Research Article

Corn Yield Response to Deficit Irrigation During Low and High Sensitive Growth Stages and Planting Methods under Semi-Arid Climatic Conditions

Manzoor[1]*, Ahmad Khan[1], Amir Sohail[2], Shahzad Ali[1], Fawad Ali Shah[3], Junaid Iqbal[3], Muhammad Owais Khan[4] and Sultan Nawaz[4]

[1]Department of Agronomy, the University of Agriculture, Peshawar, Khyber Pakhtunkhwa, Pakistan; [2]Department of Plant breeding and genetic, the University of Agriculture, Peshawar, Khyber Pakhtunkhwa, Pakistan; [3]Department of Horticulture, the University of Agriculture, Peshawar, Khyber Pakhtunkhwa, Pakistan; [4]Department of Soil and Environmental Sciences, the University of Agriculture, Peshawar, Khyber Pakhtunkhwa, Pakistan.

Abstract | Water regulations have decreased irrigation water supplies in KPK and some other semi-arid areas of the Pakistan. When available water is not enough to meet crop water requirements during the entire growing cycle, it becomes critical to know the proper irrigation timing that would maximize yields and profits. The objective of this study was to evaluate the effects of water stress imposed at low and high sensitive growth stages (six leaves, twelve leaves, flowering and grain filling stages) and role of different planting methods (Ridge, Flat and Broadcast) in soil moisture conservation for maize crop. The research was carried out using RCBD with split plot arrangement having 4 replications at Agronomy Research Farm, The University of Agriculture Peshawar, during May 2017. Deficit Irrigations were allotted to main plots, while planting methods were allotted to sub plots. Deficit irrigations had significant ($P \leq 0.05$) affect on all parameters excluding number of plants at harvest. Full irrigation (10 irrigations) had significantly more plant height (189.25 cm), 1000 grain weight (211.25 g), leaf area (425.95 cm^2), number of leaves (16.23), grain yield (3352.75 kg), biological yield (10726.08 kg) and shelling percentage (47.78). Whereas one irrigation missing at six leaves stages produced maximum Harvest index (33.99 %). In case of planting methods, ridge planting had significantly higher plant height (186.10 cm), Plant at harvest (61316.60), thousand grain weight (205.90 g), leaf area (422.92 cm^2), grain yield (2948.35 kg), biological yield (10562.30 kg). While broadcast planting produced high Shelling percentage (46.90). The interaction of planting methods and deficit irrigations, maize grow on ridge method and give full irrigations produced higher plant height (192 cm), ridge and one irrigation missing at six leaves stages had more Harvest index (35.06%)) and high Shelling percentage (49.27) was obtained on broadcast planting with full irrigation. On the basis of the above results it is recommended that in water scare area grow maize on ridge planting method and give deficit irrigation at vegetative stage (one irrigation missing at six leaves stages) in order to increased water productivity (Efficiency).

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***Correspondence** | Manzoor, Department of Agronomy, the University of Agriculture, Peshawar, Khyber Pakhtunkhwa, Pakistan; **Email:** manzoor375351@gmail.com
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Introduction

Maize (*Zea mays* L.) is a monoecious plant of family Poacea and is widely cultivated in tropical, subtropical and temperate regions of the world. It is grown at an altitude of 3300 meters from above sea level at latitude of 50° north to 40° south. In 2014, it was grown on 1168.5 thousand hectares with production of 4944.5 thousand tones and productivity yield of 4317 kg ha^{-1} (MNFSR, 2014). In Khyber Pakhtunkhwa province after wheat crop maize is the subsequent main crop. In major part of the farming system it is used as a feed for animal and staple food in the rural areas of the province, especially at high altitudes. It is also used in industries for making starch, oil, polishes, etc. (Aziz et al., 1992). During 2014, maize was cultivated on 470.9 thousand hectares in Khyber Pakhtunkhwa with production of 914.8 thousand tones and yield of 1943 kg ha^{-1} (MNFSR, 2014). Water scarcity, inefficient irrigation system, weed infestation and poor preparation of soil are the main reasons of low production.

Water is a fundamental resource for every forms of life counting plants; but due to inefficient use of water and climate change it availability is declining. One third part of the world is water, out of that the fresh water is existing on only 3% of it, two-third part of fresh water is locked in ice caps and glaciers while the remaining 3rd part is available for human beings. Presently 70% of the available fresh water is utilized by agriculture and producing about 40% of world food necessity. However, at the end of 2025, for agriculture we will require 15% extra water because the population of the world is growing speedily at a rate of 1.5% which is raising pressure on water resources. In year 2025 the availability of per capita water will be declined to a threshold level of 1000 m^3 while the required per capita water is 5660 m^3 (Karim, 2006).

In Pakistan agriculture sector is considered as the backbone of economy of the country by contributing about 24% in GDP (GOP, 2012). In surface irrigation water losses occurred through deep percolation, leakage losses, seepage losses, evaporation and runoff with an irrigation efficiency of 30-40%. So, the deficient irrigation water in critical stages and losses of water are the main factors limiting crop productivity. So, the government encourages farmers to adapt pressurized irrigation system rather than surface irrigation method (Ali et al., 2007). Drip irrigation is one of the best irrigation methods in water scare areas, in this method the water is frequently and slowly applied to the root zone of the crop or directly to the land rather than to apply to the whole filed surface. This method also sustains optimum water content in the root zone of crop. But locally the farmers are not adapting pressurized irrigation systems practically. The main reasons for trickle or drip irrigation failure are; high quality availability of water that do not contain soil or sand particles because it blocks the emitters of the pressurized irrigation system while most of our irrigation water contain soil and sand particles, initially for it installation high investment is needed, required water application pattern similar for its maintenance and operation the farmers had low technical education. In addition to this, presently Pakistan is facing energy shortage and particularly in rural areas the farmers either do not have electricity or the electricity is not available on time for running trickle or drip irrigation system.

Currently researchers and planners had diverted their concentration toward deficit irrigations strategy which has been extensively accepted as a important plan for water scare areas (Fereres and Soriano, 2007). Water productivity is maximized with deficit irrigations, which is the major limiting factor. The target of deficit irrigation is to stabilized yield and improved water productivity (Zhang and Oweis, 2008). In deficit irrigation the plants are exposed up to certain levels of water stresses either throughout the entire growing season or during a particular period (Karrou et al., 2012) with an expectation that, any yield decrease will be immaterial compare with the gained benefits by utilizing the saved water to irrigated other agriculture crops. Pereira et al. (2008) USA reported that only 13% reduction in grain yield of wheat occurred with the application of deficit irrigation up to 60%. However, economic impact of yield decline and response of crop to water are the important information required for efficient utilization of deficit irrigation. Khan et al. (2007) reveled that in water deficit areas the important thing for farmers is to increased water productivity rather than to increase the yield of crop and maximum area can be irrigated with water saved by deficit irrigations.

Deficit irrigations gradually affected water productivity, generally with sufficient yield, the farmer get high economic benefits and income due to yield stabilization in association with rain fed farming.

In contrast with full irrigation, deficit irrigation decreased the risk of certain diseases like fungus that occurred in high humidity.

In order to make water saving techniques practicable for farmer in Pakistan and obtaining maximum water productivity, crop should be grown under a specific level of deficit irrigations and deficit irrigations should be given at a specific stage of the crops because each crop has its own critical limits up to which it can tolerate water stress, but after that limits the losses in the yield and growth of the crop starts, (Zhang and Oweis, 2008). The photosynthesis rate is significantly decreasing with sever and moderate water stress but the mild water stress had a less effect on photosynthesis Li et al. (2018). Soil moisture conservation techniques in combination with deficit irrigation and best sowing techniques can overcome on the grain yield losses by deficit irrigations.

Against the less water productivity in the conventional flat planting method with surface irrigation method, many developing countries of the world had taken initiative to shift their planting method to ridge planting method. In addition to saving a large quantity of water, it also helps to boost the productivity of crop. In ridge planting method irrigation water drain quickly from its surface, which helps to minimized the chances of de-oxygenation in upper rooting zone of the crops by avoiding water pond in the field.

Due to increasing population the fibers and food demand is increasing and on the other hand the per unit irrigated area water availability is decreasing. The demand of maize is expected to be increase several folds as the population is increasing. Thus, circumstances demand a sustainable increased of crop yield per unit area with scare water resources. Farmers are well skilled in conventional agronomic practices and traditional irrigation method (flood irrigation method) but cannot adopted latest irrigation technologies due to their low economic situation, deficiency of technical experience and education of farmers for maintaining and operating of the irrigation system, unavailability of economical and local parts of efficient irrigation system. In the light of the farmer's education, farming experience and financial condition, suitable planting method and deficit irrigation method can be a best alternative for saving water. These technologies are practically examined separately by scientists; however, the combined effect of planting method with deficit irrigations has not yet investigated. This study was carried out to examine the effect of planting methods and deficit irrigations on yield and yield components of maize.

Materials and Methods

The experiment was conducted at Agronomy Research Farm, The University of Agriculture Peshawar, located at 34.02⁰ N and 71.48⁰ E with an elevation of 359 meters above the sea level during May 2017. According to 30-year climatic data Peshawar is warm to hot, semi-arid and subtropical climate with mean annual temperature of 22.7 °C (72.9 °F) and with annual rainfall of 445 mm of which 42% was received during the three-month duration (February – April) (Figure 1). The weather condition of The Agriculture University Peshawar during the experimental period is shown (Figure 2).

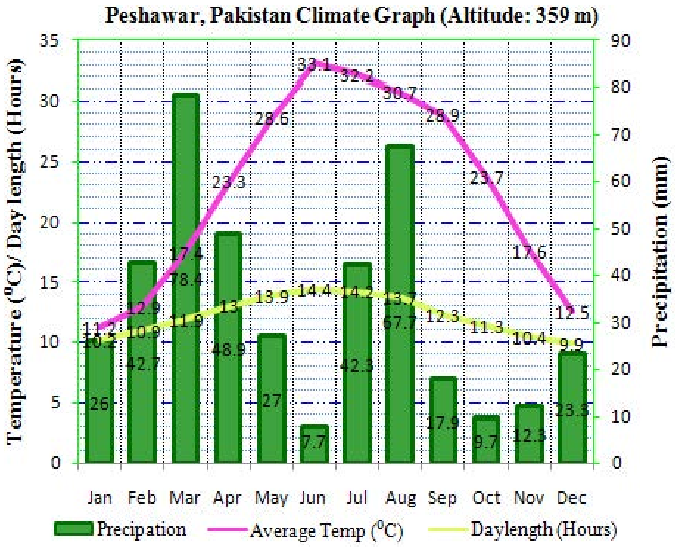

Figure 1: *Thirty years climatic data of Peshawar.*

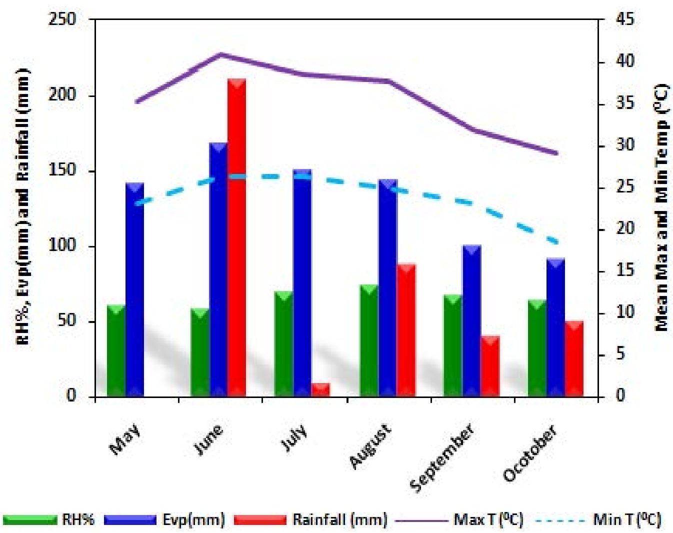

Figure 2: *Weather data of the university of agriculture Peshawar during entire experimental duration.*

The experimental location soil was sandy loam, slightly alkaline, low in organic carbon, non-saline with high available K, medium P and low N content. All the soil characteristic was determined by FAO methods. The permanent wilting point (PWP) and field capacity (FC) decreased slightly with depth (Table 1a).

Table 1a: *Basic soil characteristics at 0-15 cm soil depth.*

Soil characteristic	**Soil depth (cm) 0-15**
Soil texture	**Sl**
Sand (%)	60.1 ± 3.6
Silt (%)	33.0 ± 2.2
Clay (%)	6.9 ± 0.9
Bulk density (Mg m^{-3})	1.69 ± 0.06
FC	15.3 ± 2.9
PWP	7.64 ± 1.1
pH	8.3 ± 0.4
EC (dS m^{-1})	0.13 ± 0.03
Organic carbon (%)	0.29 ± 0.06
Available N (kg ha^{-1})	88.4 ± 9.6
Available P (kg ha^{-1})	15.6 ± 2.5
Available K (kg ha^{-1})	55.0 ± 9.6

Table 1b: *Schematic diagram of deficit irrigations at different growth stages of maize crop.*

Required Irrigations		**Irrigations Management**				
No. of Irrigations	**Growth stages**	I_0	I_1	I_2	I_3	I_4
1st Irrigation	At sowing time	✓	✓	✓	✓	✓
2nd Irrigation	V1 (First leaf)	✓	✓	✓	✓	✓
3rd Irrigation	V3 (Three leaves)	✓	✓	✓	✓	✓
4th Irrigation	V6 (Six leaves)	✓		✓	✓	✓
5th Irrigation	V9 (Nine leaves)	✓	✓	✓	✓	✓
6th Irrigation	V12 (Twelve leaves)	✓	✓	×	✓	✓
7th Irrigation	R0 (Anthesis stage)	✓	✓	✓	×	✓
8th Irrigation	R1 (Silking stage)	✓	✓	✓	✓	✓
9th Irrigation	R2-R3 (Blister and Milk stage)	✓	✓	✓	✓	×
10th Irrigation	R4 (Dough stage)	✓	✓	✓	✓	✓

The experiment was laid out in RCBD with split plot having 4 replications. Irrigations Management (Full irrigation (10 irrigations), one irrigation missing at six leaves stages, one irrigation missing at twelve leaves stage, one irrigation missing at flowering stage and one irrigation missing at grain filling stage) (Table 1b) were allotted to main plots, while planting methods (Ridge, Flat and Broadcast) was allotted to sub plots. The size of sub plot was 12.25 m^2 (3.5 m × 3.5 m). Each subplot was consisting of 5 rows having 70 cm row-to-row and 20 cm plant-to-plant distance. Variety Azam with seed rate 30 kg ha^{-1} was used. The recommended rate of NPK (120-60-0 kg ha^{-1}) was applied uniformly to all plots. Full P and half N were at the time of sowing and half N was applying at five leaves stage.

Experimental and data recording procedure

Leaf area was recorded by taking a sample of randomly selected 3 representative plants from each subplot. Leaves were separated and average leaf area was calculated with the help of a leaf area meter (CI-202, USA) Chai et al. (2016). Leaves per plant were counted in ten plants randomly selected from each subplot and then its average was taken. Data regarding number of plant at harvest was calculated by harvesting the total plants in three central rows in each subplot and converted accordingly. Thousand grains was counted at random from each treatment and weighed with the help of a sensitive electric balance to record 1000-grain weight. In each plot five plants was randomly selected from ground level to tip and with the help of meter rod recorded plant height. Shelling percentage is calculated by putting the values in Equation 1, Tanveer et al. (2003).

$$\text{Shelling percentage} = \frac{\text{Grain weight of five ears}}{\text{Whole weight of five ears (grains + shells)}} \times 100 \quad \ldots(1)$$

While grain yield of maize was calculated by harvest five rows, the ears was husked, dried and dehelled. Grain yield was recorded on $plot^{-1}$ basis and then converted into kg ha^{-1} by using the following Equation 2;

$$\text{Gain yield (kg ha}^{-1}) = \frac{\text{Grain yield (5 rows)}}{\text{R} - \text{length (m)} \times \text{R} - \text{R distance (m)} \times \text{No. of rows harvested}} \times 10000 \quad \ldots(2)$$

For biomass yield, four central rows of each subplot was harvested, sun dried, weighed and converted into kg ha^{-1} by using Equation 3.

$$\text{Biological yield (kg ha}^{-1}) = \frac{\text{Biological yield (5 rows)}}{\text{R} - \text{length (m)} \times \text{R} - \text{R distance (m)} \times \text{No. of rows harvested}} \times 10000 \quad \ldots(3)$$

The harvest index was calculated by Equation 4:

$$\text{HI (\%)} = \frac{\text{Grain yield (kg ha}^{-1})}{\text{Biological yield (kg ha}^{-1})} \times 100 \quad \ldots(4)$$

Water productivity is defined most often as the average amount of output per unit of water applied on a field Equation 5.

$$\text{WPAW (kg per m}^3) = \frac{\text{Output (kg per ha)}}{\text{Water Applied (m}^3\text{ per ha)}} \quad \ldots(5)$$

Table 2: *Effect of planting methods and deficit irrigations on leaf area (cm^2), leaves plant^{-1}, plants at harvesting, 1000-grain weight (g), plant height (cm), shelling percentage, grain yield (Kg ha^{-1}) and harvest index (%) of maize.*

Treatments		Leaf area (cm^2)	Leaves plant^{-1}	Plants at harvesting	1000- grain weight (g)	Plant height (cm)	Shelling percentage	Grain yield (Kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
Deficit irrigations	D0	425.95 a	16.23 a	58326	211.25 a	189.25 a	47.78 a	3352 a	10726 a	31.28 b
	D1	390.22 d	13.08 b	58270	195.33 b	174.17 c	45.89 b	3228 b	9528 c	33.99 a
	D2	388.53 d	12.92 b	58273	190.83 bc	179.83 bc	45.44 b	3167 b	9942 b	31.86 b
	D3	410.80 c	15.42 a	58285	180.83 c	184.17 ab	45.31 b	2417 c	10558 a	22.90 c
	D4	418.02 b	15.47 a	58309	181.50 bc	181.42 bc	43.14 c	2221 d	10492 a	21.16 d
	$LSD_{(0.05)}$	0.854	0.307	Ns	4.012	2.229	0.326	27.720	76.157	0.351
Planting methods	RM	422.92 a	15.14	61316 a	205.90 a	186.10 a	44.79 b	2948 a	10562 a	28.11
	FM	408.43 b	14.54	57339 b	188.40 b	179.45 b	44.86 b	2902 b	10154 b	28.75
	BM	388.76 c	14.19	56221 c	181.55 b	179.75 b	46.90 a	2781 b	10031 b	27.86
	$LSD_{(0.05)}$	0.841	Ns	3.800	1.913	0.681	0.190	14.672	39.646	Ns
Planting methods ×Deficit irrigations	RMD0	447.24	16.65	61350	238.00	192.00	46.61	3341	11136	29.99
	RMD1	403.40	13.75	61294	205.75	176.00	44.87	3369	9609	35.06
	RMD2	401.53	13.50	61297	202.00	184.75	45.94	3225	10257	31.45
	RMD3	426.93	16.00	61309	190.00	188.00	44.51	2493	11098	22.47
	RMD4	435.48	15.80	61333	193.75	189.75	42.01	2312	10709	21.59
	FMD0	423.72	16.15	57373	201.75	189.75	47.47	3421	10657	32.10
	FMD1	392.18	12.75	57317	193.25	174.50	45.53	3245	9327	34.79
	FMD2	394.32	12.75	57320	189.25	178.25	42.62	3185	9868	32.28
	FMD3	411.42	15.25	57332	179.50	184.25	45.41	2428	10448	23.24
	FMD4	420.51	15.80	57356	178.25	170.50	43.25	2231	10472	21.31
	BMD0	406.88	15.90	56255	194.00	186.00	49.27	3295	10384	31.74
	BMD1	375.07	12.75	56199	187.00	172.00	47.26	3071	9649	32.10
	BMD2	369.73	12.50	56202	181.25	176.50	47.76	3091	9701	31.87
	BMD3	394.05	15.00	56214	173.00	180.25	46.03	2329	10128	23.00
	BMD4	398.06	14.80	56238	172.50	184.00	44.16	2120	10295	20.60
	$LSD_{(0.05)}$	Ns	Ns	Ns	Ns	3.402	0.948	Ns	Ns	0.860

Note: *D0: Full irrigation (10 irrigations); D1: Deficit Irrigation (one irrigation missing at six leaves stages); D2: Deficit Irrigation (one irrigation missing at twelve leaves stage); D3: Deficit Irrigation (one irrigation missing at flowering stage); D4: Deficit Irrigation (one irrigation missing at grain filling stage) and RM: Ridge planting method; FM: Flat planting method; BM: Broadcast planting method; NS: non-significant; LSD: least significant difference.*

Statistical analysis

The analysis of variance procedure was followed according to RCBD with split plot arrangement. Means was compared using least significant differences (LSD) test at P≤ 0.05 upon significant F-test Jan et al. (2009).

Results and Discussion

Leaf area (cm^2)

Statistical analysis of the data showed that deficit irrigation had a significant (P≤ 0.05) effect on leaf area (cm^2). Planting methods had significantly (P≤ 0.05) affected leaf area of maize. The interaction of deficit irrigation and planting methods had a non-significant effect on leaf area (cm^2) of maize Maximum leaf area (425.95 cm^2) was observed from full irrigation (10 irrigations). The treatment deficit irrigation (one irrigation missing at grain filling stage and one irrigation missing at flowering stage) produced leaf area (418.02 and 410.80 cm^2) ranked 2nd and 3rd respectively. Minimum leaf area (388.53 cm^2) of maize was recorded from deficit irrigation (one irrigation missing at twelve leaves stage). This was because of water stress in vegetative stage which decreased the rate of photosynthesis. Gonzalez et al. (2015) and Halli et al. (2017) reported that increased in water up to optimum level increased plant vegetative growth. More leaf area (422.92 cm^2) was recorded from ridge planting method, followed by flat planting method with leaf area (408.43 cm^2). Less leaf area (388.76 cm^2) of maize was observed from broadcasting planting method. This was due to the fact that soil is more aerated and fertile in ridge method as compare to broadcast planting method where the soil is compact and less fertile, so produced less leaf area. Khan et al. (2015) and Singh Brar et al. (2016) reported that in broadcast planting method leaf area is decreased as compare to flat and ridge planting methods.

Number of leaves plant^{-1}

Analysis of the data showed that deficit irrigation had a significant ($P \leq 0.05$) effect on number of leaves plant^{-1}. The planting methods had not significantly affected number of leaves plant^{-1} of maize. The interaction of deficit irrigation and planting methods had a non-significant effect on number of leaves plant^{-1} of maize. Highest number of leaves plant^{-1} (16.23) were observed from full irrigation (10 irrigations), followed by deficit irrigation (one irrigation missing at grain filling stage and one irrigation missing at flowering stage) ranked 2nd and 3rd and produced number of leaves plant^{-1} (15.47 and 15.42) respectively. Lowest number of leaves plant^{-1} (12.92) of maize was recorded from deficit irrigation (one irrigation missing at twelve leaves stage). Vegetative growth is increased with more availability of water in vegetative stage which enhance rate of photosynthesis. Tari (2016), Mohammadi et al. (2017) and Rudnick et al. (2017) reported that giving stress to maize in vegetative stage decreased number of leaves per plant.

Plants at harvesting

Analysis of the data show that plants at harvesting were significantly ($P \leq 0.05$) affected by planting methods Table 2. Deficit irrigations had a non significant effect on plants at harvesting of maize. The interaction of deficient irrigation and planting methods for plants at harvesting was non-significant. The treatment planting methods show that maximum plants at harvesting (61316) were recorded from ridge planting method, followed by flat planting method (57339). Minimum plants at harvesting (56221) were obtained from broadcasting planting method. This is due to the fact that in ridge planting method plant survival rate is high as compare to broadcast planting method because in ridge planting method there was less chances of lodging, the plant is fully expose to light and more availability of water and nutrients to plants due to more porosity of soil. Gupta et al. (2010), Zamir et al. (2013), Khan et al. (2015) and Pang et al. (2018) reported that ridge planting method had more plants at harvesting as compared to broadcast and flat planting methods.

Thousand grain weight (g)

Analysis of the data revealed that thousand grain weight was significantly ($P \leq 0.05$) affected by deficit irrigation Table 2. Planting methods had a significant ($P \leq 0.05$) effect on thousand grain weight. The interaction of deficit irrigation and planting methods for thousand grain weight was non-significant. More thousand grain weight (211.25 g) of maize was observed with application of Full irrigation (10 irrigations). The treatment of deficit irrigations (one irrigation missing at six leaves stages and one irrigation missing at twelve leaves stage) was ranked 2nd and 3rd with thousand grain weight of (195.33 and 190.83 g) respectively. Less thousand grain weight (180.83 g) of maize was recorded from treatment of deficit irrigation (one irrigation missing at grain filling stage). Water stress in grain filling duration resulting in decreasing in the assimilation of dry matter to the grain, also sterility of pollen grain are the main cause of decreasing thousand grain weight. Du et al. (2015) and Linker et al. (2017) reported that water stress in reproductive stage decreased thousand grain weight of maize. Thousand grain weight of maize as affected by planting methods showed highest thousand grain weight (205.90 g) of maize was observed from ridge planting method and followed by flat planting method with thousand grain weight (188.40 g). The lowest thousand grain weight (181.55 g) was harvested from treatment of broadcast planting method. In broadcast planting method the soil is compact not well aerated so root not deep penetrated in the soil and not up take more nutrients from soil. Majid et al. (2008), Chai et al. (2016), Singh et al. (2016) and Pang et al. (2018) reported maximum thousand grain weight in ridge planting method.

Plant height (cm)

Plant height of maize was significantly ($P \leq 0.05$) affected by deficit irrigation Table 2. The effect of planting methods on plant height was significant ($P \leq 0.05$). The interaction of deficit irrigation and planting methods for plant height was significant ($P \leq 0.05$). Maximum plant height (189.25 cm) was observed from treatment of full irrigation (10 irrigations). The treatment of deficit irrigation (one irrigation missing at flowering stage and one irrigation missing at grain filling stage) was ranked 2nd and 3rd with plant height (184.17 and 181.42 cm). Minimum plant height (174.17 cm) was observed from treatment of deficit irrigation (one irrigation missing at six leaves stages). Water plays an important role in photosynthesis. Water is a raw material from which carbohydrates are manufactured from carbon dioxide and water in the presence of sunlight. Water even act as a structural agent, when plant cell contains abundance of water they are turgid and plants stand erect; when there is a moisture deficiency, the cells are flaccid and the plants droops and wilt. Tari (2016), Shah et al. (2006) and Jia et al. (2017) reported that well-watered maize plant has more plant height while water stress produced dwarf maize plant. The treatment of planting method (ridge planting) produced maximum plant height (186.10 cm). Minimum plant height (179.45 cm) was recorded from flat planting and broadcasting planting methods. In ridge planting root is deeply penetrated in the soil due to no soil crust problems and more soil porosity, thus reduces lodging and uses the water efficiently. While broadcast planting method had crust problems and root not deep penetrated in the soil resulted in low water and nutrients uptake to the leaves, decreases the photosynthesis rate. Mahajan et al. (2007), Majid et al. (2008), Khan et al. (2015) and Pang et al. (2018) reported that ridge planting method produced more plant height as compared with broadcast and flat planting method. The Figure 3 revealed maximum plant height (192.00cm) was observed from interaction of ridge planting methods and full irrigation (10 irrigtions) followed by interaction of ridge planting method and deficit irrigation (one irrigation missing at grain fill stage). Minimum plant height (1760.50cm) was observed from interaction of flat planting methods and deficit irrigation (one irrigation missing at grain fill stage).

Shelling percentage

Data concerning shelling percentage indicated that shelling percentage was significantly (P ≤ 0.05) affected by deficit irrigations Table 2. The planting methods has significantly (P ≤ 0.05) affected shelling percentage of maize. The interaction effect of deficit irrigation and planting methods on shelling percentage of maize was significant (P≤0.05). Maximum shelling percentage (47.78) was recorded from full irrigation (10 irrigations). The treatment of deficit irrigation (one irrigation missing at grain filling stage and one irrigation missing at flowering stage) ranked 2nd and 3rd had shelling percentage (45.89 and 45.44) respectively.

Minimum shelling percentage (43.14) was observed from deficit irrigation (one irrigation missing at grain filling stage). Shelling percentage is decrease when maize received stress in reproductive stage due to high evapotranspiration rat, low photosynthetic rate and less assimilation of dry matter. Mohammadi et al. (2017), Hussain et al. (2012) and Li et al. (2018) reported that deficit irrigation in reproductive stage decreased grain dry weight more as compare to cob dry weight, so resulted in decreased shelling percentage. Maximum shelling percentage (46.90) was recorded from broadcasting planting method, followed by flat planting method had shelling percentage (44.86). Minimum shelling percentage (44.79) was observed from planting method (ridge planting). Because from ridge method planting cob dry weight was increased more as compare to percent increase in grain dry weight which resulted in low shelling percentage. Tanveer et al. (2003), Khan et al. (2015) and Akbar et al. (2017) reported that in ridge planting method shelling percentage was increased as compare to broadcast planting method. The Figure 3 showed highest shelling percentage (49.27) was observed from interaction of broadcasting planting methods and full irrigation (10 irrigations), followed by interaction of broadcast planting method and deficit irrigation (one irrigation missing at twelve leaves stage) (47.76). Minimum shelling percentage (42.01) was observed from interaction of ridge planting methods and deficit irrigation (one irrigation missing at grain fill stage).

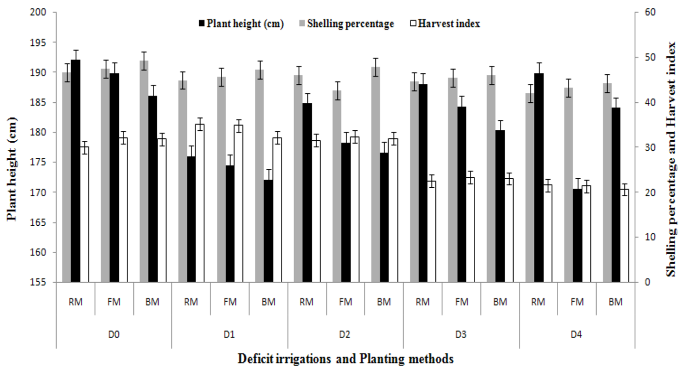

Figure 3: *Effect of planning methods and deficit irrigation on plant height (cm), shelling percentage and harvest index of maize.*
Note: *RM: Ridge planting method; FM: Flat planting method; BM: Broadcast planting method and D0: Full irrigation (10 irrigation); D1: Deficit irrigation (one irrigation missing at six leaves stages); D2: Deficit irrigation (one irrigation missing at twelve stage); D3: Deficit irrigation (one irrigation missing at flowering stage); D4: Deficit irrigation (one irrigation missing at grain filling stage). The vertical bars represents the mean ± the standard error of the mean (n=3).*

Grain yield (Kg ha^{-1})

Statistical analysis of the data revealed that grain yield was significantly (P ≤ 0.05) affected by deficit irrigation Table 2. The planting methods has significantly (P ≤ 0.05) affected grain yield of maize. The interaction of deficit irrigation and planting methods for grain yield was non-significant. Maximum grain yield (3352 kg ha^{-1}) was harvested from treatment of Full irrigation (10 irrigations) to maize crop. The treatment of deficit irrigation (Nine irrigations but one irrigation was missing at six leaves stages) has produced grain yield (3228 kg ha^{-1}) followed by grain yield (3167 kg ha^{-1}) from treatment of nine irrigations but one irrigation was missing at 12 leaves stage of maize crop. The treatment (nine irrigations but one irrigation was missing at flowering stage) has showed grain yield of 2417 kg ha^{-1}. Minimum grain yield (2221 kg ha^{-1}) was recorded from application of nine irrigation but one irrigation was missing at grain filling stage of maize crop. This reveals a decrease of 3.70%, 5.53%, 27.90% and 33.75% in grain yield harvested from treatments deficit irrigation (one irrigation missing at six leaves stages, one irrigation missing at twelve leaves stage, one irrigation missing at flowering stage and one irrigation missing at grain filling stage) respectively as compared with Full irrigation (10 irrigations). The highest grain production from application of Full irrigation (application of 10 irrigations at different growth stages) has ensured availability of water for utilization of maize crop. The application of full/recommended irrigations has compensated evapotranspiration losses during peak temperature ranges in summer season. The application of full/recommended irrigations has facilitated the mineralization process in soil and uptake of nutrients by maize plants. The highest vegetative growth was ensured due to application of full/recommended irrigations which more availability of water and nutrients to the plants in vegetative and reproductive stages of maize crop, water stress in reproductive stage decreased grain yield. Golzardi et al. (2017), Rudnick et al. (2017) and Li et al. (2018) reported that grain yield of maize was decreased by water stress at reproductive stages. The highest grain yield 2948 kg ha^{-1} was recorded from planting method (ridge planting). The planting method (flat planting) was ranked 2nd with grain yield 2902 kg ha^{-1}. The lowest grain yield (2781 kg ha^{-1}) was harvested from treatment of broadcast planting method. This reveals an increase of 5.99% and 4.34% in grain yield from planting methods (Ridge and Flat planting method) respectively as compared with broadcast planting method. Ridge planting had more aeration and good drainage system which provided good soil condition for proper root development, ensuring efficient use of nutrients and irrigation for proper growth and development. Ridge planting method also reduced soil crust problem which help in root penetration and root development, while broadcast and flat planting method the crust problem is more, which restricted root growth and penetration. Arif et al. (2001), Bakht et al. (2011), Irshad et al. (2014), Qamar et al. (2014) and Pang et al. (2018) reported more grains yield in ridge planting method as compared to broadcast and line planting method.

Biological yield (kg ha^{-1})

Analysis of the data showed that deficit irrigation had a significant (P ≤ 0.05) effect on biological yield. The effect of planting method on biological yield was significant (P≤ 0.05). The interaction of deficit irrigation and planting methods had non-significant effect on biological yield of maize. Maximum biological yield (10726 kg ha^{-1}) was observed from Full irrigation (10 irrigations) followed by deficit irrigation (one irrigation missing at flowering stage and one irrigation missing at grain filling stage) (10558 and 10492 kg ha^{-1}). This reveals a decrease of 11.16%, 7.31%, 1.56% and 2.18% in biological yield from treatments deficit irrigation (one irrigation missing at six leaves stages, one irrigation missing at twelve leaves stage, one irrigation missing at flowering stage and one irrigation missing at grain filling stage) respectively as compared with Full irrigation (10 irrigations). Minimum biological yield (9528 kg ha^{-1}) was observed from treatment of deficit irrigation (one irrigation missing at six leaves stages). The application of full/recommended irrigations has compensated evapotranspiration losses during peak temperature ranges in summer season. The application of full/recommended irrigations has facilitated the mineralization process in soil and uptake of nutrients by maize plants. The highest vegetative growth was ensured due to application of full/recommended irrigations which more availability of water and nutrients to the plants in vegetative and reproductive stages of maize crop, water stress in vegetative stage decreased biological yield. This shows that availability of water in vegetative stages enhances the photosynthesis rate which resulted in more vegetative growth and biological yield of maize. Greaves and Wang (2017), Ha (2017) and Mohammadi et al. (2017) reported that deficit irrigation in vegetative stages effected biological yield as compare to deficit irrigation in reproductive stages which effected grain yield. Highest biological yield (10562 kg ha^{-1}) was recorded from ridge planting method, Flat planting method ranked 2nd (10154 kg ha^{-1}) and broadcasting planting method produced lowest biological yield (10031 kg ha^{-1}). This reveals an increase of 19.08% and 4.43% in biological yield of maize from planting methods (Ridge and Flat planting methods) respectively as compared with broadcast planting method. This is due to the fact that ridge planting method provided good soil environment like soil porosity and drainage system for root penetration and nutrients uptake, thus reduce lodging. Arif et al. (2001), Tanveer et al. (2003), Memon et al. (2007), Bakht et al. (2011) and Khan et al. (2015) reported that ridge planting method produced high biological yield.

Harvest index (%)

Deficit irrigation and had a significant ($P \leq 0.05$) effect on harvest index Table 2. Planting methods had a non-significant effect on harvest index. The interaction of deficit irrigation and planting methods had a significant ($P\leq 0.05$) effect on harvest index of maize. Maximum harvest index (33.99 %) were observed from deficit irrigation (one irrigation missing at six leaves stages) followed by deficit irrigation (one irrigation missing at twelve leaves stage) and Full irrigation (10 irrigations) (31.86 and 31.28 %). Minimum harvest index (21.16%) was recorded from deficit irrigation (one irrigation missing at grain filling stage). Golzardi et al. (2017), Mohammadi et al. (2017) and Xue et al. (2018) reported that maximum harvest index of maize was produced when filed was well irrigated. The Figure 3 showed highest harvest index (35.06%) was observed from interaction of ridge planting methods and deficit irrigation (one irrigation missing at six leaves stage), followed by interaction of flat planting method and deficit irrigation (one one irrigation missing at six leaves stage) (34.79%). Lowest harvest index (20.60%) was observed from interaction of broadcast planting methods and deficit irrigation (one irrigation missing at grain filling stage).

Water productivity (Kg m^{-3})

Data concerning Water productivity (Kg m^{-3}) indicated that Water productivity was significantly ($P \leq 0.05$) affected by deficit irrigations (Figure 4). The planting methods has significantly ($P \leq 0.05$) affected Water productivity of maize. The interaction effect of deficit irrigation and planting methods on Water productivity of maize was significant ($P\leq0.05$). Maximum Water productivity (1.79 Kg m^{-3}) was recorded from deficit irrigation (one irrigation missing at six leaves stage) followed by deficit irrigation (one irrigation missing at twelve leaves stage) (1.34 Kg m^{-3}). Minimum Water productivity (0.58 Kg m^{-3}) was observed from deficit irrigation (one irrigation missing at grain filling stage) and one irrigation missing at flowering stage (0.64 Kg m^{-3}). Water productivity is high when maize received stress in vegetative stages. Mohammadi et al. (2017), Hussain et al. (2012) and Li et al. (2018) reported that deficit irrigation in reproductive stage decreased Water productivity more as compare to vegetative stages. Maximum Water productivity (1.10 Kg m^{-3}) was recorded from Ridge planting method, followed by flat planting method had Water productivity (1.08 Kg m^{-3}). Minimum Water productivity (1.03 Kg m^{-3}) was observed from planting method (Broadcast planting). Because in ridge method planting water store in the root zone and also less evaporation from soil surface which resulted in high Water productivity. Tanveer et al. (2003), Khan et al. (2015) and Akbar et al. (2017) reported that in ridge planting method Water productivity was increased as compare to broadcast planting method. The Figure 4 Showed highest Water productivity (1.87 Kg m^{-3}) was observed from interaction of Ridge planting method and deficit irrigation (one irrigation missing at sic leaves stage). Minimum Water productivity (0.56 Kg m^{-3}) was observed from interaction of broadcast planting method and deficit irrigation (one irrigation missing at grain fill stage).

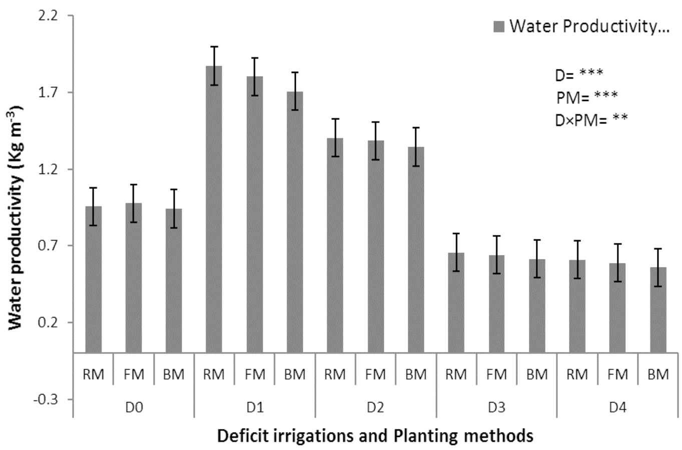

Figure 4: *Effect of planting methods and deficit irrigations on Water productivity (Kg m^{-3}) of maize.*

Note: *D0: Full irrigation (10 irrigations); D1: Deficit Irrigation (one irrigation missing at six leaves stages); D2: Deficit Irrigation (one irrigation missing at twelve leaves stage); D3: Deficit Irrigation (one irrigation missing at flowering stage); D4: Deficit Irrigation (one irrigation missing at grain filling stage) and RM: Ridge planting method, FM: Flat planting method; BM: Broadcast planting method. NS: non-significant; LSD: least significant difference.*

Conclusions and Recommendations

In the light of objective of our experiments and the results discussed following conclusion can be drawn. First Deficit irrigation in flowering and grain filling stage seriously affected grain yield of maize, while deficit irrigation in vegetative stages not resulted in higher decreased in yield. Second Full irrigation (10 irrigations) give significantly heavier thousand grain weight, grain yield and biological yield and third Ridge planting produced maximum thousand grain weight, grain yield and biological yield as compared to flat and broadcast planting methods. On the basis of the above results it is recommended that in water scare area grow maize on ridge planting method and give deficit irrigation at vegetative stage (one irrigation missing at six leaves stages) inoder to increased water productivity (Efficiency).

Novelty Statement

Due to global warming, we will face water shortages for crops in future, my research is to make a pre plane for that problems.

Author's Contributions

SA, AS and AK, conceived and designed the experiments. M, Performed the experiments. M, MOK and SN, Analyzed the data. FAS and JI, contributed materials/ analysis/ tools. M, wrote the paper.

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