Integrated effects of water stress and plastic film mulch on yield and water use efficiency of grain maize crop under conventional and alternate furrow irrigation method

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Abstract

The field trial was carried out at the Malir farm, Sindh Agriculture University, Tandojam to evaluate the irrigation water practices on the performance of grain maize yield. In field experiment involved two types of furrow irrigation methods (conventional and alternate furrow irrigation), two water stress level (sufficiently and severely water stress levels) and mulch practice (without mulch and plastic film mulch). Total eight treatments were laid out in a complete randomized block design along with three replications. The conventional and alternate furrow irrigation method was assigned to the main plot while the water stress and plastic film mulching were in the sub-plots. The results showed that the plant height, leaves, stem girth, cob length, 1000-grain weight, dry biomass and crop harvest index were significantly affected by irrigation methods. Significant highest plant growth and grain yield of maize crop were observed with the conventional furrow irrigation method than with the alternate furrow irrigation method. However, the crop yield and water use efficiency (WUE) was increased significantly by the plastic film mulching. The results revealed that the sufficient water stress was effective in sustaining crop yield and WUE than crop irrigating at the several water stresses. The interaction effect of furrow irrigation and water stress, and furrow irrigation and plastic film mulch had significant on WUE of the grain maize. The WUE of maize crop was significantly higher under the alternate furrow irrigation method as compared to conventional furrow irrigation method if it was mulched with plastic film and irrigated at sufficiency water stress level.

1. Introduction

In the arid and semi-arid regions, the water stress is the primary task for the crop productions, temporal model exacerbates and the spatial hassle. Therefore, the design or irrigation methods don't address the situations of soil moisture availability for crop and the competition schemes do not address sectors. Hence, it becomes critical to increase the agriculture production. The agricultural production depends on the availability of freshwater resources. Therefore, it compels urgently to manipulate the available freshwater recourses in any respect ranges (Tariq and Khalid, 2009; Baye, 2011; Soothar et al., 2019a; Soothar et al., 2019b). Farmers usually prefer conventional surface irrigation method for maize cultivation in Sindh County, and while these irrigation water applications are responsible for considerable wastage of irrigation water and, reduction in crop yields. Moreover, micro irrigation methods have been avoided by formers, because they require colossal cost of installation and maintenance. Similarly, all the things considered, farmers, particularly, smallholders, will need to discover ways to boost their production on the limited land and water available through technology and management practices.

Maize is regarded as an internationally prime commodity driving world agriculture. It has great importance in Pakistan because the rapidly growing population already fearing the low availability of food. The maize crop can be used as the primary food, mostly in the rural areas of advance countries such as Pakistan (Arif et al., 2011 and Kori et al., 2017). It contributes 2.2% to the value added in agriculture and 0.4% to the GDP (GoP, 2016). Besides, grain maize is a high delta crop and can be achieving maximum crop yields if required amount of water and nutrients available (Nasri et al., 2010). Moreover, it is very sensitive to water stress. According to researchers, plant at seed filling stage when water stress and nutrient deficiencies cause of reduce the seed yield (Lauer, 2006; Yaseen et al., 2014; Tankari et al., 2021).

Plastic film mulching practice is the most improving techniques which enhanced the soil fertility, and to make conditions more favorable for growth (Chakraborty et al., 2008; Memon et al., 2017; Thider et al., 2020).

Mulching is one management method that can be used to conserve water by preventing surface evaporation, controlling weeds, regulating soil surface temperature, improving overall soil quality by increasing soil organic matter, stimulating soil activity, increasing nutrient availability and increase crop yield (Zhou et al., 2009; Patil et al., 2013). On other hand, many researchers have used fixed and alternate furrow irrigation methods, and they found that both resulted in improved WUE and reduced evaporation compared to CFI method (Li et al., 2007; Javed et al., 2019 Abd-El-Halim, 2013). Crop production is negatively impacted by water scarcity when using mulching techniques, and it has good potential to increase soil moisture retention under water-limited conditions (Jabran et al., 2015). Likewise, mulching is an economical and effective management method for controlling the moisture of the soil in root zone of crop (Shaikh et al., 2022).

Alternate furrow irrigation is just like the conventional method in planting, consists on irrigation every other furrow (Irrigation odd and even furrow alternatively). Irrigation water whether in every furrow or only in alternate furrow showed no effect on corn plant development, growth or grain yield (Eldoma et al., 2016; Eba et al., 2018). Similarly, Jemal et al. (2020); Mebrahtu et al. (2019) and Eba et al. (2018), they reported that the significantly higher WUE of maize crop under alternate furrow irrigation (AFI) as followed by conventional furrow irrigation (CFI) method. Under AFI, total irrigation water used roughly half of that irrigation water applied to the conventional practice (Siyal et al., 2016) and (Shaikh et al., 2022). Considerable reduction in applied water due to the alternate-furrow irrigation at 8 and 14-days interval and water saving were about 10% and 32%, respectively, comparable to conventional furrow irrigation (Maksoud et al., 2002). On above facts and figure, the present research experiment was carried out on the integrating effect of different water stress level and plastic film mulch on plant growth, yield and WUE of maize under conventional and alternate furrow irrigation.

2. Materials And Method

2.1 Study area

The field experiment was conducted to evaluate the integrated effect of different mulching practices and water stress on grain maize crop different furrow irrigation practices at the experimental station of Sindh Agriculture University, during two cropping seasons. It is located on Google position between $25^{0}24^{'}59.35^{''}$N and longitude $61^{0}31^{'}41.37^{''}$E and at the elevation of about 23 meter above Mean Sea Level (MSL). It was noted in the figure that the highest ET_o observed in the month of April. The minimum and maximum air temperatures, rainfall (mm), ET_o (mm) and relative humidity during the experimental periods for grain maize are shown in Figure 1. The experimental soil was classified as silty clay loam and silty clay (the detailed soil textural classes measured by hydrometer method are presented in the Table 1), with a pH of 7.38, soil electrical conductivity ($EC_{1:5}$) of 0.23 dS m^{-1}, soil bulk density of 1.45 g cm^{-1}, soil porosity of 47.12%, soil moisture content of 21.91%, soil water holding capacity of 288 mm m^{-1} upto 1-160 cm depth and average data are also summarized in Table 1.

2.2 Treatment and experimental setup

The experimental design was based on a complete randomized block design with including two types of irrigation modes, two water stress level and plastic mulching practice. Total 08 combine treatments were arranged along with three replications, and experimental setup presented in the Table 2. During experimental total twenty four sub-plots with an mean field size of 3 y 4 m were prepared.

2.3 Land preparation, crop variety, planting methods, fertilizers dose

The total area under study was plagued thoroughly by moldboard plow and disc harrow, and the level with a leveler. Furrows were constructed manually using spades. The 30y87 of a Pioneer variety of grain maize crop was used in this research study. The seeds were sown at the row spacing of 0.55 cm and plant t plant spacing of 20 cm. However, fertilizers doses were as per the recommendations (MINFAL, 2005).

2.4 Irrigation water depth and quality, and measurement

The irrigation water application was done at 50 and 80% for the soil moisture layer to 100 cm of field capacity according to the designed water stress under all treatment plots. In order to determine the irrigation depth and frequency for maize crop was computed by using the CROPWAT model. The depth of irrigation water to crop was measured using cutthroat flume. Supply of required depth of irrigation water under the all replicates plot of the treatments for the maize crop by empirical equation (Tager et al., 2017; Soothar et al., 2021). However, the irrigation water were received fro irrigation channel having EC_W of 0.35 dS m^{-1} and pH of 7.8.

In this study, mean gross irrigation water applied under the different treatments are shown in the Figure 2, irrigation water use under the CFI method was significantly higher than the AFI method as presented in the Table 3. It amounted to 6633 m^3 ha^{-1} per season in conventional furrow irrigation method compared to 3133 m^3 ha^{-1} per season in the alternate furrow irrigation method. The plants in the water stress plots used 5200 m^3 ha^{-1} more compared to the alternate furrow irrigation plots which consumed 4700 m^3 ha^{-1} per season. Besides, under plastic film mulching condition non-significant difference among treatments. Therefore, the data showed that number of irrigation events (18) and net irrigation (297 mm) was found in both plastic mulching and non-mulching condition.

2.4 Sampling, measurements and analysis

Before experiment, the soil samples were collected upto 100 cm soil layer with 20 cm intervals and also collected soil samples after harvesting from each the replicates. Soil moisture contents (SMCs) were calculated by the gravimetric method. The climatic data including average relative humidity, rainfall, sunshine, wind speed, temperature per day was collected from the nearest Agro-meteorological station. Plant height, leaf area and leaves $plant^{-1}$ was determined regularly at different days after sowing (Breda, 2008; Soheil, 2009; Kori et al., 2017). At the physiological maturity, all the selected plants were harvested and, divided into biomass and grain yields. After then determine stem girth, 1000 grains weight, grains yield, biomass and crop harvest index of maize crop (Thider et al., 2020). The dry biomass was measured after oven drying at 70°C to constant weight of harvested plants. The crop harvest index was determined through the grain yield divided the plants biomass. Irrigation water productivity for all designed treatments was calculated as the maize yield divided by water consumed for crop production (Soothar et al., 2019b).

2.5 Statistical analysis

The field collected data were statistically analyzed using ANOVA techniques. The correlations and statically analysis were done in term of soil, crop growth parameters and water productivity using Excel spreadsheet and SPSS package (SPSS version 20.0, SPSS Inc, USA).

2.6 Economic benefits

In order to compute economic benefits, the mulching and labor charges were obvious differences in the input cost of the different treatments. In this study, we were calculated total input value by additions of labor charge, mulching cost, water charges, and seed and fertilizer costs. Finally, we were compute net income difference from control treated grain maize plot.

3. Results

3.1 Plant growth parameters

3.1.1 Plant height

The plant height of grain maize was significantly affected by the irrigation methods with water stress and plastic film mulching throughout the cropping season (Figure 3 and Table 4). Underwater stress and mulching treatment, conventional furrow irrigation (CFI) method still had a significantly greater plant height compared with the AFI method. Within the two water stress levels, the greater plant height was noted in the 80% soil moisture depletion at field capacity when compared to other higher water stress level under same irrigation method. Across the irrigation method factor, alternate irrigation treated plants showed significantly lower plant height. However, the plant height of grain maize was significantly affected by different furrow irrigation methods with plastic mulch and water stress levels at different growth stages. Overall, results shows that the plant height was highly significantly affected among the treatments from 15 to 140 DAS.

3.1.2 Leaves $plant^{-1}$

Analysis of variance revealed that the CFI and AFI methods with plastic mulching and different irrigation level were significantly influenced on the number of leaves of grain maize throughout the cropping season (Table 5 and Figure 4). Results indicates that the maximum number of leaves was recorded from no mulch at 80% field capacity irrigation level in the CFI at 85 DAS, followed by the AFI, whereas maximum number of leaves was observed from plastic mulch at 80% field capacity irrigation level in the CFI, followed by the number of leaves were recorded under AFI method. However, the effect of different furrow irrigation methods with plastic mulch at 50% field capacity irrigation level has significant influenced on the number of leaves.

3.1.3 Leaf area plant^{-1}

Under water stress and mulching treatment, CFI still had a non-significantly affected plant leaf area compared with the AFI method. Within the two water stress levels, the higher leaf area of maize plant was noted in the 80% field capacity when compared to other higher water stress level under same irrigation method (Figure 5). Across the irrigation method factor, alternate irrigation treated plants showed lower a leaf area of maize plant. However, the leaf area of grain maize was significantly affected by plastic mulch and water stress levels at different growth stages (Table 6).

3.1.4 Stem girth

Stem girth of grain maize was significantly affected by furrow irrigation methods and irrigation water stress and non-significantly different among the mulching practice, as shown in the Table 7. The result clearly shows that the higher stem girth was found with the CFI; the average stem girth recorded was 3.46 cm as compared to the AFI method. Irrigation at sufficiently (80%) and severely (50%) water stress/levels, significantly decreased average stem girth of grain maize to 3.54 cm and 3.03 cm, respectively. A significant difference (p value 0.001) was recorded in stem girth under the sufficiently (80%) and severely (50%) water stress/levels. Moreover, the stem girth of maize crop was non-significantly affected among the mulching and non-mulching practices. In addition, the factors interaction of irrigation methods x water stress, irrigation methods x mulching practice, water stress x mulching practice and irrigation methods x water stress x mulching practice was non-significant at the *p* level of 0.05.

3.1.5 Cob length

Average cob length of grain maize was significantly affected by conventional and alternate furrow irrigation methods and non-significantly different among the water stress and mulching practice, as shown in the Table 7. The results clearly showed that the more cobs length was recorded with the CFI; the average cob length observed was 19.01 cm as compared to the AFI method. In addition, the factor interaction of irrigation methods x water stress, irrigation methods x mulching practice, water stress x mulching practice and irrigation methods x water stress x mulching practice were non-significant at the *p* level of 0.05.

3.2 Grain components of maize crop

3.2.1 1000-grains weight

Average 1000-grain weights of maize crop were highly significantly affected by different three factors (irrigation methods, water stress and mulching practice), as shown in the Table 7. The experimental result show that the maximum seed index was observed with the CFI; the average 1000-grains weights recorded were 246 as compared to the AFI method. However, irrigation at sufficiently (80%) and severely (50%) water stress/levels, highly significantly decreased average 1000-grain weights of grain maize to 238 gm to 208 gm, respectively. Moreover, the 1000-grain weights of maize crop were significantly affected among the mulching and non-mulching practices, the maximum seed index was recorded under plastic film mulching as compared to non-mulch practice. In addition, the factor interaction of water stress x plastic film mulching practice was found significant at the *p* level of 0.05.

3.2.2 Grain yield

The yield of grain maize was highly significantly affected by the different treatment factors (irrigation methods, water stress and plastic film mulching practice), as shown in the Table 7. The result clearly shows that the maximum grain yield of maize crop was found with the CFI; the average grain yield recorded was 19.92 tha^{-1} as compared to the AFI methdo. Irrigation at sufficiently (80%) and severely (50%) water stress/levels, highly significantly decreased average grain yield of grain maize to 16.99 and 13.82 tha^{-1}, respectively. Moreover, the non-mulch and plastic film mulching practice, significantly increased grain yield to 14.23 and 16.58 tha^{-1}, respectively. In addition, the factor interaction of irrigation methods x water stress was found significant at the *p* level of 0.05. Besides, interaction of irrigation methods x mulching practice, water stress x mulching practice and irrigation methods x water stress x mulching practice was non-significant at the *p* level of 0.05.

3.2.3 Biomass

Dry biomass of grain maize at the harvesting stage as significantly affected by the different three factors (irrigation methods, water stress and plastic film mulching), data are present in the Table 8. The result clearly shows that the maximum dry biomass of grain maize was recorded under the CFI; the average biomass observed was 6.37 tha^{-1} as compared to AFI method. A significant difference (*p* value 0.01) was recorded in the dry biomass under furrow irrigation methods. The dry biomass of maize crop were significantly affected by the sufficiently (80%) and severely (50%) water stress. The non-mulch and plastic film mulching practice significantly increased dry biomass to 5.47 and 6.00 tha^{-1}, respectively. In addition, the factors interaction of irrigation methods x water stress and water stress x plastic film mulching was found significant at the p of 0.05. Besides, interaction of irrigation methods x mulching practice and irrigation methods x water stress x mulching practice were non-significant at the *p* level of 0.05.

3.3 Crop harvest index and water productivity

3.3.1 Crop harvest index (CHI)

CHI of grain maize at the harvesting stage was significantly affected by furrow irrigation methods, irrigation water stress and mulching practice, as shown in the Table 8. The results clearly show that the highest CHI was found with the CFI; the average CHI recorded was 3.12 as compared to the AFI method. A significant difference (*p* value 0.001) was recorded in CHI under the irrigation methods. Irrigation at sufficiently (80%) and severely (50%) water stress significantly decreased average stem girth of grain maize to 2.75 and 2.49, respectively. A significant difference (*p* value 0.01) was recorded in CHI under the sufficiently (80%) and severely (50%) water stress/levels. Moreover, the non-mulch and plastic film mulching practice significantly increased CHI to 2.52 and 21.71, respectively. In addition, the factor interaction of irrigation methods x water stress was found significant at the *p* level of 0.001. Besides, factors interaction of irrigation methods x mulching practice, water stress x mulching practice and irrigation methods x water stress x mulching practice was non-significant at the *p* level of 0.05.

3.3.2 Irrigation water productivity

Irrigation water productivity (IWP) of grain maize was significantly affected by furrow irrigation methods, irrigation water stress and mulching practice, as shown in the Table 8. The results clearly show that the maximum IWP was found with the AFI; the average IWP calculated was 3.27 as compared to the CFI method. However, a significant difference (*p* value 0.001) was recorded in IWP under the water stress and mulching practice. Irrigation at sufficiently (80%) and severely (50%) water stress, significantly decreased average IWP of grain maize to 3.38 and 2.91, respectively. Moreover, the non-mulch and plastic film mulching practice significantly increased IWP to 2.87 and 3.42, respectively. In addition, the factors interaction of irrigation methods x water stress and irrigation method x mulching practice was found significant at the *p* level of 0.001 and 0.05, respectively. Besides, factors interaction of water stress x mulching practice and irrigation methods x water stress x mulching practice were non-significant at the *p* level of 0.05.

4.4 Correlation analysis between different parameters of grain maize

Correlation analysis between various growth and yield parameters of grain maize crop was highly significantly associated positively with all parameters analyzed except water use and irrigation water productivity under different treatments, r^2 values are presented in the Table 9. The data shown that stem girth was positively significantly correlated with seed index, cob length, grain yield, dry biomass, CHI and water use. Moreover, the experimental data showed that the 1000-grain weight was positively significantly correlated with cob length, grain yield, dry biomass, CHI and water use. However, the data indicated that the cob length was significantly positivity corrected with crop yield, dry biomass and water use. However, the data showed that the grain yield was highly positive significantly correlated with dry biomass, CHI, water use and irrigation water productivity. Moreover, the results showed that the dry biomass highly positive significant correlated with CHI and water use. Besides, experimental results indicated that the CHI was highly positive significant correlated with water use and irrigation water productivity.

4.5 Economic Benefits

The use of plastic film mulching materials and labor caused under different treatments are presented in the Table 10. During present study, the in all treatments input cost followed the order T1, T2, T3, T4, T5, T6, T7 and T8. The maximum net income 757224 was found under T1 and the minimum net income 231752 was found under T7 as compared to T3 (conventional furrow irrigation method + severely water stress + no-mulch practice).

4. Discussion

4.1 Effect of irrigation method, water stress and plastic film mulching on plant growth

Conventional and alternate furrow irrigation with plastic film mulch and water stress levels significantly affect on different plant growth parameters of maize crop (Figure 3 to 5 and Table 4 to 7). The results showed that the maximum plant growth parameters such as plant height, number of leaves and leaf area of grain maize were recorded under non-mulch at 80% field capacity treatment in the CFI as compared to the AFI method. Similarly, in plastic film mulching, the maximum plant growth parameters were observed for the CFI with plastic mulch at 80% field capacity of the irrigation level as compared with the alternate furrow irrigation method. Moreover, under water stress condition, the highest plant growth parameters of grain maize was observed from 50% field capacity irrigation level in non-mulch with CFI as compared to the AFI. While, the plant growth parameter also significantly higher in plastic film mulch with 50% field capacity of the irrigation level with CFI as compared to the AFI. The our experimental results were similar with Mulugeta and Kananan (2015); Zelalam (2017) and Meskelu et al. (2018), they reported that the CFI provide better yield components and plant height than the AFI. However, Thinder et al. (2020) also reported that the different mulching conditions had a substantial impact on plant growth parameters of the maize crop. This might be attributed to the greater SMCs in the root zone under CFI method's, which leads to optimal growth conditions.

5.2 Effect of irrigation method, water stress and plastic film mulching on yield compounds

The CFI and AFI of water management practices showed a very significantly affects on the grain yield components of grain maize (Table 7 and 8). Data regarding 1000-grains weight of maize were showed significantly affected among the different treatments. The maximum average weight of 1000 seeds was recorded with the CFI method than that of AFI method. The CFI yielded the maximum grain yield at 5.7 t ha^{-1} are followed by AFI, as in Mebrahtu et al., (2019). They reported that the highest biomass was harvested in the CFI. Similarly, Makino (2011) suggests that 90% biomass plants are found in photosynthetic products, in which irrigation water is the main source. A similar result was also published by Mulugeta and kannan (2015) increases in surface grain and biomass yield in maize were observed by using CFI with 100% water requirements rather than in alternative and fixed furrow irrigation. According to the Shamsi et al. (2010), soil water contents, which led to a reduction in the plant biomass, and Gua et al. (2013) also found same results. Mo et al. (2017) suggested that corn increased biomass by 73.5% under plastic mulch as compared to non-mulch. Jemal et al. (2020) suggested that the CFI could be used to maximize grain yield in the absence of water stress. Similarly, many other researchers reported similar results (Yaseen et al., 2014; Mulugeta and Kannan, 2015; Xu et al., 2015; Meskelu et al., 2018). Similarly, the mulch with plastic film improved soil hydrothermal conditions and greatly accelerated the emergence of wheat leaves and tiller growth. According to Ding et al. (2019), as a result of the application of plastic film mulch, transpiration (Zhou et al., 2009) and evaporation rate from soil (Zribi et al., 2015) decreased, and maize yield increased.

5.3 Effect of irrigation method, water stress and plastic film mulching on CHI and WUE

The CHI and WUE of grain maize crop was significantly affected under different treatments (Table 8). The WUE was found to have a favorable relationship with grain yield and yield components (Shamsi et al. 2010). We found higher water productivity of grain maize crop under the AFI and similar results given by the Ea et al. (2018) and Mebrahtu et al. (2019). Different forms of mulch highly significantly influenced water productivity of maize crop. Kang et al. (2000) pointed out that alternating furrow irrigation gives overall better performance for growing WUE and, compared to the AFI, results in a significantly reduction in corn grain yield (Panigrahi et al., 2011; Meskelu et al., 2018). According to Meskelu et al. (2018), grain yield reduces in the alternate furrow irrigation method was non-significant unlike the fixed furrow irrigation method. Montazar and Kosari (2007) hypothesized that the WUE of various crops, consisting of maize, can be increased by mulching to retain soil moisture for suitable plant growth. Maintaining soil water content in the root zone because of mulching can improve the transpiration as well as nutrient absorption and transport in the platform body with narrow water presented. Thinder et al. (2020) reported that the AFI increased WUE in the intercropping, India. According to Nigusie et al. (2020) and Abebe et al. (2020), they found that the AFI enchaining water productivity as compared to the CFI treated in different field crops. According to Siyal et al. (2016), they found that the total volume of irrigation water used in the AFI was about half than in the CFI. However, with a significant reduction of water used under the AFI treated okra crop declined slightly (7.3%). The significantly higher water use efficiency under AFI is almost double compared to CFI treated plants.

4. Conclusions

From the present study, grain yield and WUE of maize crop can be increased significantly by the plastic film mulch. Under CFI method with mulch and non-much plots resulted in higher crop water use during the cropping season, by the way of increased evapotranspiration losses, as compared to the AFI plots. The experimental results showed that the sufficient water stress level was effective in the sustaining crop yield and WUE than crop irrigating at the several water stresses. In case of AFI is to be adapting for grain maize production, irrigation WUE of maize can be increased if the entire irrigated field are mulched with plastic film and the irrigation done at 80% soil water holding capacity. The maximum net income Rs: 757224.00 were found under T_1 and the minimum net income Rs: 231752.00 were found under T_7 as compared to T_3. Therefore, it is needed to continued explore the AFI method option along with water stress and mulching practices for the long run impact of these factors in the perennial cropping pattern.

Declarations

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Availability of Data and Materials All data that support the findings are available from the corresponding author upon reasonable request.

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Tables

Table 1.

The basic properties of initial soil profile up to 0-160 cm depth

Soil property	Soil layer (cm)	Values	Soil property	Soil layer (cm)	Values
Soil texture	0-20	Silty clay loam	Soil moisture content (%)	0-20	18.84
	20-40	Silty clay loam		20-40	19.67
	40-60	Clay loam		40-60	20.07
	60-80	Silty clay loam		60-80	20.81
	80-100	Silty clay		80-100	22.31
	100-120	Silty clay		100-120	23.23
	120-140	Clay loam		120-140	24.18
	140-160	Silty clay loam		140-160	26.18
Dry bulk density	0-160	1.45g cm^{-3}	Water holding capacity	0-160	288 mm m^{-1}
$EC_{1:5}$	0-20	0.28	Soil pH	0-20	7.7
	20-40	0.20		20-40	7.5
	40-60	0.18		40-60	7.5
	60-80	0.22		60-80	7.4
	80-100	0.39		80-100	7.0
	100-120	0.18		100-120	7.4
	120-140	0.22		120-140	7.3
	140-160	0.20		140-160	7.3

Table 2.

Treatment arrangements and combinations (irrigation method, water stress and plastic mulching)

Irrigation method	Water stress	Mulch practice	Treatments
Factor – A	**Factor – B**	**Factor – C**	
Conventional furrow Irrigation	Sufficiently	No mulch	T1
		Plastic film much	T2
	Severely	No mulch	T3
		Plastic film much	T4
Alternate furrow Irrigation	Sufficiently	No mulch	T5
		Plastic film much	T6
	Severely	No mulch	T7
		Plastic film much	T8

Note: Sufficiently and severely water stress = 80% and 50% soil water holding capacity, respectively.

Table 3.

Main factor effects and interactions of furrow irrigation method, water stress and plastic mulching on irrigation interval, irrigation events, water apply and water use

Factor levels/interactions	Irrigation events (number)	Net irrigation (mm)	Gross irrigation (mm m^{-1})	Water applied (mm)	Water use (m^3 ha^{-1})
Furrow irrigations					
Conventional	18±1.01	396±20.28	660.00±33.46	660.00±33.46	6600±337
Alternate	18±1.01	198±10.14	330.00±17.24	330.00±17.24	3300±169
Water stress					
Sufficiently	19±0.00	312±105.47	520.00±175.45	520.00±175.45	5200±175
Severely	17±.00	282±95.33	470.00±159.23	470.00±159.23	4700±1589
Mulch					
No-mulch	18±1.01	297±101.67	495.00±1.69.44	495.00±1.69.44	4950±1694
Plastic mulch	18±1.01	297±101.67	495.00±1.69.44	495.00±1.69.44	4950±1694

Table 4.

ANOVA output for the effect irrigation methods (IM), water stress (WS) and mulching practice (MP) on mean plant height of grain maize at different days after sowing (DAS).*, ** and *** indicate the significant differences among the treatments according to Duncan's multiple range test at $p \leq 0.05$, 0.01 and 0.001 level, and ns indicate the non-significant differences

Factor	Days after sowing					
	15	30	40	55	85	140
IM	*	***	***	*	***	***
WS	***	***	***	***	***	***
MP	ns	***	*	***	***	***
IM x WS	ns	ns	ns	*	*	ns
IM x MP	**	ns	ns	ns	ns	ns
WS x MP	ns	ns	ns	ns	ns	ns
IM x WS x MP	**	ns	ns	ns	ns	ns

Table 5.

ANOVA output for the effect irrigation methods (IM), water stress (WS) and mulching practice (MP) on mean leaves per plant of grain maize at different days after sowing (DAS). *, ** and *** indicate the significant differences among the treatments according to Duncan's multiple range test at $p \leq 0.05$, 0.01 and 0.001 level, and ns indicate the non-significant differences

Factor	Days after sowing					
	15	30	40	55	85	140
IM	***	***	***	***	***	***
WS	***	***	***	***	***	***
MP	ns	***	**	***	**	***
IM x WS	ns	*	ns	ns	ns	***
IM x MP	ns	ns	ns	ns	ns	**
WS x MP	ns	ns	ns	ns	ns	ns
IM x WS x MP	*	**	ns	ns	ns	ns

Table 6.

ANOVA output for the effect irrigation methods (IM), water stress (WS) and mulching practice (MP) on mean leaf area per plant of grain maize at different days after sowing (DAS). *, ** and *** indicate the significant differences among the treatments according to Duncan's multiple range test at $p \leq 0.05$, 0.01 and 0.001 level, and ns indicate the non-significant differences

Factor	Days after sowing					
	15	30	40	55	85	140
IM	*	ns	ns	ns	***	ns
WS	ns	***	***	***	***	***
MP	***	***	ns	***	*	ns
IM x WS	ns	ns	ns	ns	**	***
IM x MP	***	ns	ns	ns	ns	ns
WS x MP	ns	ns	ns	*	ns	ns
IM x WS x MP	ns	ns	ns	ns	ns	*

Table 7.

Main factor effects and interactions of furrow irrigation method, water stress and plastic mulching on mean stem girth, cob length, 1000 grains weight and grains yield

Factor levels/interactions	Stem girth (cm)	Cob length (cm)	1000-grains weight	Grain yield (tha^{-1})
Furrow irrigations				
Conventional	3.46 ± 0.69^{a}	19.01 ± 1.48^{a}	246 ± 32^{a}	19.92 ± 2.73^{a}
Alternate	3.12 ± 0.53^{b}	18.18 ± 1.21^{b}	199 ± 39^{b}	10.89 ± 2.98^{b}
Significance	*	*	***	***
LSD (at 5%)	5.04	6.60	43.4	349.9
Water stress				
Sufficiently	3.54 ± 0.53^{a}	18.86 ± 1.24	238 ± 35^{a}	16.99 ± 4.80^{a}
Severely	3.03 ± 0.78^{b}	18.33 ± 1.52	208 ± 42^{b}	13.82 ± 5.48^{b}
Significance	**	ns	***	***
LSD (at 5%)	11.09	2.65	17.35	43.30
Mulch				
No-mulch	3.15 ± 0.71	18.40 ± 1.37	211 ± 39^{b}	14.23 ± 5.25^{b}
Plastic mulch	3.42 ± 0.69	18.79 ± 1.44	235 ± 42^{a}	16.58 ± 5.29^{a}
Significance	ns	ns	**	***
LSD (at 5%)	3.27	1.44	11.50	23.68
Interactions				
Furrow irrigation x Water stress	ns	ns	ns	*
Furrow irrigation x Mulch	ns	ns	ns	ns
Water stress x Mulch	ns	ns	*	ns
Furrow irrigation x Water stress x Mulch	ns	ns	ns	ns

ns = Not significant, * = Significant at the 0.05 level, ** = Significant at the 0.01% level and *** = Significant at the 0.001% level.

Table 8.

Main factor effects and interactions of furrow irrigation method, water stress and plastic mulching on mean biomass, crop harvest index and irrigation water productivity

Factor levels/interactions	Biomass ($t ha^{-1}$)	Crop harvest index	Irrigation water productivity
Furrow irrigations			
Conventional	6.37±0.67 [a]	3.12±0.36[a]	3.02±0.37 [b]
Alternate	5.10±0.29 [b]	2.12±0.52[b]	3.27±0.80 [a]
Significance	**	***	*
LSD (at 5%)	0.40	138.8	5.65
Water stress			
Sufficiently	6.10±0.89 [a]	2.75±0.47[a]	3.38±0.63 [a]
Severely	5.37±0.54 [b]	2.49±0.81[b]	2.91±0.54 [b]
Significance	**	**	***
LSD (at 5%)	0.20	9.13	18.94
Mulch			
No-mulch	5.47±0.73[b]	2.52±0.68 [b]	2.87±0.51 [b]
Plastic mulch	6.00±0.83[a]	2.71±0.65 [a]	3.42±0.63 [a]
Significance	*	*	***
LSD (at 5%)	0.86	5.13	26.04
Interactions			
Furrow irrigation x Water stress	*	***	***
Furrow irrigation x Mulch	ns	ns	*
Water stress x Mulch	*	ns	ns
Furrow irrigation x Water stress x Mulch	ns	ns	ns

ns = Not significant, * = Significant at the 0.05 level, ** = Significant at the 0.01% level and *** = Significant at the 0.001% level.

Table 9.

Correlation analysis between various parameters of maize crop under different irrigation methods, water stress and mulching treatments

	SG	SI	CL	GY	BM	CHI	WU	IWP
SG	1							
SI	0.249*	1						
CL	0.263*	0.310**	1					
GY	0.349**	0.613**	0.303**	1				
BM	0.443**	0.683**	0.369**	0.847**	1			
CHI	0.245*	0.509**	0.227	0.938**	0.623**	1		
WU	0.299*	0.596**	0.322**	0.878**	0.850**	0.750**	1	
IWP	0.158	0.127	0.045	0.307**	0.059	0.456**	-0.162	1

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).
SG = Stem girth, SI= Seed Index (1000-grain weight), CL = Cob length, GY = Grain yield ($t ha^{-1}$), BM = Biomass ($t ha^{-1}$), CHI = Crop harvest index, WU = water use ($m^3 ha^{-1}$), IWP =Irrigation water productivity.

Table 10.

Mean economic benefits ($rupees ha^{-1}$) of maize production under different treatments (furrow irrigation method, water stress and plastic mulching)

Irrigation Method Factor – A	Water Stress Factor – B	Mulch practice Factor – C	Treatments	Labor charge	Mulching cost	Tractor Changes	Seed and fertilizer cost	Total input value (TIV)	Total output value	Output/input
Conventional furrow Irrigation	Sufficiently	NM	T1	7200	-	13225	53422	73822	831046	11.2
		PFM	T2	7200	80000	13225	53422	153822	884497	5.7
	Severely	NM	T3	7200	-	13225	53422	73822	697298	9.4
		PFM	T4	7200	80000	13225	53422	153822	826424	5.3
Alternate furrow Irrigation	Sufficiently	NM	T5	7200	-	13225	53422	73822	486752	6.5
		PFM	T6	7200	80000	13225	53422	153822	566041	3.6
	Severely	NM	T7	7200	-	13225	53422	73822	305574	4.1
		PFM	T8	7200	80000	13225	53422	153822	424151	2.7

NM = No mulch, PFM = Plastic film mulch, TIV, total input value = LC + MMC + SFC; All the price values were according to the local market.

Figures

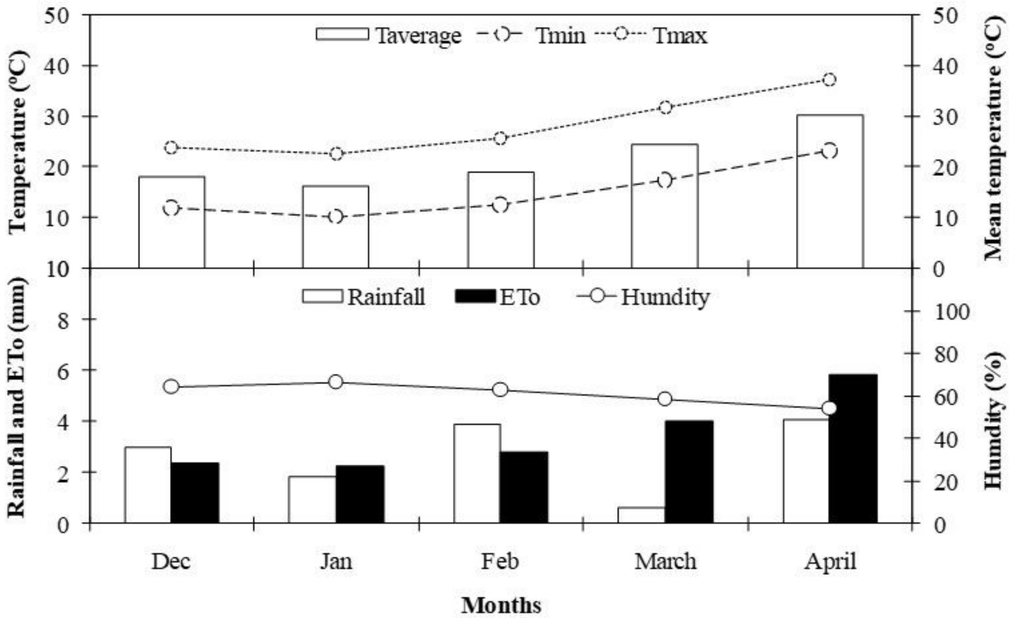

Figure 1

Monthly air temperature (minimum, maximum and average, °C), rainfall (mm), ET_o (mm) and relative humidity during the experimental periods for corn maize.

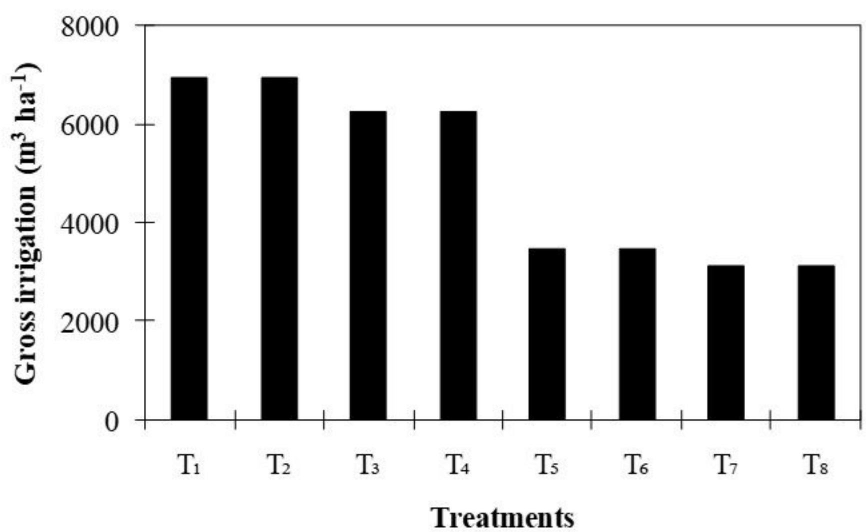

Figure 2

Total gross irrigation water used under different irrigation methods (IM), water stress (WS) and mulching practice (MP) throughout the base period both cropping seasons. T_1, T_2, T_3, T_4, T_5, T_6, T_7 and T_8 indicates the combined factor treatments, respectively.

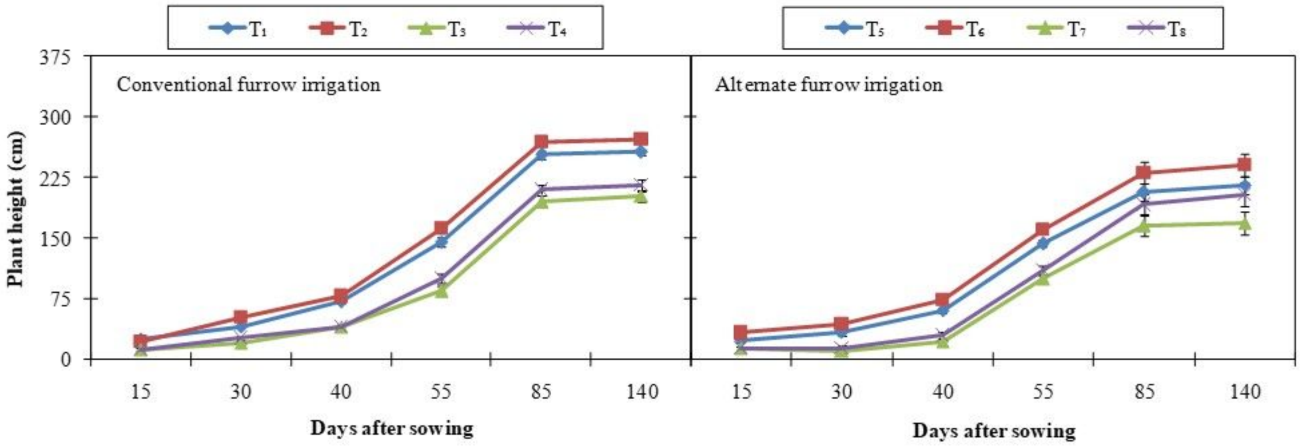

Figure 3

Mean plant height of grain maize crop as affected by irrigation methods (IM), water stress (WS) and mulching practice (MP) throughout the growing seasons. T_1, T_2, T_3, T_4, T_5, T_6, T_7 and T_8 indicate the combined factor treatments, respectively. The values are means ± SE (n=3).The small bars are standard error.

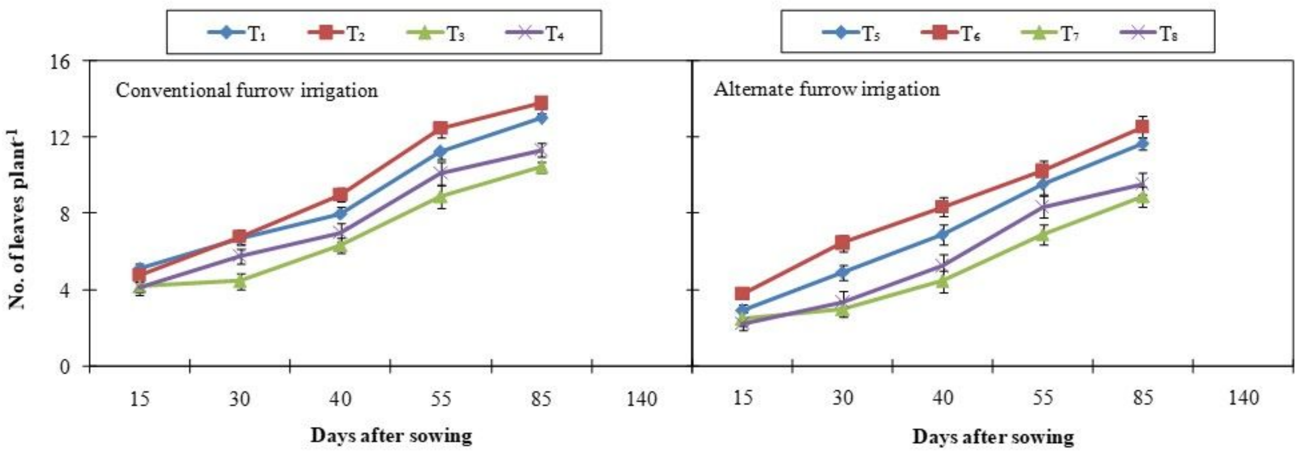

Figure 4

Mean leaves per plant of grain maize crop as affected by irrigation methods (IM), water stress (WS) and mulching practice (MP) throughout the growing seasons. T_1, T_2, T_3, T_4, T_5, T_6, T_7 and T_8 indicate the combined factor treatments, respectively. The values are means ± SE (n=3). The small bars are standard error.

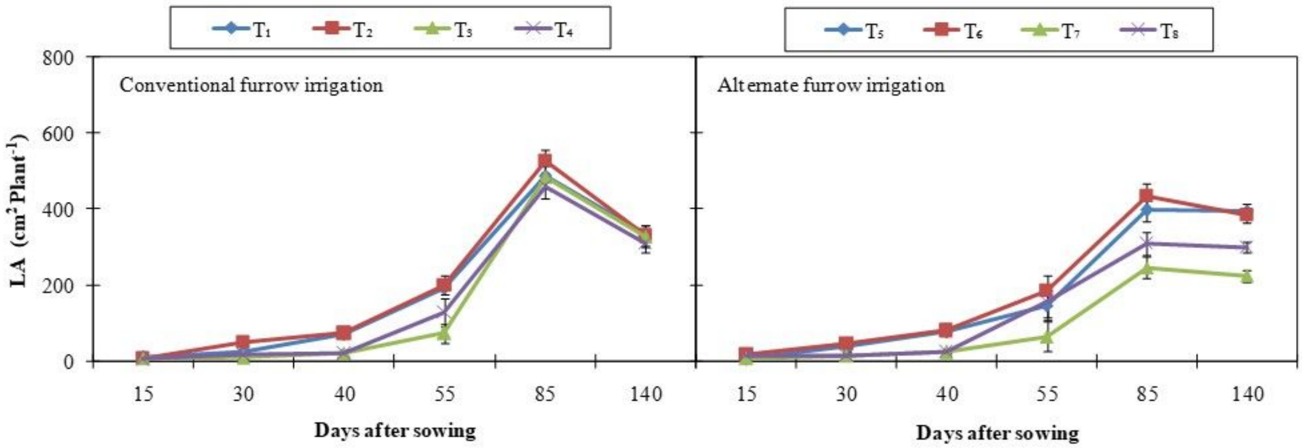

Figure 5

Mean leaf area per plant of grain maize crop as affected by irrigation methods (IM), water stress (WS) and mulching practice (MP) throughout the growing seasons. T_1, T_2, T_3, T_4, T_5, T_6, T_7 and T_8 indicate the combined factor treatments, respectively. The values are means ± SE (n=3). The small bars are standard error.