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RESEARCH ARTICLE

Effect of Different Irrigation and Management Practices on Corn Growth Parameters

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ABSTRACT

In a field study, crop responses were investigated under three treatments; firstly irrigation system (bed-furrow irrigation and drip irrigation systems), secondly water quality (good, marginal and poor quality waters), and thirdly irrigation frequency/interval (2, 4 and 6 days). The experiment was laid out in a completely randomized design arrangement with three replications of all levels of different treatments in the experiment. Field observations suggest that plant height, dry matter weight, grain yield and harvest index were all quadratically related with irrigation frequency. The variables performed better in 2 and 6 day frequency plots compared with those of 4-day plots. Good quality water upgraded plant dry matter weight by 11.7%. The main effect of irrigation quality on plant dry matter weight was observed statistically significant. Similarly grain yield were 7.5, 6.38 and 5.33t/ha respectively for good, marginal and poor quality water. The main effect of irrigation water quality tested highly significant for grain yields. Crop parameters registered better performance for bed-furrow irrigated plots compared with drip irrigated ones in respect of plant height (1.0%), dry matter weight (5.8%) and corn yield (21.9%). It is conclude that good quality irrigation water produces better crop yield under 2 and 6-day irrigation frequency, followed by 4-day irrigation frequency.

INTRODUCTION

The importance of irrigated agriculture to Pakistan's economy is explained by the fact that irrigated land supplies more than 90% of agricultural outputs and contributes about 22% of the Gross Domestic Production (GDP) and employs 45% of the employment strength of Pakistan (Anonymous, 2008a,b). It is estimated that the population increase rate has considerably reduced from over 3% in 1980s to 2.09% in 2009-10, but still high (Ahmad and Farooq, 2010). The population increase stresses more food and fiber and put huge pressure on water resources of Pakistan (Blood, 1994). The existing availability of water per capita of Pakistan is 1200 m^3 and it will become 855 m^3 in 2020 (Kamal, 2008). Geographical area of Pakistan is 79.6 million hectares. Out of this, 21.9 million hectares is cultivated (Blood, 1994). About 70% of this cropped area lies in Punjab, 20% in Sindh, below 10% in KPK Province, while only 1% in Baluchistan. In this view, Pakistan ranked among the highest magnitudes of irrigated area for crops in the world. The culturable waste areas contributing the worthy potential of crop production add up to 8.9 million hectares. However, Cultivated land is expanding remarkably from 11.6 million hectares in 1947 to 22.6 million hectares in 1997 (Ahmad and Farooq, 2010). Fresh water availability for irrigated agriculture is becoming a huge challenge now a day in the world as well as in Pakistan. The consequences of the use of marginal and poor quality water for crop production can be control by the use of proper irrigation application method. Keeping in view, the present study was undertaken to investigate the impacts of irrigation water qualities and frequencies on corn growth parameters during 2011-2012 under drip (drip laterals on raised beds) and raised bed irrigation systems with furrows.

MATERIALS AND METHODS

Study site: Research study was conducted at the farm of the Postgraduate Agricultural Research Station (PARS), University of Agriculture, Faisalabad, Pakistan during the Rabi period of 2011-12 on corn. The site represents irrigated agricultural area of central Punjab of Pakistan at 31^o North (longitude) and 73^o East (latitude); 184m above sea level (ASP, 2006). The research site consists of alluvial deposits having calcareous characteristics. Topography of research site was fair with semi-arid climate. The climatic data were collected from automatic weather station installed at the research site. It was found that summer was hottest and winter was coldest month. During the summer season, the maximum temperature and minimum temperature was 50 and 27°C, respectively. During the winter season the maximum and minimum temperature was 23 and 6°C, respectively. The highest rainfall occurred in July to September. The average rainfall recorded was 439 mm/year.

Treatments: Treatments include two main irrigation methods i.e. drip and bed-furrow irrigation methods.

Treatments for Bed- Furrow irrigation

Bed-furrow irrigation method was taken as conventional irrigation method to be tested for three water qualities (good, marginal and poor).

Treatments for drip irrigation

T_1: Irrigation Water Quality; T_2: Irrigation Frequency/ Interval

Replications: 3 (R1,R2,R3); Total Sample size: 36 plots

W1 = Good quality water; W2 = Marginal quality water; W3 = Poor quality water

D1 = 2-day Irrigation interval; D2 = 4-day Irrigation interval; D3 = 6-day Irrigation interval R.B = Bed-furrow irrigated plots

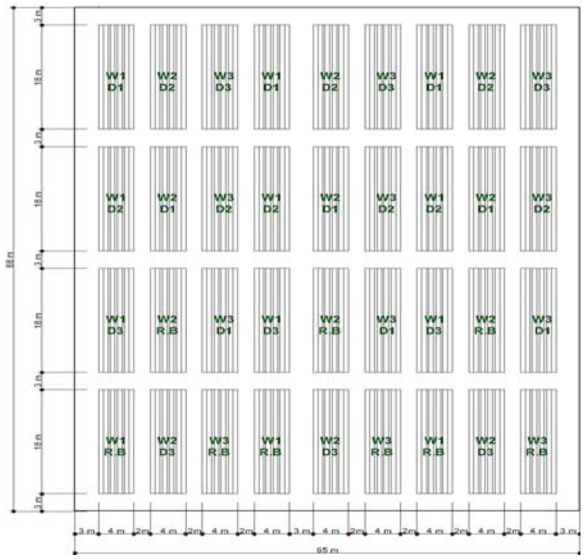

Fig. 1: Layout of research study

RESULTS AND DISCUSSION

Soil physical characteristics

Soil physical properties like texture, structure, infiltration, bulk density, field capacity etc., were determined using their standard procedure. Soil texture was determined using hydrometer method for various layers (0-15, 15-30, 30-45 and 45-60 cm).Soil texture was established using textural triangle by Moodie et al. (1959) developed at United States Department of Agriculture. Soil texture turned up as sandy loam.

Infiltration rate

Soil infiltration rate at the experimental site was measured prior to the initiation of the study. In order to prevent runoff, it is essential that the emitters' irrigation rate is equal to or less than the infiltration rate (Alberta Agriculture, Food and Rural Development, 2004). The infiltration rates ranged from 0.74 - 0.80 cm/h. In fact, soil infiltration rate describes the behavior of water movement in the soil profile. Infiltration rates in the present study are in accordance with the ranges of infiltration rate recorded by Rawls et al. (1982) and Gupta (1990) where they evaluated the effects of saline water use on physical characteristics of soil and reported the worsening of physical characteristics of soil using poor quality water for irrigation and resulting in the decline of porosity owing to dispersion and swelling of clay minerals by the presence of more Na ions in irrigation water.

Soil bulk density

Singh et al. (1992) and Hur et al. (1992) and Patel and Singh (1981) have reported increasing bulk densities with decreasing infiltration rates. In present study, bulk densities were measured at various points in the experimental fields using ASAE Standard S269.4. The bulk densities varied from 1.51 to 1.54 g/cm^3 (Rawls et al., 1982; Meek et al., 1988, 1992).

Field capacity

Measurement of field capacity was done by pressure plate apparatus. The soil moisture contents vary from 21.6 to 21.9% (Jabro et al., 2009 and Rawls et al., 1982) for the field soils in present experiments (Table 1). Field capacity is influenced by many factors such as initial soil–water content, soil texture and structure, type of clay, presence of or amount of organic matter, presence of impeding layer and evapotranspiration (Kirkham, 2005).

Permanent wilting point (PWP)

Permanent wilting point was measured by taking different soil samples from plots at 0-45cm depth using Pressure Plate Apparatus (Table 2). Permanent wilting point obtained after analysis is 8.4 percent by volume (Rawls et al., 1982; Hanson et al., 2000).

Table 1: Soil physical characteristics

Location	Field capacity percent moisture content (dry wt. basis)	Bulk Density (g/cm^3)	Field capacity percent moisture content (vol. basis)
1	14.1	1.53	21.6
2	14.4	1.51	21.7
3	14.3	1.54	21.9

]

Table 2: Permanent wilting point moisture content measurement

Location	Wilting point percent moisture content (wt. basis)	Bulk Density (g/cm^3)	Wilting point percent moisture content (vol. basis)
1	5.5	1.53	8.42
2	5.3	1.51	8.00
3	5.2	1.54	8.00

Table 3: Chemical properties of irrigation water

Source	EC (dS/m)	pH	SAR	RSC
Fresh water	0.25 – 0.65	7.6	3.3	1.67
Marginal water	2.00 – 2.15	7.7	14	3.23
Poor quality water	3.2 – 3.40	7.8	18	5.25

Table 4: Chemical properties of soil water extract

Location	Depth (cm)	EC (ds/m)	pH	SAR
1	0-45	2.02	8.04	3.98
2	0-45	1.83	8.17	4.01
3	0-45	1.92	8.10	4.75
Average	0-45	1.92	8.1	4.25

Table 5: Mean germination rate of corn for various treatments

Water quality	Drip irrigation frequency (days)			Bed Furrow system
	2	4	6	
	Total emergence counts / m^2			
Good	11	11	11	11
Marginal	12	13	12	11
Poor	11	12	12	12

Table 6: Mean plant heights for different irrigation water qualities and frequencies

Water quality	Drip irrigation Frequency (days)			Average	Raised bed system
	2	4	6		
	Plant Height (cm)				
Good	191.1	179.2	189.1	186.9^a	188.3
Marginal	188.2	175.9	185.4	183.6^b	184.8
Poor	179.5	174.6	179.9	179.0^c	182.1
Average	186.3^a	176.6^b	184.8^a	-	185.1

Note: Levels with different letters are statistically significant at $\alpha = 0.05$

Chemical characteristics of soil and water

Chemical analyses of water

Groundwater samples were collected after 15minutes of tube well operation and investigated for EC (electrical Conductivity), pH, residual sodium carbonate (RSC) and sodium absorption ratio (SAR) (Table 3).

Chemical analyses of soil

Chemical analyses of soil samples were carried out to estimate the electrical conductivity **(EC),** pH, and SAR at three points in a field at a depth of 0-45cm. The values these parameters are given in Table 4.

Impacts of irrigation water quality and frequency on corn growth parameters

Both the water quality and its frequency of application affect the development of corn plants. The parameters studied in the present investigation included germination rate, plant height, dry matter weight, grain yield and harvest index. The data values were statistically analysed for testing the significance of irrigation water quality and frequency parameters.

Germination rate

Germination rates for corn seedlings were observed on completion of germination in various experimental plots. It may be kept in view that the germination rates were recorded prior to application of irrigation water quality and frequency treatments, therefore the results were independent of the treatment effects (Table 5).

Plant heights

Effects of irrigation water quality and frequency on plant heights were statistically analyzed. The main effect of irrigation frequency was statistically significant for plant heights. Plant heights were 186.3, 176.6 and 184.8 cm for 2, 4, 6 day irrigation frequency respectively. The plant height decreased as the irrigation frequency increased from 2 to 4-days while the height increased as the irrigation frequency further increased from 4 to 6-days (Table 6). Balaswamy et al. (1986), Sachan and Gangawar (1996), Jiotode et al. (2002), Hussaini et al. (2001, 2002), Kumar and Mugalkhod (2005), Riaz et al. (2007),), and Inamullah et al. (2011) observed plant heights of corn under varying conditions of soil, crop, salinity, frequency climate. It is, perhaps, due to the fact that soil salts remain in diluted form in 2-day irrigation frequency and do not retard growth as compared to the 4-day irrigation frequency. In case of 6-day frequency, the applied water quantity is enough to leach down the salts out of root zone making soil environment friendly for plant growth. However, 6-day frequency cannot be appreciated for drip irrigation system as it approaches the conventional flood irrigation and results in small number of irrigation. The practices has been discouraged by other researchers (Kara and Biber, 2008). In view of all this discussion, the 2-day frequency is recommended as the most appropriate practice under the conditions of present experimentation. A desirable effect of decreasing the irrigation frequency on crop growth has also been observed by Kara and Biber (2008) where 13 irrigations performed well compared with 4 irrigations under drip system while total amount of water applied remained the same. The present study along with Kara and Biber

Table 7: Mathematical models for irrigation frequency and plant heights

Irrigation frequency	Model	Coefficient of determination
2-day	$y = 3.1x^2 - 25.1x + 228.9$	$R^2 = 0.89$
4-day	$y = 2.7x^2 - 22.6x + 222.4$	$R^2 = 0.73$
6-day	$y = 1.1x^2 - 8.4x + 192.1$	$R^2 = 0.89$

Table 8: Mean plant dry matter weight for different irrigation water qualities & frequencies

Water quality	Drip irrigation Frequency (days)			Average	Raised bed system
	2	4	6		
	Plant dry matter weight (t/ha)				
Good	20.41	18.84	20.11	19.7[a]	19.40
Marginal	17.16	15.04	16.60	16.7[b]	18.01
Poor	15.61	13.88	15.07	15.5[c]	17.44
Average	17.73[a]	15.92[b]	17.26[a]	-	-

Note: Levels with different letters are statistically significant at $\alpha = 0.05$

Table 9: Mathematical models for irrigation frequency and plant dry matter weight

Irrigation frequency	Model	Coefficient of determination
2-day	$y = 0.34x^2 - 2.82x + 24.69$	$R^2 = 0.90$
4-day	$y = 0.41x^2 - 3.37x + 22.29$	$R^2 = 0.94$
6-day	$y = 0.36x^2 - 3.05x + 20.25$	$R^2 = 0.97$

(2008) conclude that frequent irrigation in drip irrigation is paying in terms of crop growth. Their study also indicated a quadratic response of growth with irrigation frequency, that is, crop performance decreased as the number of irrigations increased from 4 to 6, but the crop response improved when irrigations were increased from 6 to 13.

The main effect of water quality also tested statistically significant and the plant height linearly decreased with deteriorating water quality. When averaged across all the treatments, plant height decreased from 186.9 to 179.0 cm (Table 6) as the water quality changed from good (EC=0.25dS/m) to poor (EC=3.4dS/m) which amounts to 4.5% reduction in growth of plants. Overall results of the study indicate that sustained application of poor quality water deteriorates soil health in the long run and proves counter-productive to growth. Many researchers (Oster, 1994; Shalhevet, 1994; Shani and Dudley, 2001; Gideon et al., 2002; Katerji et al., 2003, 2004) have advocated a continued and reasonably successful agriculture with saline water provided the leaching of salts out of root zone is managed. Alternatively, such a method of irrigation should be selected that can supply just sufficient quantity of water to the root zone to meet the evaporative demand and minimize salt accumulation inside (Bresler et al., 1982; Munns, 2002).

Another team of scientists (Stanghellini et al., 2003; Jones, 2004; Kirnak and Demirtas, 2006) have reported from their researches that the efficient use of irrigation water; for instance, drip contributes substantially to the best use of water for agriculture and improves irrigation efficiency; especially, in the areas with dry and hot climates, drip irrigation has improved water use efficiency mainly by reducing evapotranspiration losses. Thus, the present study and referenced researches clearly indicate that increasing salinity levels of irrigation water adversely affect crop growth. The average plant heights in the raised bed furrow plots, conventionally irrigated through furrows, were generally higher compared with the heights averaged across all the varying irrigation frequencies and water qualities for drip irrigation (Table 6).

It may, however be seen that the plant heights for drip irrigation system with good and marginal quality waters with *'2-day frequency'* were higher than those of raised bed system. This certainly establishes the superiority of drip irrigation system with 2-day frequency over all the other counterparts included in the experiment. In fact, 2-day frequency represents the true sense of drip irrigation since it applies water in small amounts and keeps the nutrients and water available to the plant and the chances of dry stress are altogether eliminated.

The quadratic relationship of frequency with the plant height was further studied to seek mathematical relationship between them for different irrigation water qualities. Equations for the three water qualities are given in Table 7. A strong relationship exists between the plant height and irrigation frequency as depicted by a high R^2 equaling 0.89.

Plant dry matter weight

Plant dry matter weights were measured three times during the cropping season. Dry matter weights at harvest time were statistically analyzed to investigate the effects of different treatments. The main effect of irrigation frequency was statistically significant suggesting that the irrigation efficiency had a clear impact on plant dry matter weight. Generally the effect of frequency, like that of plant height, was quadratic with 11.4% higher dry matter weight for 2-day frequency compared with 4 day frequency (Table 8). The reason for this differential response may be associated with better response of crop growth under frequent irrigation which keeps the salts of soil and water mix in diluted form as compared to 4-day irrigation frequency. It may also be observed that the plant dry matter weights were same for 2-day and 6-day irrigation frequency. The result of the study compares two important irrigation management practices i.e. frequent irrigation under 2-day interval and leaching impact of salts under 6-day interval. However, 2-day frequency shall be recommended for the drip irrigation as the 6-day interval is undesirable in drip irrigation because it behaves like flood irrigation.

Table 10: Grain yield for different water qualities and irrigation frequency

Water quality	Drip irrigation frequency (days)			Average	Raised bed system
	2	4	6		
	Grain yield (t/ha)				
Good	8.01	6.58	8.09	7.54[a]	8.78
Marginal	6.85	5.61	6.75	6.38[b]	8.03
Poor	5.75	4.73	5.58	5.33[c]	6.64
Average	6.87[a]	5.64[b]	6.81[a]	-	-

Note: Levels with different letters are statistically significant at $\alpha = 0.05$

Table 11: Mathematical models for irrigation frequency and grain yield

Irrigation frequency	Model	Coefficient of determination
2-day	$y = 2.29x^2 - 18.16x + 76.25$	$R^2 = 0.98$
4-day	$y = 1.75x^2 - 13.95x + 62.23$	$R^2 = 0.86$
6-day	$y = 1.42x^2 - 11.647x + 52.85$	$R^2 = 0.89$

Table 12: Harvest index for different water qualities and irrigation frequencies

Water quality	Irrigation frequency (days)			Average	Raised bed system
	2	4	6		
	Harvest indices				
Good	0.39	0.35	0.40	0.38	0.45
Marginal	0.40	0.37	0.41	0.39	0.44
Poor	0.37	0.34	0.37	0.36	0.38
Average	0.39	0.35	0.39	-	0.42

The responses shown by the dry matter weight are similar to those produced by the plant heights. Both 2-day and 6-day frequency plots produced equivalent but better dry matter weights compared with 4-day frequency plots. It appears that salts in the 4-day frequency plots neither remained in solute form nor they could leach down from root zone and that is why these plots showed a poor performance in respect of plant growth both in plant height and dry matter.

Once again the relationship between the frequency of irrigation and plant dry matter weight resulted in a nearly quadratic form for all the three water quality levels for the reasons discussed earlier under plant height. The quadratic equations drawn for the relationships are shown (Table 9). The effect of raised bed on dry matter weight was comparatively better than drip irrigated plots.

The effect of water quality on dry matter weight tested statistically significant. Water quality was linearly related with the dry matter weight (Table 9). Dry matter weight, on the average, was 19.7, 16.7 and 15.7 tons/ha respectively for good, marginal and poor quality waters respectively. The dry matter weight increased by 25.5% as the water quality improved from poor (EC=3.4 dS/m) to good (E=0.25 dS/m). Effects of irrigation water salinity on crop dry matter weight have been reported by Katerji (2000). Similarly many researchers have shown negative effects of salinity of irrigation water on crop growth (Oster, 1994; Shalhevet, 1994; Shani and Dudley, 2001; Gideon et al., 2002; Katerji et al., 2003, 2004). In general, research supports that drip irrigation is an ideal way of doing successful agriculture with a range of saline waters. The raised bed plots irrigated through furrows, showed higher dry matter weights compared to averaged values of other plots irrigated with drip laterals (Table 9). However, drip irrigated plots with 2-day frequency and good / marginal water quality have higher dry matter weight of crop compared with rest of the treatment combinations. Once again the superiority of 2-day frequency with light application of water produced best results.

Grain yield

The data were statistically analyzed using completely randomized design (CRD). The main effect of irrigation water quality tested highly significant suggesting that the varying water qualities produced different grain yields. The yield reductions were 1.16 and 2.21ton/ha respectively for marginal (EC=2.15 dS/m) and poor quality (EC=3.40 dS/m) water compared with that of good quality (EC=0.25 dS/m) water (Table 12). This is a noticeable difference and discourages the use of both marginal and poor quality waters for irrigation of corn plots. In addition to yield losses the obvious salt buildup resulting from the poor quality water is another factor aggravating the gravity of problem resulting from the continuous use of poor quality waters over a long period of time.

In the present study, adverse effects of poor quality water on yields have been observed for waters with ECs varying from 2.15 to 3.40 (Karlberg et al., 2012; Al-Tahir, 2001). Bernstein and Francois, (1973a, b) compared the effects of sprinkling and drip irrigation of high, medium, low-salt waters. Sprinkling with the medium-salt water reduced yields appreciably only at the highest frequency (2.3 days) but sprinkling with the high-salt water reduced yields more than 50% at all sprinkling frequencies, compared to a yield loss of only 14% by drip irrigation with this water (Bernstein and Francois, 1973 a, b). This suggests the drip irrigation as a better practice compared with sprinkler irrigation as regards the ill effects of saline water.

The main effect of irrigation frequency also registered a significant impact on grain yield (Table 10). Again the effect of 2-day and 6-day frequency were similar but they were 1.23 and 1.17 tons/ha greater in yield compared to 4-day irrigation frequency for the reasons discussed earlier. Once again this trend is quadratic suggesting that the crop yields of plants is better for 2 and 6-day frequencies compared to 4-day. In 2-day and 6-day irrigation frequencies, the 2-day frequency can be recommended for the irrigation since 6-day frequency approaches flood irrigation. Phene and Beale (1976) reported 12-14% more corn yields in drip plots than did the furrow and sprinkler irrigated plots. They reported availability of more NO_3-N in the root zone of drip irrigated plots. Increased irrigation frequency produces better results in terms of crop growth; and a similar finding has also been reported by many other researchers (Karlberg et al., 2012; Shrivastava and Parikh, 1994; Sammis, 1981; Istanbulluoglu et al. 2002; Dagdelen et al. 2006; Payero et al., 2006; Cetin et al., 1996; Howell et al., 1995; Cosculluela and Faci, 1992; Al-Tahir, 2001).

A short irrigation interval has been beneficial in drip irrigations system as it suppresses salt effects by avoiding concentration impact of salt on crop growth. Three drip irrigations resulted in 9920 kg ha^{-1} as against 9650 kg ha-1 for two irrigations (Istambulluoglu et. al., 2002) for corn and grain size also improved with number of irrigations. Crop performance improves as the interval of irrigation shortens (Kanber et al., 1989; UI 1993, 1990; Yildirim 1993, Ogretir 1994). The drip and trash mulch in sugarcane produced highest yield of about 51 t/ha with 44% water saving and the highest yield of 163 kg/ha/mm of water compared with many other treatment combinations of mulching and irrigation. Similarly, largest root length of corn was found in the light and frequent irrigation treatment by Robertson, (1980). In another study, results showed that yield variables and water use efficiencies (WUEs) increased with increasing irrigation frequency and rate (El-Hendawy and Schmidhalter, 2012).

The relationship between the frequencies is again quadratic function (Table 11). This is clearly suggesting that increased frequency for drip irrigation is beneficial in respect of water saving, nutrient and water uptake, plant dry matter weight, grain yield and above all larger water use efficiency. It should be kept in view that these experiments were conducted using drip laterals on the raised beds and they were compared with the raised bed system where irrigation was applied in furrows.

In the present study, a quadratic relationship of irrigation frequency with corn yield is similar to the findings of Kara and Biber, (2008) who report corn yield of 21.59, 19.15 and 29.16 tons/ha for 4, 6, 13 irrigations with drip system, whereas the water quality was same for each treatment. It is apparent that yield in their study was maximum with the shortest interval of drip irrigation. This establishes that shortest interval of drip irrigation provides the best plant development and finally the yield of crop.

Harvest Index

The harvest index describes ratio of grain to plant dry matter weight. In other words index translates the efficiency of system to convert the fraction of dry matter weight into grain. Harvest index is a cumulative descriptor of the system (water quality and frequency, nutrient uptake, climate, soil properties etc.) that helps estimating physiological efficiency of plant and environment it found during its life cycle. The effects of water quality and irrigation frequencies on harvest indices in corn were examined (Table 12). In case of drip irrigation, the maximum harvest indices (0.40/0.41) were observed for good/marginal quality waters especially for 2/6 day frequencies. However, plants irrigated with poor quality water with irrigation frequency 4-day produced least harvest index (0.34). Raised bed with furrow irrigation method produced highest harvest index for all the water quality levels. However, difference was comparatively higher for good quality water, followed by marginal and poor quality waters.

CONCLUSIONS

It was concluded that irrigation method, irrigation frequency and water quality considerably influenced corn yield. Drip irrigation system was found very efficient irrigation system over raised bed irrigation system even in marginal and poor quality water. It was concluded that the corn yield was high in drip system with good quality water. Good quality water under the drip irrigation system improved plant dry matter weight by11.4% when irrigation frequency changed from 2 and 6 to 4day.Similarly the difference in grain yields between the plots irrigated through good and poor quality waters was 7.5 and 5.33t/ha. It was also found that Crop parameters registered better performance for bed-furrow irrigated plots compared with drip irrigated ones in respect of plant height (1.0%), dry matter weight (5.8%) and corn yield (21.9%), However the bed-furrow irrigation cannot be preferred as it consumes more water for crop maturity. It is recommended that drip irrigation could be adopted where groundwater quality is marginal to poorto catch acceptable corn yield.

REFERENCES

Ahmad M and U Farooq, 2010. The State of Food Security in Pakistan: Future Challenges and Coping Strategies. Proceedings of the 26th AGM and Conference of PSDE, 28-30 December 2010, Islamabad, Pakistan.

Alberta Agriculture Food and Rural Development, 2004. Beneficial Management Practices: Environmental Manual for Crop Producers in Alberta. Alberta Agriculture Food and Rural Development, Edmonton, Alberta, USA.

Al-Tahir, YA Al-Nabulsi and AM Helalia, 2001. Effects of water quality and frequency of irrigation on growth and yield of barley (Hordeurnvulgare L.). Agricultural Water Management, 34: 17-24.

ASP (Agricultural Statistics of Pakistan), 2006. Government of Pakistan, Islamabad, pp: 84

Balaswamy K, BB Reddy, KA Reddy, BB Reddy and MB Reddy, 1986. Effect of planting patterns mulches and soil moisture regimes on growth and yield attributes of maize. Madras Agricultural Journal, 73: 553-557.

Bernstein L and LE Francois, 1973a. Comparisons of drip, furrow and sprinkle irrigation. Soil Science Society of America Journal, 115: 73-86.

Bernstein L and LE Francois, 1973b. Leaching requirement studies: Sensitivity of alfalfa to salinity of irrigation and drainage waters. Soil Science Society of America Journal, 37: 931-943.

Blood P, 1994 edition Pakistan: A Country Study. Washington: GPO for the Library of Congress.

Bresler E, BL McNael and DL Carter, 1982. Saline and Sodic Soils: Principles, Dynamics-Modeling. Springer-Verlag, Berlin, pp: 236.

Cetin O, 1996. Water Consumption of Second Crop Corn in the Harran Plain. Research Institute of Sanliurfa. General Publication No. 90, pp: 46.

Cosculluela F and JM Faci, 1992. Development of water production function of corn *Zea mays L.* by the use of a line-source sprinkler. Investigacion Agraria Productcion y Proteccion Vegetales, 7: 169-194.

Dagdelen, N., Yilmaz, E., Sezgin, F., Gurbuz, T., 2006. Water-yield relation and water use efficiency of cotton (Gossypium hirsutum L.) and second crop corn (Zea mays L.) in western Turkey. Agricultural Water Management, 82: 63–85.

El-Hendawy SE and U Schmidhalter, 2010. Optimal coupling combinations between irrigation frequency and rate for drip-irrigated maize grown on sandy soil. Agricultural Water Management, 97: 439-448.

Gideon O, Y De Malach, L Gillerman, I David and S Lurie, 2002. Effect of water salinity and irrigation technology on yield and quality of pears. Bio-system Engineering, 81: 237-247.

Anonymous, 2008a. Pakistan Social & Living Standards Measurement Survey 2006-07. Federal Bureau of Statistics, Islamabad, Pakistan.

Annonymous, 2008b. Assorted data and information. Pakistan Environmental Protection Agency (EPA), Ministry of the Environment, Govt. of Pakistan.

Gupta IC, 1990. Use of saline water in Agriculture. A study of arid and semi-arid zones of India. Revised Edition. Oxford & IBH, Pub. Co. Pvt., Ltd., New Delhi, India.

Hanson B, S Orloff and P Douglas, 2000. Monitoring soil moisture helps refine irrigation management. California Agriculture, 54: 38-42.

Howell TA, A Yazar, AD Schneider, DA Dusek, KS Copeland, 1995. Yield and water use efficiency of corn in response to LEPA irrigation. Transactions of the American Society of Agricultural Engineers, 38: 1737-1747.

Hussaini MA, VB Ogunlela, AA Ramalan and AM Falaki, 2001. Growth and development of maize (*Zea mays* L.) in response to different levels of nitrogen, phosphorus and irrigation. Crop Research, 22: 141-149.

Hussaini MA, VB Ogunlela, AA Ramalan, AM Falakiand and AB Lalwal, 2002. Productivity and water use in maize (*Zea mays* L.) as influenced by nitrogen, phosphorus and irrigation levels. Crop Research, 23: 228-234.

Hur B and M Agassi, 1992. Stabilizing steep slopes with soil conditioners and plants. Soil Technology 5: 249-256.

Inamullah, NH Shah, N Rehman, M Siddiq and Z Khan, 2011. Phenology yields and their correlations in popular local and exotic maize hybrids at various nitrogen levels. Sarhad Journal of Agriculture, 27: 363-369.

Istanbulluoglu A, I Kocaman and F Konukcu, 2002. Water use-production relationship of maize under Tekirdag conditions in Turkey. Pakistan Journal of Biological Sciences, 5: 287-291.

Jabro JD, RG Evans, Y Kim and WM Iversen, 2009. Estimating in situ soil–water retention and field water capacity in two contrasting soil textures. Irrigation Science, 27: 223-229.

Jiotode DJ, DL Lambe and CS Dhawad, 2002. Growth parameters and water use studies of maize on influenced by irrigation levels and row spacing's. Crop Research, 24: 292-295.

Jones HG, 2004. Irrigation Scheduling: advantages and pitfalls of plant-based methods. Journal of Experimental Botany, 55: 2427-2436.

Kamal Simi, 2008. Women and Water: Issues of Entitlement, Access and Equity." In Pakistani Women in Context: A Companion Volume to the Pakistan Country Gender Assessment. Islamabad, World Bank.

Kanber R, O Tekinel, R Bastug, S Onder and N Baytorun, 1989. Peanut yield as affected by deficit Irrigation, Soil Texture, Sowing date and Irrigation interval. In: Irrigation theory and sowing date and Irrigation interval. In: irrigation theory and practices (Ed: Rydzeuski and ward). Southampton, UK.

Kara T and C Biber, 2008. Irrigation frequencies and corn (*Zea mays* L.) yield relation in Northern Turkey. Pakistan Journal of Biological Sciences, 11: 123-126.

Karlberg L, J Rock, JG Annandale and JM Styne, 2012. Low-cost drip irrigation -A suitable technology for southern Africa: An example with tomatoes using saline irrigation water. http//www.sciencedirect.com /science/article.

Katerji N, JW van Hoorn, A Hamdy, M Mastrorilli, 2003. Salinity effect on crop development and yield, analysis of salt tolerance according to several classification methods. Agricultural Water Management, 62: 37-66.

Katerji N, JW van Hoorn, A Hamdy, M Mastrorilli, 2004. Comparison of corn yield response to plant water stress caused by salinity and by drought. Agricultural Water Management, 65: 95-101.

Kirkham MB, 2005. Principles of soil and plant water relations. Elsevier, Burlington, United States.

Kirnak H and MN Demirtas, 2006. Effects of different irrigation regimes and mulches on yield and macro nutrition levels of drip-irrigated cucumber under open field conditions. Journal of Plant Nutrition, 29: 1675-1690.

Kumar A and S Mugalkhod, 2005. Response of baby corn to planting methods and irrigation schedules under drip. MS Thesis, University of Agricultural Sciences, Karnataka state, India.

Meek BD, EA Rechel, LM Carter and WR DeTar, 1988. Soil compaction and its effect on alfalfa in zone production systems. Soil Science Society of America Journal, 51: 233-236.

Meek BD, EA Rechel, LM Carter and WR DeTar and AL Urie, 1992. Infiltration rate of a sandy loam soil: Effects of traffic, tillage, and plant roots. Soil Science Society of America Journal, 56:908-913.

Moodie, C.D., H.W. Smith and R.A. McCreery, 1959. Laboratory Manual for Soil Fertility, pp: 31-9 (Mimeographed). Washington State College, WA, USA

Munns R, 2002. Comparative physiology of salt and water stress. Plant Cell Environment, 25: 239-250.

Ogretir K, 1994. Yield response of maize to water under Eskisehir conditions. Directorate of Rural Services. Eskisehir Research Institute Publications, No. 234/182, Eskisehir-Turkey.

Oster JD, 1994. Irrigation with poor quality water-review article. Agricultural Water Management, 25: 271-297.

Patel MS and NT Singh, 1981. Changes in bulk density and water intake rate of a coarse textured soil in relation to different levels of compaction. Journal of Indian Society of Soil Science, 29: 110-112.

Payero JO, SR Melvin, S Irmak and D Tarkalson, 2006. Yield response of corn to deficit irrigation in a semiarid climate. Agricultural Water Management, 84: 101-112.

Phene CJ and OW Beale, 1976. High-frequency Irrigation for Water Nutrient Management in Humid Regions. Soil Science Society of America Journal, 40: 430-436.

Rawls WJ, DL Brakensiek and KE Saxton, 1982. Estimation of soil water properties. Transactions of ASAE, 25: 1316.

Riaz M, M Jamil and TZ Mahmood, 2007. Yield and Yield Components of Maize as affected by Various Weed Control Methods Under Rain-fed Conditions of Pakistan. International Journal of Agriculture & Biology, 09: 152-155.

Robertson WK, LC Hammond, 1980. Effects of Plant-Water Stress on Root Distribution of Corn, Soybeans, and Peanuts in Sandy Soil. Agronomy Journal, 72: 548-550.

Sachan SS and US Gangawar, 1996. Effect of row spacing, moisture conservation practices and levels of nitrogen on growth and yield of maize (*Zea mays* L.) under rainfed conditions. Indian Journal of Soil Conservation, 24: 125-127.

Sammis TW, 1980. Comparison of sprinkler, trickle, subsurface and furrow irrigation methods for row crops. Agronomy Journal, 72: 701-704.

Shalhevet J, 1994. Using water of marginal quality for crop production: major issues. Agricultural Water Management, 25: 233-269.

Shani U., Dudley L.M., 2001. Field studies of crop response to water and salt stress. Soil Science Society of America Journal 65:1522-1528.

Shrivastava PK and MM Parikh, 1994. Effect of drip Irrigation and mulching on tomato yield. Agricultural Water Management, 25: 179-184.

Singh KK, TS Colvin, DC Erbach and AQ Mughal, 1992. Tilth Index: An approach to quantifying soil tilth. Transactions of the ASAE, 35: 1777-1785.

Stanghellini C, FLK Kempkes and P Knies, 2003. Enhancing environmental quality in agricultural systems. Acta Horticulturea, 609: 277-283.

Ul MA, 1993. A research on the investigation of yield response of maize grown as second crop under Menemen plain conditions. PhD Thesis, Graduate School of Nature and Applied Sciences, Aegean University, Izmir, Turkey.

Yıldırım O, S Kodal, F Selenay, Y Yıldırım and EA Ozturk, 1996. Corn grain yield response to adequate and deficit irrigation. Turkish Agricultural and Forest Journal, 20: 283-288.