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EFFECT OF DIFFERENT IRRIGATION METHODS ON WATER USE EFFICIENCY AND YIELD OF MAIZE CROP

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ABSTRACT

A field experiment was conducted to evaluate the effect of three different irrigation methods including ridge planting (T_1), planting under furrow irrigation (T_2) and line planting under basin irrigation (T_3) on soil physical properties, water use efficiency, plant growth parameters and yield of maize crop. The water requirement for maize crop was determined using CROPWAT (8.0) Model. Statistical analysis showed that the average values of the dry bulk density, soil porosity, plant height, crop yield and water use efficiency were significant ($P< 0.05$), while other parameters such as stem girth, number of leaves per plant, number of cobs per plant and 1000-grain weight were non-significant ($P> 0.05$) under all treatments. The results showed that the total volume of water applied to crop under T_1 was lower (3632), compared to T_2 (3936) and T_3 (5904). Average plant height, number of leaves per plant and number of cobs per plant were higher under T_1 compared to T_2 and T_3. However, the stem girth of plant was higher under T_3, followed by T_1 and T_2. T_1 produced more 1000-grains weight and yield of crop, followed by T_2 and T_3. Similarly, the average water use efficiency was higher under T_1 compared to T_2 and T_3. Hence, ridge planting under furrow irrigation method could be put in practice to save water and to achieve higher water use efficiency in water scarce areas, while in water stress areas, planting under furrow irrigation may be employed.

Keywords: CROPWAT, irrigation methods, maize crop, water use efficiency, yield

INTRODUCTION

The rapid growth in population and urbanization has increased the demand of water globaly, which has raised the cost of water (Tariq and Khalid 2009). Pakistan is also experiencing severe shortage of water (Qureshi, 2011). Therefore, it is indispensable to manage the available fresh water resources at all levels; from catchment to irrigated district and to the fields. The management of water at the macro level is indeed expensive, time consuming

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and difficult. However the management of water at the field scale is relatively inexpensive, more feasible and practical and it can be implemented in a short period of time. The management of water at the field scale can be achieved through adoption of more efficient and effective irrigation methods (Siyal *et al.*, 2016).

The farmers often adopt traditional flood irrigation methods, because modern drip and sprinkler irrigation methods require high cost of installation, operation and maintenance. These practices have created the problems of waterlogging and salinity and reduction in the overall irrigation efficiency (Tagar *et al.*, 2012). Hence, traditional flood irrigation methods need to be practiced using proper scientific techniques at the farmers' fields to enable farmers to minimize wastage of water.

Maize *(Zea mays* L.*),* a member of the family poaeeae (Gramineae) is an annual, short duration, long day, cross-pollinated plant. It produces about 600 million metric tons per annum on an area of about 118 million hectares. Hence, it is ranked third in the world. In Pakistan, it produces about 3.5 million metric tons on an area of about 1Mha (Jabran *et al.,* 2013) and plays a vital role in food nutrition (Arif *et al*., 2001). It can be planted in many ways such as ridge planting, furrow planting and line planting. Keeping the above facts in view, this study was conducted to evaluate the impact of different irrigation methods and yield of maize crop.

MATERIALS AND METHODS

A study was conducted at experimental site of Faculty of Agricultural Engineering, Sindh Agriculture University, Tandojam (Figure 1). It is located at latitude of 25° 25' 28" N and longitude of 68° 32' 25" E about 26 m above from mean sea level. Total field area was divided into nine plots with three replications using randomized complete block design (RCBD). The treatments included T_1 (ridge planting under furrow irrigation), T_2 (furrow planting under furrow irrigation) and T_3 (line planting under basin irrigation). The layout of experimental site is shown in Figure 1.

Figure 1. Location of experimental field (Google Earth)

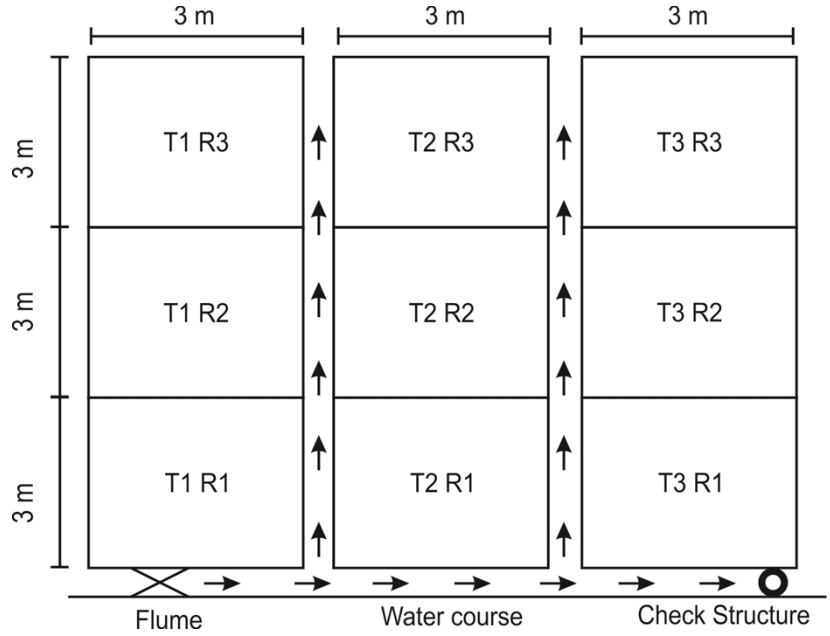

Figure 2. Layout of experimental field

Soil physical properties

The composite soil samples were collected at depths of 0-15, 15-30, 30-45, 45-60, 60-75 and 75-90 cm before sowing and after harvesting of crop. Soil texture was determined by Bouyoucos hydrometer method (Bouyoucos, 1927), dry bulk density was measured using the method adopted by Blake and Hartge (1986), field capacity was determined by Veihmeyer and Hendrickson method (1931) and porosity was calculated from dry bulk density and particle density (2.65 g/cm^3) values. The infiltration rate of field was determined by double-ring infiltrometer method (Klute, 1986). The results of the physical properties are shown in Table 1.

Table 1. Soil physical properties

Parameter	Average value
Soil texture	Silt loam
Dry bulk density	1.10 g cm^{-3}
Soil porosity	60 %
Field capacity	34 %
Infiltration rate	7.9 mm/hr

Quality of water

Groundwater was used as the source of irrigation water throughout the experiment. Table 2 depicts that the groundwater used for irrigation was of good quality (EC_w < 1500 µS/cm, SAR < 10).

Table 2. Quality of the groundwater used in the experiment

Source of water	Water quality parameters		
Tube Well (Groundwater)	ECw (µS/cm)	pH	SAR
	1342	7.9	6.81

Sowing of crop

Maize cultivar Rafan: R23-15 was sown by hand drilling method at the rate of 30 kg ha^{-1}. The row to row distance was 75 cm and plant to plant distance was 30 cm (MINFAL, 2005).

Application of fertilizers

The fertilizers were applied as per recommendations of On Farm Water Management (MINFAL, 2005).

Irrigation plan

CROPWAT model was used to determine the daily and the full season water requirement of maize crop (Figure 3). Meteorological data (i.e., rainfall, wind speed, humidity, minimum and maximum temperature and sunshine hours) was collected from Drainage and Reclamation Institute of Pakistan (DRIP) Tandojam.

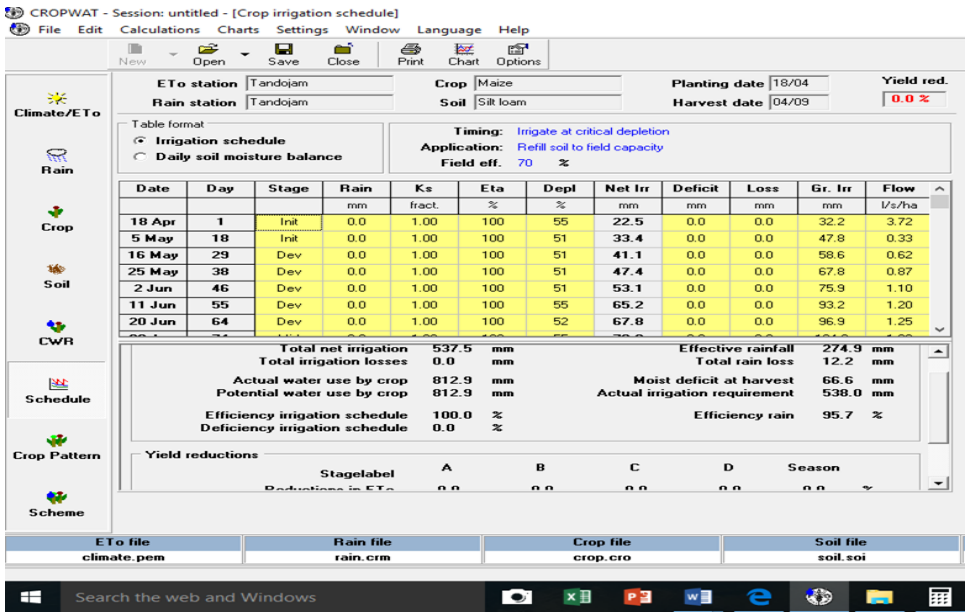

Figure 3. CROPWAT (8.0) showing irrigation schedule for maize cultivated

To apply the required depth of irrigation water to plots, a cut throat flume (20.32cm × 45.72 cm) was installed at the center of channel (Skogerboe and Hyatt, 1967). The time to apply required depth of water was determined by following formula (Isrealson *et al.*, 1980):

$$T = \frac{A \times D}{Q}$$

Where,

Q = discharge (cumec)
T = time of application (hour)
A = area to be irrigated (hectare)
D = depth of irrigation to be applied (m)

Crop growth parameters

The experimental field was visited on weekly basis and the crop growth parameters including plant height (cm), stem girth (cm), number of leaves per plant, number of cobs per plant and 1000-grains weight were measured as described by Abdou *et al.* (2011).

Yield of crop

Five randomly selected cobs were picked from each plot, packed in specified bags and then tagged. The yield of crops was then recorded using digital balance (0.001 g) and then converted in kg ha^{-1}.

Water use efficiency

The water use efficiency (WUE) under each treatment (i.e. ridge planting, furrow planting and line planting) was calculated using following formula (Henry *et al*., 2006):

$$WUE = \frac{Y}{W_t}$$

Where

WUE is the water use efficiency (kg m^{-3})
Y is total yield of crop (kg ha^{-1})
W_t is the total water consumed (m^3 ha^{-1})

Statistical analysis

The collected data was statistically analyzed through one-way ANOVA (analysis of variance) using statistical software package Statistix (Version-8.1). The means were compared by Tukey test at $P \leq 0.05$.

RESULTS

Statistical analysis of the data showed that the average values of dry bulk density, soil porosity, plant height, crop yield and water use efficiency were significant ($P < 0.05$), while other parameters such as stem girth, number of leaves per plant, number of cobs per plant and 1000-grain weight were non-significant ($P > 0.05$) under all irrigation method treatments.

Results showed that total volume of water applied to crops was 3632, 3936 and 5904 under T_1, T_2 and T_3, respectively (Table 3). The total volume of water applied to crops under T_1 was lower (3632), compared to T_2 (3936) and T_3 (5904).

Table 3. Total volume of water applied to maize crop

No. of Irrigation	Date of Irrigation			Water Applied (m^3 ha^{-1})		
	Ridge planting	Furrow planting	Line planting	Ridge planting	Furrow planting	Line planting
Soaking Dose	-	18-05-2015	18-05-2015	-	667	1000
1st	25-04-2015	17-05-2015	17-05-2015	167	219	329
2nd	07-05-2015	25-05-2015	25-05-2015	196	259	388
3rd	17-05-2015	01-06-2015	01-06-2015	219	279	419
4th	25-05-2015	08-06-2015	08-06-2015	259	283	425
5th	01-06-2015	14-06-2015	14-06-2015	279	310	465
6th	08-06-2015	20-06-2015	20-06-2015	283	333	499
7th	14-06-2015	26-06-2015	26-06-2015	310	306	459
8th	20-06-2015	01-07-2015	01-07-2015	333	307	460
9th	26-06-2015	09-07-2015	09-07-2015	306	315	472
10th	01-07-2015	19-07-2015	19-07-2015	307	339	509
11th	09-07-2015	30-07-2015	30-07-2015	315	319	479
12th	19-07-2015	-	-	339	-	-
13th	30-07-2015	-	-	319	-	-
			Total	3632	3936	5904

The results of plant growth parameters are presented in Figures 4 to 7. The average plant height was 159 cm, 151 cm and 150 cm, the stem girth of plant was 1.89 cm, 1.85 cm and 1.97, cm the numbers of leaves per plant was 10.8, 10.8 and 10.47, and number of cobs per plant was 1.6, 1.5 and 1.46 under T_1, T_2 and T_3, respectively. These results imply that average plant height, number of leaves per plant and number of cobs per plant were higher under T_1 compared to T_2 and T_3 treatnments. However, the stem girth of plant was higher under T_3, followed by T_1 and T_2. The results of weight of 1000-grains and yield of crop are presented in Figures 8 and 9. The weight of 1000-grains was 300, 167 and 267 under T_1, T_2 and T_3, respectively. Yield of crop was 4268, 3298 and 2924 kg ha^{-1} under T_1, T_2 and T_3, respectively. The results showed that T_1 produced more 1000-grains weight, followed by T_2 and T_3. Similarly the yield of crop was higher under T_1 than T_2 and T_3. The average water use efficiency was 1.17, 0.84 and 0.50 under T_1, T_2 and T_3 (Figure 10). It is evident that water use efficiency (WUE) was higher under T_1 compared to T_2 and T_3 treatments.

DISCUSSION

In Pakistan, maize is generally irrigated with traditional flood irrigation methods such as basin, border and furrow methods. These methods not only waste a substantial amount of water, which create waterlogging and salinity problems; but also leach the valuable nutrients beneath the root zone of crop. Therefore, traditional flood irrigation methods need to be practiced using proper scientific techniques at the farmers' fields to enable farmers to minimize wastage of water.

Maize plays a vital role in food nutrition (Arif *et al*., 2001). It can be planted in many ways such as ridge planting, furrow planting and line planting. Therefore, the present study was conducted to evaluate the impact of irrigation methods in terms of water use efficiency and yield of crop.

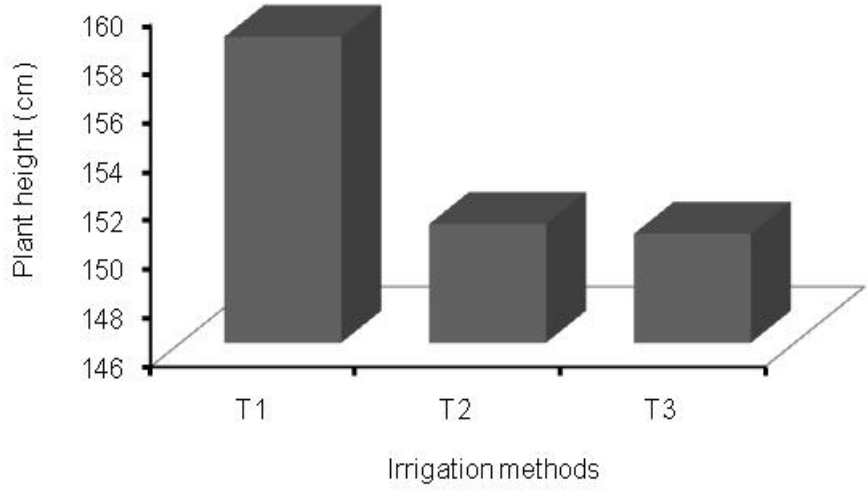

Figure 4. Plant height under all irrigation method treatments

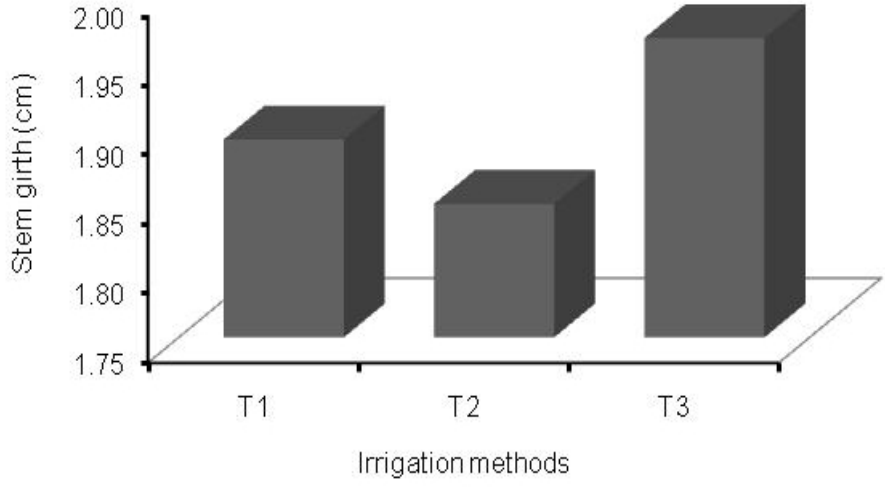

Figure 5. Stem girth under all irrigation method treatments

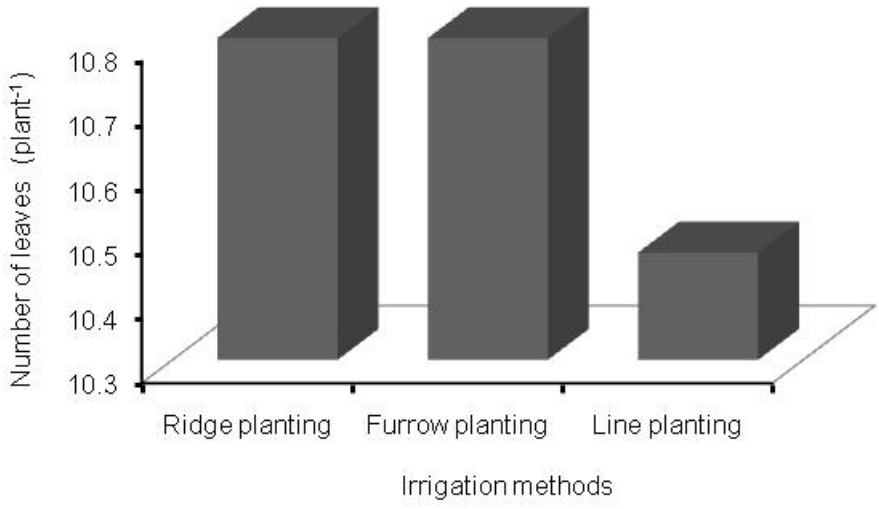

Figure 6. Number of leaves per plant under all irrigation method treatments

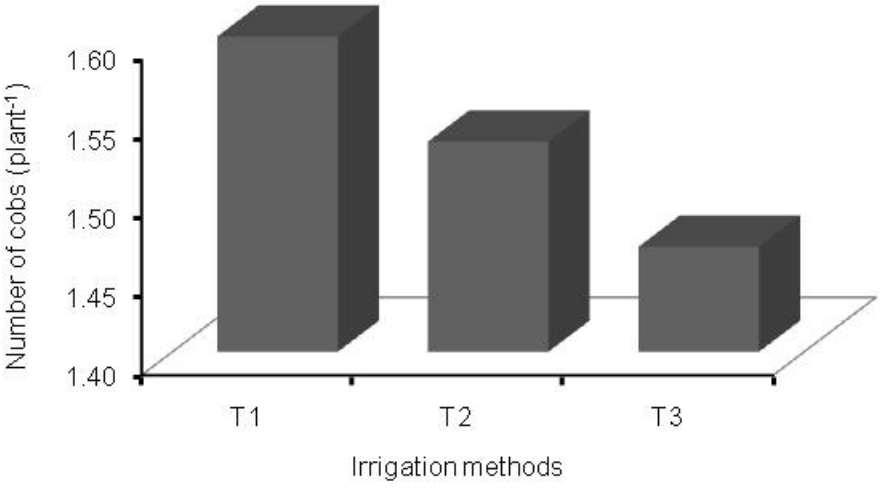

Figure 7. Average number of cobs per plant under all irrigation method treatments

Figure 8. 1000-grain weight under all irrigation method treatments

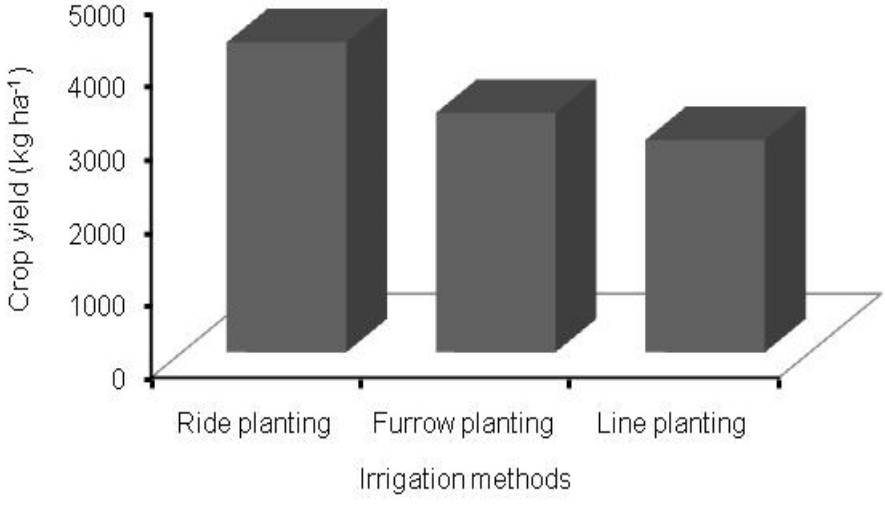

Figure 9. Maize yield under all irrigation method treatments

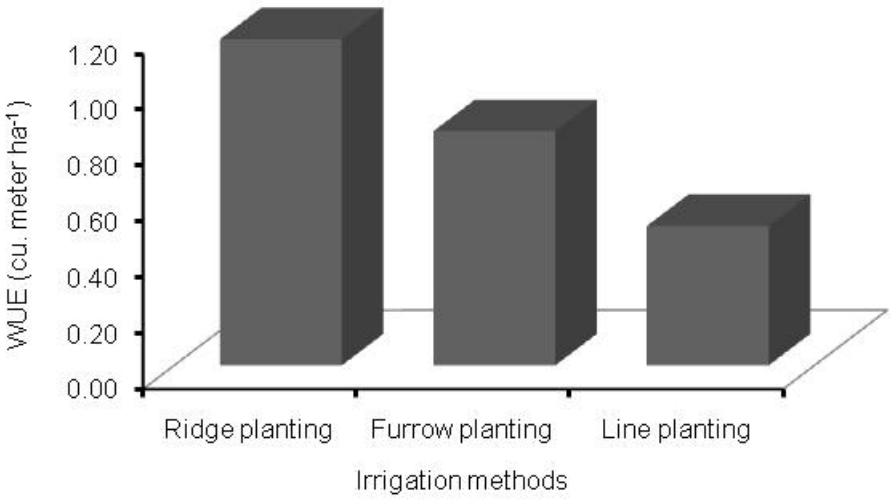

Figure 10. Water-use-efficiency under all irrigation method treatments

It is inferred from the results that the total volume of water applied to crops under T_1 was lower (3632)**,** compared to T_2 (3936) and T_3 (5904). Similar results were also found by Adeniran *et al.* (2010) and Shafiq *et al.* (2002), who reported that total volume of water applied under ridge planting irrigation method was less than that of basin. Average plant height, number of leaves per plant and number of cobs per plant were higher under T_1 compared to T_2 and T_3. However, the stem girth of plant was higher under T_3, followed by T_1 and T_2. T_1 produced more 1000-grains weight and yield of crop, followed by T_2 and T_3. Similarly the average water use efficiency was higher under T_1 compared to T_2 and T_3. This may be due to the fact that ridge planting provided better soil conditions and efficient use of irrigation water and fertilizers. These results are closely linked to Arif *et al*. (2001) who reported that the plant growth parameters were significantly affected by different planting techniques. Ridges provided better aeration and adequate availability of moisture that resulted in more plant population compared to furrow planting under furrow irrigation method and line planting under basin irrigation method. This is consistent with Chassot and Richner (2002), who reported that ridge planting provided better root development, enhanced water and nutrients availability and improved grain yield of maize crop. In a study Jehan *et al.* (2011), found highest grain yield under ridge plating as compared to basin irrigation method. Similarly Wang *et al.* (2016) reported that the water use efficiency of ridge planting was higher than that of basin planting. This is consistent with Karimvand *et al.* (2013), who reported that ridge planting method is more appropriate than that of basin planting method.

CONCLUSION

The results have shown that the total volume of water applied to crops under T_1 was lower (3632) compared to T_2 (3936) and T_3 (5904). Average plant height, numbers of leaves per plant and number of cobs per plant were higher under T_1

compared to T_2 and T_3. However, the stem girth of plant was higher under T_3, followed by T_1 and T_2. The T_1 produced heavy grains and more yield, followed by T_2 and T_3. Similarly the average water use efficiency was higher under T_1 compared to T_2 and T_3. Thus ridge planting under furrow irrigation found to be efficient method, followed by planting under furrow irrigation method and line planting under basin irrigation method.

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