70% MAD (BFS + mulch + 70% MAD). The adopted or most commonly used size of bed-furrow system for maize was 60 cm bed and 30 cm furrow. The row to row distance was maintained at 45 cm for bed-furrow and in ridge-furrow the row to row distance was maintained at 67.5 cm. Source of irrigation water supply was canal water and as well as tube well water. Experimental layout is shown in Figure 1.

Soil physical and chemical properties: Soil physical and chemical properties were examined using the standard procedures. Physical properties of soil include texture, structure, infiltration, bulk density and field capacity. Soil samples were taken from different locations (four at corner side and one at center) in field at four different depths of soil *i.e.*, 0-15cm, 15-30cm, 30-45cm and 45-60 cm and used in the laboratory for analysis with the help of hydrometer method. For different soil layers percent of sand varied from 62.39 to 67.25, silt it varied from 22.42 to 16.75, while for clay the values varied from 15.31 to 14.92.Increasing trend of bulk density was observed with the increasing depth. Average respective values of bulk densities were 1.54, 1.56, 1.58 and 1.6 g/cm^3. Amin *et al.* (2015) provided the same outcomes for sandy loam soil types.

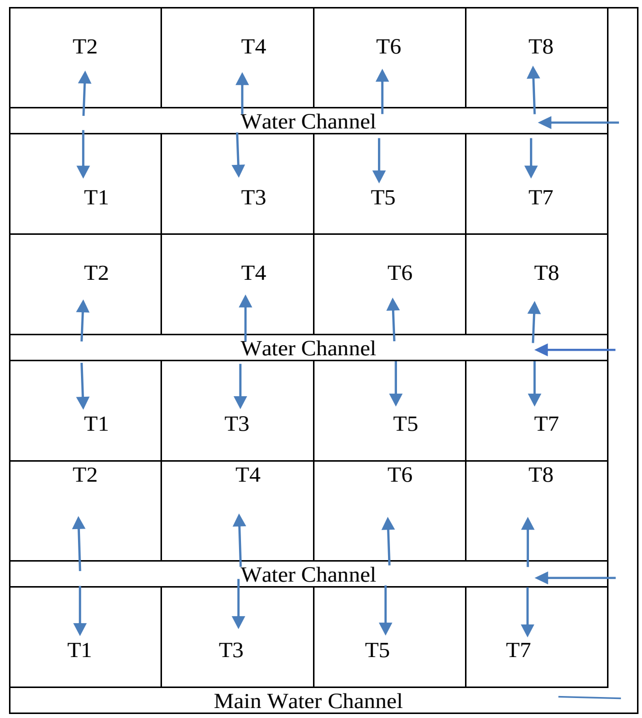


Figure 1. Experimental layout

Infiltration rate varied from 0.79 to 0.89 cm/ hr, and the average infiltration was recorded as 0.81 cm/hr. Previously, Gupta (1990), Anjum (2014), Amin *et al.* (2015) and Nawaz (2018) also calculated the same range of results for the sandy loam soils. The overall wilting point obtained was 8.35%.The resulted values of permanent wilting point were in accordance with the values reported by Nawaz (2018) and Anjum *et al.* (2104) for the soil type. Field capacity for soils at location 1 and 4 ranged from 18.9% to 19.1 %, while values for location 1 and 3 ranged from 19.0 % and 19.3 % at some depths. Calculated results are in the range of results obtained by Nawaz *et al.* (2017), Anjum *et al.* (2014) and Jabro *et al.* (2009) for similar soil types. Soil chemical properties were investigated in the laboratory including electrical conductivity (EC in dS/m), pH, ratio of NPK and organic matter as shown below in the Table 3.

Table 1. Physical Characteristics of Soil

Sample No.	Infiltration Rate (cm/h)	Soil Depth (cm) 0-15	16-30	31-45	46-60
		Bulk Density (g/cm^3)			
1	0.89	1.50	1.52	1.55	1.61
2	0.84	1.54	1.56	1.58	1.59
3	0.76	1.57	1.61	1.60	1.60
4	0.81	1.51	1.59	1.58	1.59
5	0.79	1.61	1.53	1.59	1.57
Average	0.81	1.54	1.56	1.58	1.60

Table 2. Experimental Field Capacity and Permanent Wilting Point of Soil

Locations	Depths (cm)	Field capacity (m^3/m^3)	Permanent wilting point (m^3/m^3)
1	0-15	19.10	8.40
	16-30	19.00	8.40
	31-45	18.90	8.20
	46-60	18.90	8.20
	Average (0-60)	18.98	8.30
2	0-15	19.30	8.50
	16-30	19.20	8.50
	31-45	19.10	8.50
	46-60	19.10	8.30
	Average (0-60)	19.18	8.45
3	0-15	19.10	8.40
	16-30	19.10	8.40
	31-45	19.00	8.40
	46-60	19.00	8.30
	Average (0-60)	19.05	8.37
4	0-15	19.10	8.50
	16-30	19.00	8.30
	31-45	18.90	8.30
	46-60	18.90	8.30
	Average (0-60)	18.98	8.35
Overall Average		19.05	8.37

Table 3. Chemical Properties of the Soils of Study Area

Parameters	Sample locations 1	2	3	4	Average
ECe (ds/m)	0.82	0.85	0.77	0.83	0.817
pH	8.01	7.87	7.96	7.84	7.92
Nitrogen %	0.0175	0.0315	0.0140	0.0245	0.021
Phosphorus (ppm)	6.1	5.8	4.2	7.2	5.82
Potassium K (ppm)	120	80	110	101	102.7
Organic matter %	0.35	0.63	0.28	0.49	0.43

***Irrigation Scheduling*:** Irrigation scheduling was done by soil moisture monitoring on daily basis. First irrigation was applied after one week of sowing to all the treatments. Available water was found by using the below formula.

***Available Water = F.C- PWP*:** Where, an F.C stand for field capacity and PWP represents the permanent wilting point. The depth of the irrigations was found with the following formula.

***Depth of Irrigation= (F.C- M.C) /100× Root Zone Depth*:** The root zone depth was determined based on guidelines provided in FAO Irrigation and Drainage paper 24. As the crop was grown in 9 of August 2017/18, so the rooting depth values for maize crop were taken as 0.4m for the month of September, 0.9m for October and 1.2m for November and December. Depth of water to be applied was determined by using the net required depths divided with application efficiency.

***Gross Depth Applied= Net Required Depth/ Application Efficiency*:** Application efficiency was taken as 0.6 for furrow-ridge treatments and 0.7 for furrow-bed treatments. Total number of irrigations applied to treatments T_1, T_2, T3 and T_4 were twelve, while ten irrigations were applied to T_5, T_6, T_7 and T_8treatments having MAD based irrigation scheduling. Discharge of the water channel was measured at the time of irrigation using cut-throat flume. Then to apply the gross depth, time for irrigation was calculated with the formula as below;

$$Q \times t = A \times D$$

Where, Q is discharge, t is the time of irrigation, A represents the area and D is the gross depth shows the depth. Soil moisture monitoring and irrigation scheduling performed for all the eight treatments is presented graphically in Figure: 2, while the summary regarding dates of irrigations and depths of water applied on each irrigation and for each treatment, is presented in Table 4.

Table 4: Dates and depths of irrigation

Date of irrigation	Depths of irrigations (mm) T1	T2	T3	T4	T5	T6	T7	T8
16/08/2017	75	75	75	75	75	75	75	75
23/08/2017	75	75	75	75	75	75	75	75
30/08/2017	50	50	50	50	50	50	50	50
8-09-2017	50	50	50	50	50	50	50	50
18/09/2017	83	80	58	48	80	67	68	38
26/09/2017	49	42	45	43	-	-	-	-
27/09/2017	-	-	-	-	48	47	-	-
28/09/2017	-	-	-	-	-	-	58	56
02/10/2017	105	101	90	91	-	-	-	-
09/10/2017	105	101	90	91	116	102	-	-
10/10/2017	-	-	-	-	-	-	129	120
19/10/2017	99	97	101	93	-	-	-	-
20/10/2017	-	-	-	-	112	119		
24/10/2017	-	-	-	-	-	-	125	115
30/10/2017	107	109	98	95	-	-	-	-
01/11/2017	-	-	-	-	205	184		
08/11/2017	-	-	-	-	-	-	164	169
10/11/2017	138	130	123	123	-	-	-	-
14/11/2017	-	-	-	-	140	142	-	-
22/11/2017	138	142	123	123	-	-	-	-
23/11/2017	-	-	-	-	-	-	169	145
Total Depth	1074	1052	978	957	951	911	963	893

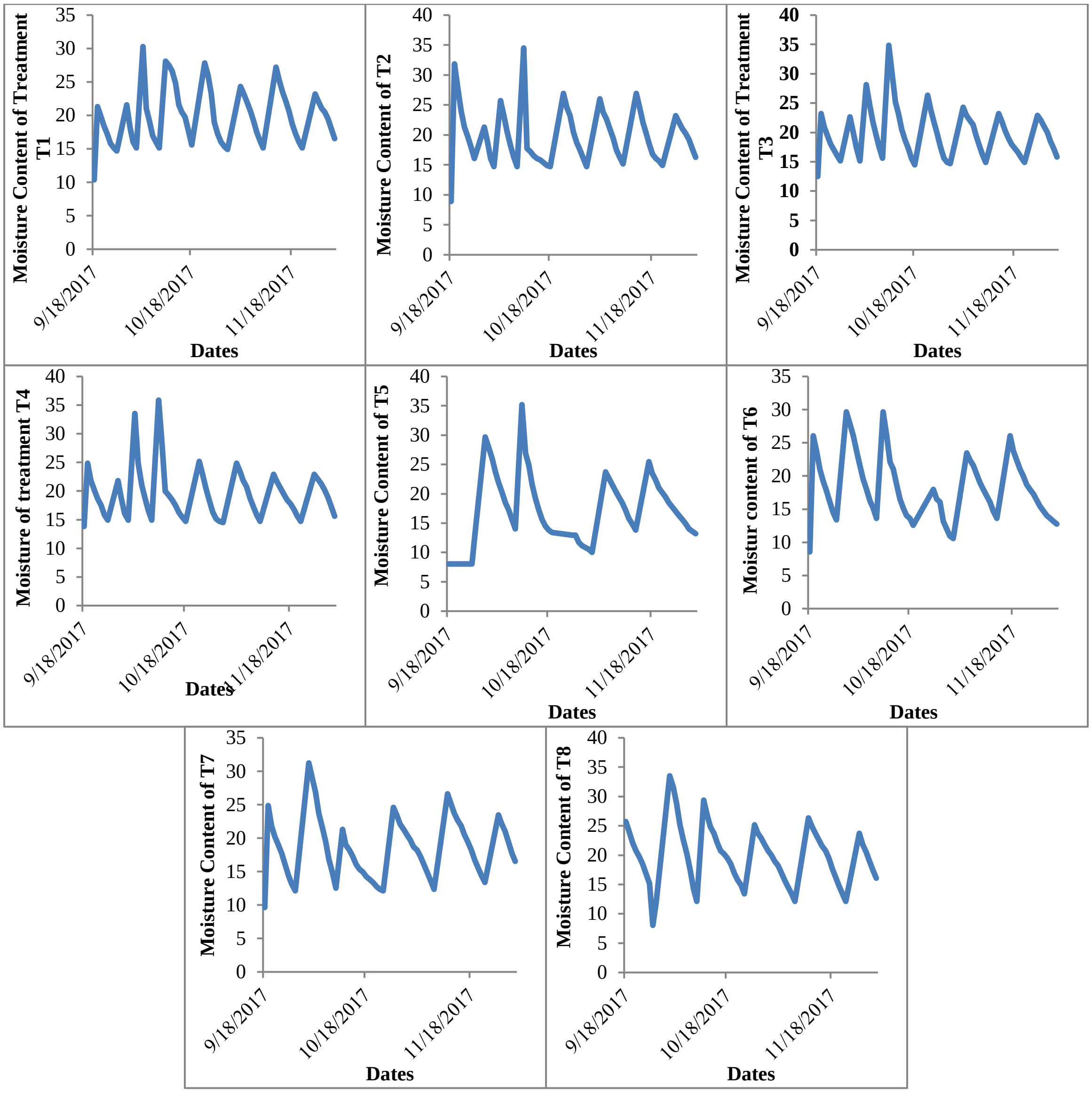


Figure 2: Soil moisture profile and irrigation scheduling for the eight treatments

From Figure 2, it can be observed that irrigations were more frequent in first four treatments as the soil moisture depletion was allowed only up-to 50% of available water, whereas the irrigations were delayed and are, therefore, in less number in T_5 to T_8. This is because the soil moisture was allowed to deplete up-to 60% in T_5 and T_6 and 70% in T_7 and T_8. However, as the light irrigations are difficult to apply in any gravity irrigation method, water losses were more in first four treatments, while the water distribution uniformity was found better in increased MAD level based irrigations resulting in better yield and water productivity.

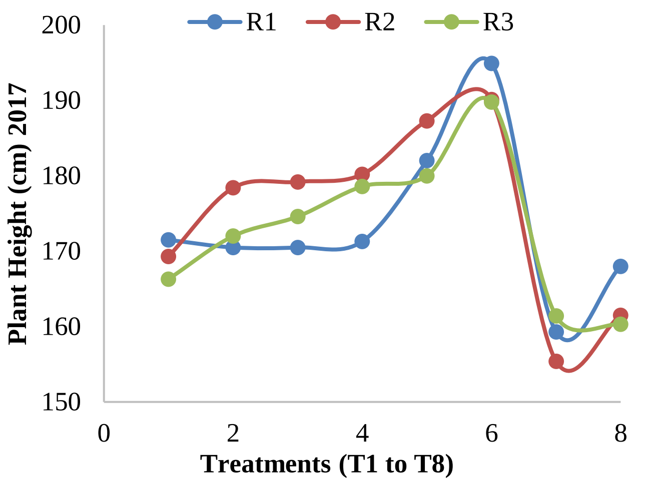
Difference between total depths of water applied between the respective even and odd treatments is due to mulching, which resulted in moisture conservation; hence, resulting in less depth of water to be applied at the time of irrigation compared with its respective non-mulch treatment.

Statistical Approach: Using Statistical Analysis Software (Statistix 8.1), all the tables were prepared for statistical analysis. Least significant differences (LSD) were used for finding the differences between the treatments' means. Differences were measured statistically significant at $p \leq 0.05$ (Montgomery, 2008).

RESULTS AND DISCUSSION

Impact of planting methods with delayed irrigation and moisture conservation techniques on maize growth parameters: Planting methods with different MAD levels based irrigation and moisture conservation techniques affect the growth of maize crop.

Plant Height**:** Plant heights of maize plants were recorded at harvesting time during both years. T_6 (BFS + mulch + 60% MAD) showed maximum plant heights as 191.60 cm (2017) and 193.4 cm (2018). Results showed that plant height of treatment T_6 was 9.3% more than T2 (CRS + mulch) and that of T_4 (BFS+ mulch) was 1.73% more than T_2. Whereas, the plant height in T_8 (BFS + mulch + 70% MAD) was 6.3% less than that of T_2. Bed furrow had shown highest plant height either with mulching or without mulching following the same pattern in both years (2017 & 2018). In T_7 (BFS + no mulch + 70% MAD) and T_8, minimum plant height was recorded either at mulching *i.e.*, 163.27 cm (2017) and 165.31 cm (2018) or without mulching *i.e.*, 158.70 cm (2017) and 161.8 cm (2018).



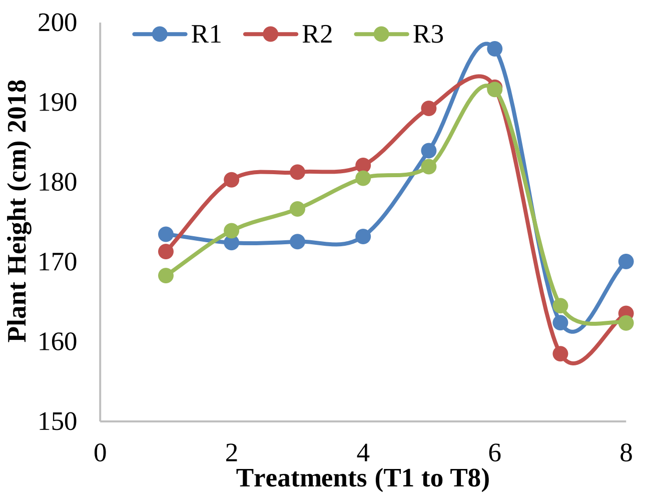


Figure 3. Graphical representation of plant heights during 2017 & 2018

This is because the increased MAD level up-to 70% in T_7 and T_8 much delayed the irrigations, resulting in water stress and thus, affecting crop growth. Better plant height in even numbered treatments in comparison to their respective odd numbered treatments proved that adding mulching in both ridge-furrow and bed-furrow improved the plant height efficiently. The results of current study were according to Yadav *et al.* (2018) in which maize crop at raised bed showed improved plant growth and good soil moisture conservation. Level of carbon dioxide directly affected the plant height and yield in maize crop by crop water balance (Durand *et al.*, 2018). In another study, Zulfiqar *et al.* (2017) suggested that 50mm moisture deficit provided the maximum plant height (154.3 cm), while crop providing the 100 mm deficit showed the smallest plant height (146.67 cm). So, it was concluded that plant height under deficit irrigation was not highly affected in comparison to the ridge furrow under irrigation method.

Grain yield**:** The grain yield in mulching treatments was higher than without mulching irrespective of sowing method in both years. Results showed that grain yield of T_6(BFS + mulch + 60% MAD) were 23% more than T_2 (CRS + mulch), while grain yield of T_4 (BFS + mulch) was 22.53% more than T_2 (CFS + mulch); however, grain yield of T_8 (BFS + mulch + 70% MAD) was 7% less than T_2. Treatments T_8 and T_7 (BFS + no mulch + 70% MAD) had minimum grain yield among all treatments *i.e.*, 7.27 and 5.95 t/ha respectively in 2017, while in 2018, minimum yield was 7.16 tons per hectare observed in T_7. The decreasing trend of grain yield in all the treatments is such as $T_4>T_6>T_3>T_5>T_2>T_1>T_8>T_7$ in 2017, while in 2018 the pattern was $T_6>T_4>T_3>T_5>T_2>T_1>T_8>T_7$. The results of present work were found in accordance of Li *et al.* (2018) in which grain yield of maize crop is better in deficit irrigation than regular irrigation. In a similar research done by Shahsavari-Gughar (2018), they suggested that yield of crop, seed weight, number of seeds per row and number of seeds were increased by 1.4%, 1.8%, 13% and 8.7% respectively by providing the 80% water requirement to maize crop rather than providing the full irrigation to crop. On the other hand, Karasu *et al.* (2015) concluded that deficit irrigation in maize increased the percentage of crude protein and oil of grain by improving the efficient usage of irrigation water but reduced the grain yield and other yield components. Among ridge and bed furrow sowing methods, bed planting has been proved to improve the crop yield as compared to traditional method and improve the water productivity by saving the irrigation water in water stressed conditions (Bakhsh *et al.*, 2018; Hussain *et al.*, 2018; Zhang *et al.*, 2019).

Dry matter**:** The dry matter in all mulching treatments is higher than without mulching treatments irrespective of sowing method during both years. The maximum value of dry matter has been observed in T_6 (BFS + mulch + 60% MAD) (27.16 tons per hectare) followed by T_5, T_2, T_4, T_3, T_1, T_8 and T_7, while in 2018 the maximum value of dry matter was observed in T_6 (28.07 tons per hectare). Dry matter results showed that T_6 was 6.44% more than T_2, dry matter of T_2 and

T_4 were equal and dry matter of T_8 was 7.1% less than T_2. The decreasing trend in 2018 was $T_6>T_5>T_2>T_4>T_3>T_1>T_8>T_7$. The minimum value of dry matter has been shown by T_7 that is 23.41 t/ha and 25.73 t/ha respectively in 2017 and 2018.

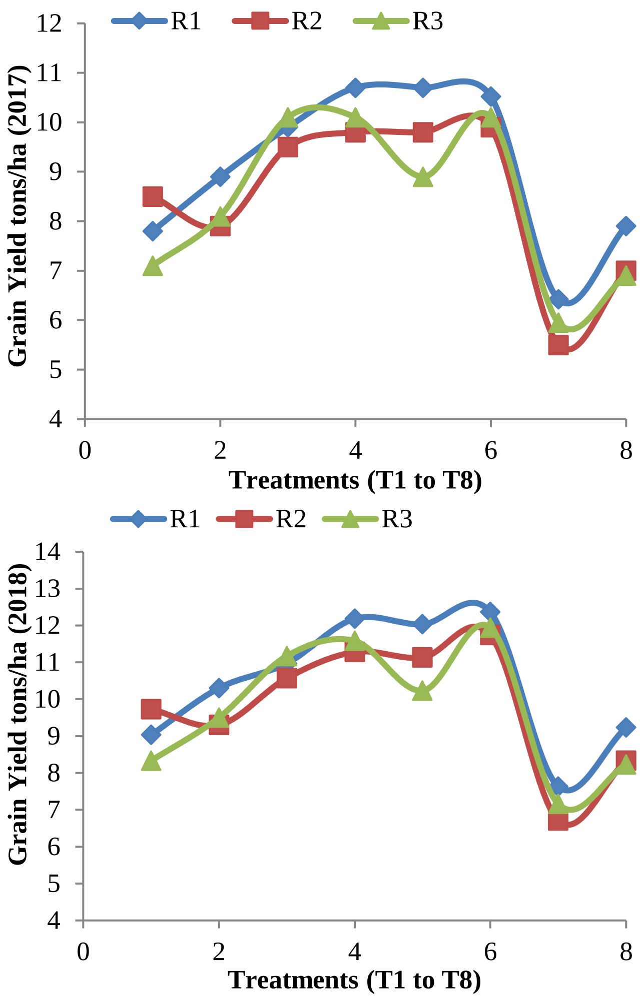


Figure 4. Graphical representation of Grain Yield during 2017 & 2018

Mulching increases the organic carbon sequestration of soil and mono-crops of maize have higher levels of total nitrogen of soil and soil organic carbon with mulching treatment (Chen *et al.*, 2018). Light fraction of organic matter has close correlation with physical, biological and chemical characteristics of soil (Zanatta *et al.*, 2019). According to a research done by Zhang *et al.* (2019), straw mulching improved the GY and total biomass of maize field as compared to non-mulching. Straw mulching also improved the nitrogen efficiency probably due to lower leakiness of sheath bundle cells to carbon dioxide. According to Liu *et al.* (2019), soil organic matter can be stabilized with management of maize straw mulching in arable land.

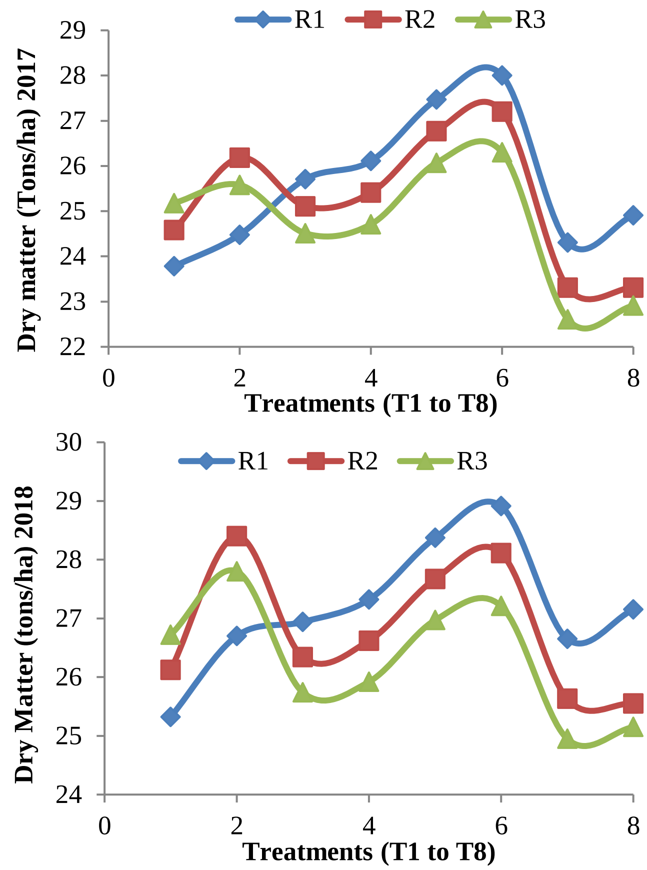


Figure 5. Graphical representation of dry matter during 2017 & 2018

***Harvest Index (HI)*: **Data of HI of 2017 was statistically significant *i.e.,* $P \leq 0.05$ as shown in ANOVA Table (Table 5) while the data of HI 2018 was statistically non-significant *i.e.,* $P \geq 0.05$. The maximum value of HI was observed in T_4 (BFS + mulch) as0.39 (2017) followed by T_3 (0.38), T_6 (0.37), T_5 (0.36), T_2 (0.32), T_1 (0.31), T_8 (0.3) and T_7 (0.25) while, in 2018 was observed maximum value of harvest index has shown in T_4 as 0.43 followed by T_6, T_3, T_5, T_2, T_1, T_8 and T_7.HI is defined as ratio of harvested grains and dry matter of total shoot, determine the balances of crop carbon that gave estimation of grain yield and directly correlated to grain yield (Unkovich *et al.*, 2010). It can be affected by various environmental factors like soil water content, high air temperature, and salinity of irrigation water, ground water depth, quality of soil, plant population and genotype. Harvest index can be determined from the beginning of crop growth or at maturity level of crop. Hence, in all modelling methods like AquaCrop model, harvest index is used to estimate the yield of crop. In the current study, harvest index was calculated at maturity level of crop. According to Wang *et al.* (2018), mulching treatment in maize crop had affected the harvest index and above ground biomass irrespective of cultivar. High harvest index may correlate to higher yield of grain. As harvest index is dependent of grain yield, therefore, same trend of decrease in harvest index is present showing minimum harvest index in T_7 *i.e.*, 0.38.

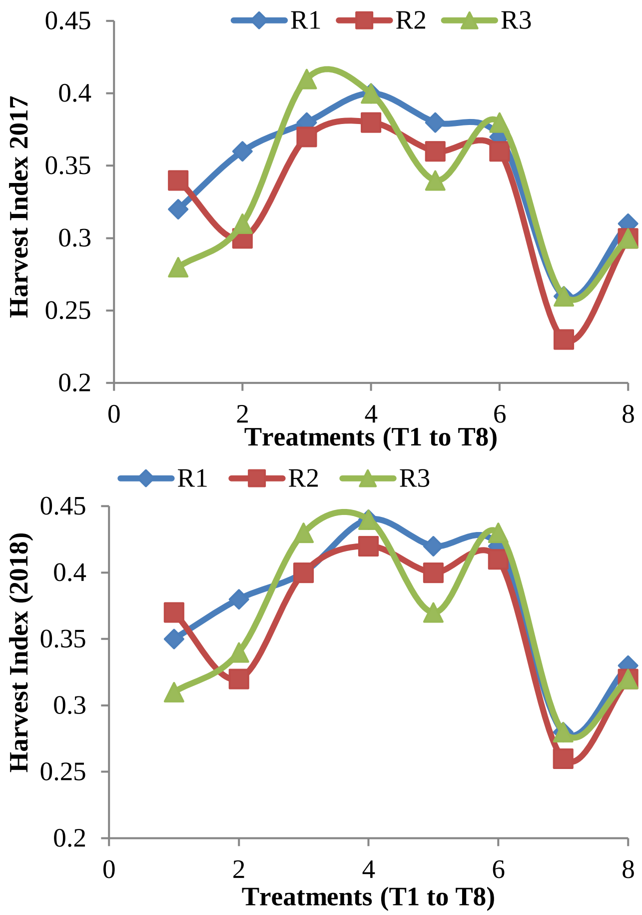


Figure 4. Graphical representation of Harvest Index during 2017 & 2018

Water depth**:** Results of water depth during both years have been detailed in Table 3. Water depth of T_2 was 13.4% and 5%more than T_6 and depth of applied water of T_2 was 9% and 4.7% more than T_4during 2017 and 2018, respectively. However, depth of T_2 was 15% and 8% more than T_8during 2017 and 2018, respectively. Increased MAD level in terms of deficit irrigation reduced the water depth.

Water Productivity**:** The maximum value of water productivity was recorded in T_6 during 2017 (1.01kg/m^3) and 2018 (1.14kg/m^3) whereas, the minimum value of water productivity was observed in T_7 (0.56& 0.69 kg/m^3) in 2017& 2018, respectively. Water productivity of T_6 was 30% more than T_2 and water productivity of T_4 was 5% more than T_2. However, the water productivity of T_2 was 3% more than T_8. Water productivity of crop can be varied by irrigation regimes, precipitation during different seasons, soil pH and organic matter of soil (Zheng *et al.*, 2018). Regular deficit irrigation increases the water use efficiency due to the following main reasons. First is the increase of guard cell transduction that is a cause of loss of transpiration rate. Second is the optimum control of stomata that enhances the transpiration ratio as well as process of photosynthesis. Third factor includes the smaller evaporative surface in combination with the limited root-zone irrigation which minimizes the soil evaporation. This enhances the nutrient uptake and recovery and reduced leaf respiration and closure of stomata with the maintained photosynthesis and biochemical traits. This mechanism includes enzymatic activity and enhanced signaling molecules (Chai *et al.*, 2016).

Conclusion**:** The present study was conducted to evaluate the effects of sowing methods and irrigation practices on the yield and water productivity of maize crop. Outcomes of both years showed that 60% MAD level on bed-furrow with wheat straw

Table 3. Results of water depth

Planting methods	**Without mulching (2017)**	**Without mulching (2018)**	**Mulching (2017)**	**Mulching (2018)**	**Average (2017)**	**Average (2018)**
Ridge furrow	1074	1123	1052	1110	1063A	1117A
Bed furrow (50% MAD)	978	1072	957	1058	968 B	1065 B
Bed furrow (60% MAD)	951	1052	911	1039	931 C	1046 C
Bed furrow (70%MAD)	963	1028	893	1026	928 C	1027 D
Average	992 A	1066 A	953 B	1062 A		

Table 4. Water productivity

Planting methods	**Without Mulching (kg/m^3) 2017**	**Without Mulching (kg/m^3) 2018**	**Mulching (kg/m^3) 2017**	**Mulching (kg/m^3) 2018**	**Average (2017)**	**Average (2018)**
Ridge furrow	0.67	0.8	0.71	0.87	0.69 C	0.84C
Bed furrow (50% MAD)	0.91	1.01	0.96	1.1	0.94 B	1.06B
Bed furrow (60 % MAD)	0.93	1.07	1.01	1.14	0.97 A	1.1 A
Bed furrow (70% MAD)	0.56	0.69	0.73	0.83	0.65 D	0.76 D
Average	0.77 B	0.89 B	0.85 A	0.99 A		

mulching showed best results for all parameters like plant height, grain yield, harvest index, dry matter weight and water productivity as compared to the control treatment with no deficit on ridge-furrow with conventional irrigation method application. Study concluded clearly that the bed-furrow method with 70 percent MAD without mulch had minimum values for all the measured parameters, indicating that delaying irrigation up-to 70% MAD is not recommended. Results of the study supported that bed-furrow with delayed irrigations up-to 60% MAD level with moisture conservation technique of mulching may be used successfully to achieve optimum yield and water productivity.

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