The Journal of Animal & Plant Sciences, 24(5): 2014, Page: 1518-1524
ISSN: 1018-7081

IMPACT OF IRRIGATION MANAGEMENT PRACTICES AND WATER QUALITY ON MAIZE PRODUCTION AND WATER USE EFFICIENCY

M. Irfan, M. Arshad, A. Shakoor† and L. Anjum

Department of Irrigation and Drainage, University of Agriculture, Faisalabad, Pakistan
†Correspondence Author E-mail: aamirskr@yahoo.com

ABSTRACT

In order to study the effect of irrigation methods and water quality on maize yield and water use efficiency, the research work was carried out at Postgraduate Agricultural Research Station (PARS), Faisalabad, Pakistan. Six treatments i.e. T_1D (Drip irrigation with good quality water), T_2D (Drip irrigation with marginal quality water), T_3D (Drip irrigation with poor quality water), T_1R.B (Raised bed irrigation with good quality water), T_2RB (Raised bed irrigation with marginal quality water) and T_3RB (Raised bed irrigation with poor quality water) with three replication of each treatment were used. Field data regarding germination rate, plant height, crop yield and the water use efficiency were collected and the results were analyzed. It was found that irrigation method and water quality both affected the plant height, germination rate, maize production and the water use efficiency. It was concluded that the maize crop yield (8487kg/ha) and water use efficiency (13.92kg/ha-mm) was high in T_1D. The crop yield in T_2D, T_3D, T_1RB, T_2RB and T_3RB treatment were reduced by 5, 12, 19, 29 and 37%, respectively. It was recommended that drip irrigation would be adopted where groundwater quality is marginal to poor quality to get high crop production and water use efficiency.

Key words: Drip irrigation; water use efficiency; raised- bed; CROPWAT model.

INTRODUCTION

In the whole world, demand of water has increased, while the availability of fresh water was bounded in worldwide and water scarcity affected every continent of the globe and about 700 million people in 43 countries were under water stress (World Bank, 2011). The available sources of water cannot fulfill the increasing demand of water and hence the scarcities of water may change with the changing patterns of weather. The scarcity of water is also deeply linked with food security. Thus, irrigation system can play an important role to food security and sustainable income, specifically in developing countries. More than 900 million people live in water shortage river basins (closed basins), while more than 700 million peoples are living in those areas, where the limit to water resources is fastly approaching. One billion people were living in those basins where economic constrained boundary the speed of more required investments in water management (Molden *et al*., 2007).

Pakistan falls in the region of arid to semi-arid, where precipitation changes from less than 100mm to above 1050mm against to the possible demand of 1778mm. This huge difference between supplies and demand is met by irrigation. Increasing of water shortage and limited supplies is the major problem of Pakistan and there is already 48.6% culturable waste while the population has increased from 32.4 million in mid of 1948 to 144.5 million in 2003, and increased to 168 million in 2010. The estimated population for the year 2025 would be 221 million (Qureshi *et al*., 2011).

Irrigation remained an important practice in agriculture in Pakistan and used more than 97% of its water resource for crop production and food production (Shaikh, 2000). The competition for fresh water in the development of urbanization, industry and agriculture caused the decline of fresh water for irrigation on the earth (Ma *et al.*, 2008). The estimated efficiency of irrigation system in Pakistan was 35.5 percent (Qureshi *et al*., 2011), which showed that the agriculture water that reached the fields was not precisely used by the crops. Furthermore, the poor quality of water caused reduction in yield (Tanwir *et al*., 2003; Rukhsana *et al*., 2005). In short, there is need of management of water which may increase the water use efficiency and hence the grain yield. Thus, it is necessary and feasible to use the irrigation water for agriculture using the modern management practices and techniques, such as drip irrigation and the raised-bed system.

Maize is one of the most grown crops and ranked third in the world. The area under maize is more than 118 million hectares with an average production of about 600 million metric tons per annum. In Pakistan, area under maize is over 1Mha and ranked fourth largest crop with the average production 3.5 million metric tons (Jabran *et al.*, 2013).

Raised-bed farming is not a new idea but in Asia and other parts of the world, raised beds and furrows are used for irrigation for centuries. Raised-bed irrigation enhances sunlight utilization by 10 to 15 percent. The raised-bed is like a man-made baffle-board, which could delay seepage of rainwater and good response to drought. Raised-bed planting could also prevent waterlogging and control weeds and also save water upto 50% and yield 20-25% over flood irrigation system (Verhulst *et al.*, 2011).

Drip irrigation system is being used in all over the world and the leading countries are France, South Africa and USA with 90, 37 and 21% area under drip, respectively. Drip irrigation system is more efficient than other methods such as surface irrigation methods. Drip irrigation system had field level application efficiencies of 70 - 90%, as losses of deep percolation and surface runoff are decreased to very low (Ashraf, 2012). In was found that in maize crop the 75% of the roots present in top 40cm soil layer and similar for drip irrigation system (Wan and Kang, 2006; Wang *et al*., 2007). Drip irrigation can maintain high soil metric potential in the roots due to its slow rate and high frequent application. Thus, reduction in osmotic potential can also be counter balance by consistence irrigation water for maintain the high crop growth. Therefore, drip irrigation has been regarded as the most advantageous method for applying irrigation water to crops. Drip irrigation system could be used for more crops per unit water to be grown and this system allows crop cultivation in those areas where water availability is very low to irrigate by surface method. The main objective of the study was to estimate the impact on maize crop yield and water use efficiency for drip and raised-bed irrigation systems due to variation in water quality.

MATERIALS AND METHODS

Experimental site: The field experiment was carried out at the research area of the Postgraduate Agricultural Research Station (PARS), University of Agriculture, Faisalabad, Pakistan during the Rabi period of 2011-12 on maize crop. The study area comprised alluvial deposits mixed with loess having calcareous characteristics. Topography of study area was fair with semi-arid climate. The climatic data were collected from Agricultural Meteorology Cell, Department of Crop Physiology, University of Agriculture, Faisalabad. The climate data included rainfall, reference evapotranspiration, minimum and maximum temperature as shown in Figure 1. It was found that summer was hottest and winter was coldest. 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 while maximum reference evapotranspiration was recorded in May and June. The average rainfall recorded was 439 mm/year and the average monthly evapotranspiration was 1257mm/year.

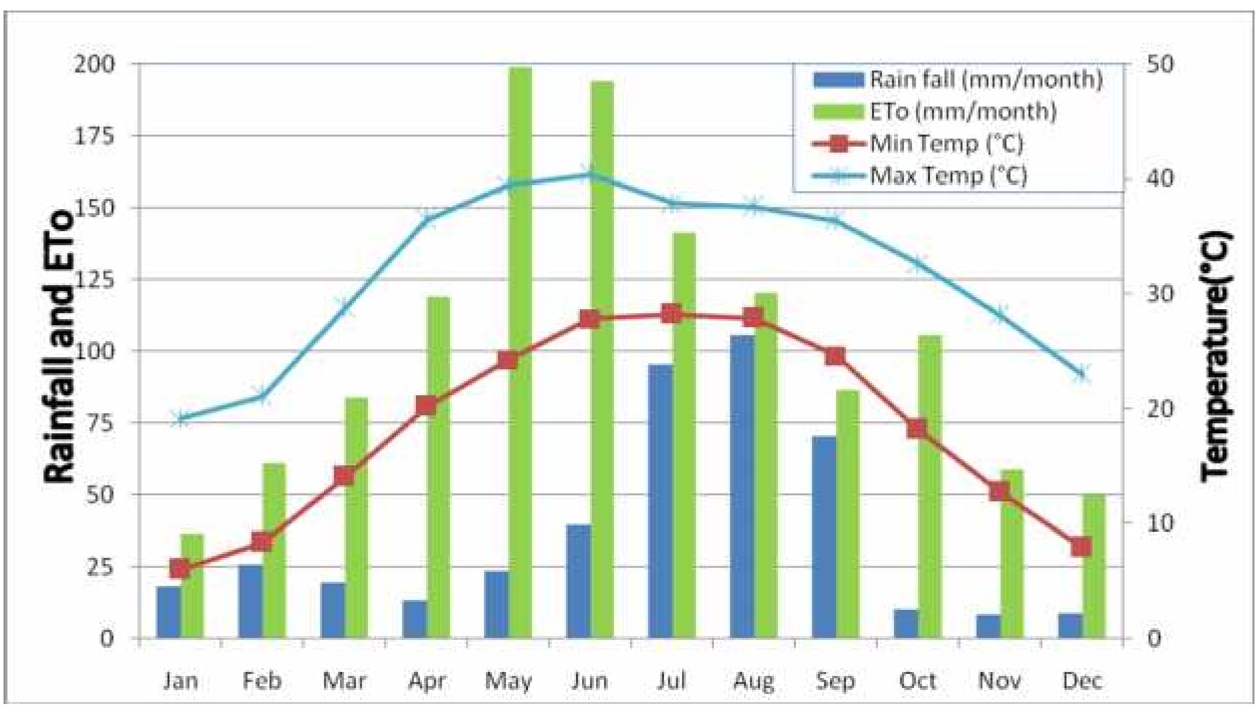

Figure 1: Monthly climatic data

Soil Analysis: Soil texture analysis was carried out with hydrometer for the soil samples and results are given in Table 1. The soil type of study area was found sandy clay loam.

Table 1: Soil textural analysis

Depth (cm)	(%) sand	(%) silt	(%) clay	Soil type
0-6	66.1	8	25.9	
6-12	65.9	15.2	18.9	Sandy clay loam
12-18	70.1	16.4	13.5	

Water analysis: The samples of irrigation water were analyzed to determine electric conductivity (EC) and sodium adsorption ratio (SAR). The good quality water used varied from as: EC (0.35 to 0.47dS/m) and SAR (0.95 to 1.99). The marginal quality water used varied from as: EC (1.65 to 1.93dS/m) and SAR (3.02 to 3.51) and the poor quality water used varied from as: EC (2.9 to 3.34dS/m) and SAR (4.13 to 4.61).

Experimental design: The following treatments were practiced on maize crop, as shown in Figure 2.

T_1D = Drip irrigation with good quality water
T_2D = Drip irrigation with marginal quality water
T_3D = Drip irrigation with hazardous quality water
T_1RB = Raised-bed irrigation with good quality water
T_2RB = Raised-bed irrigation with marginal quality water
T_3RB = Raised-bed irrigation with hazardous quality water

Every treatment was replicated three times with the experimental plots arranged in a randomized complete block design. The total numbers of experimental unit were 18 with each plot size of 6.74m ×31.33m.

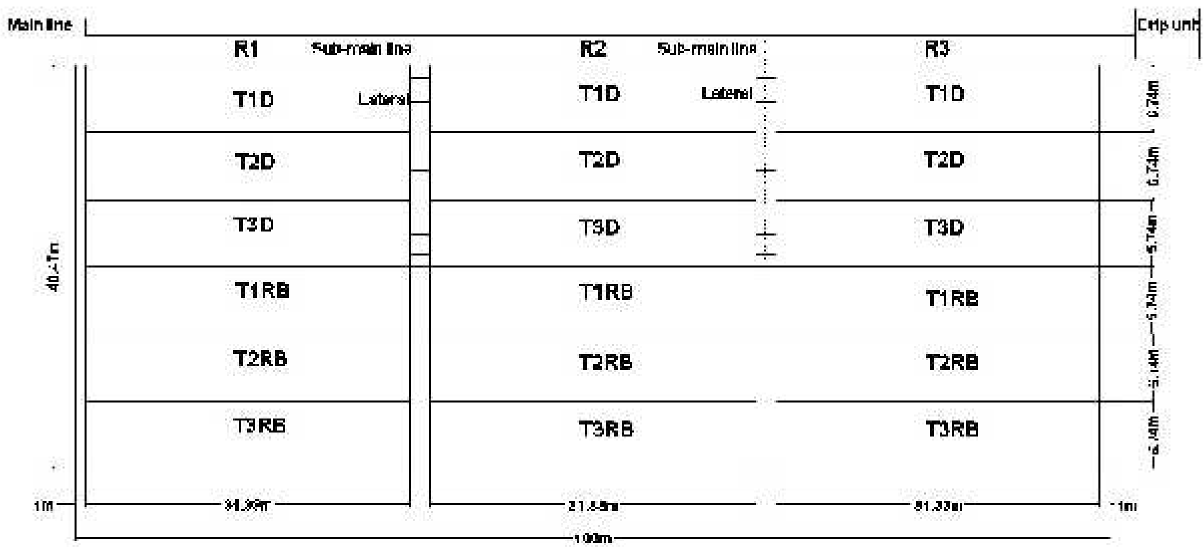

Figure 2: Field layout

Observations and measurements: The number of seedlings was counted daily from sowing to thinning for calculating the seedling emergence rate in the growing season of maize. The emergence rate was calculated based on the amount of sown. Ten plants in every plot were chosen to determine the germination rate, plant height, grain yield and water use efficiency. Soil samples were taken at 0-6, 6-12 and 12-18cm depths from each plot with an auger before the sowing to check the available moisture content in the soil. The data obtained from the experiment were analyzed by the analysis of variance and the means of different treatments were compared using the least significant difference test.

Water use efficiency: The water use efficiency was determined using following formula.

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

Where,

WUE = Water use efficiency (kg/ha-mm)
Y = Crop yield (kg/ha)
TIW = Total irrigation water applied during the growing season (mm).

Irrigation scheduling using CROPWAT model: The CROPWAT model was used to determine the reference evapotranspiration (ET_o), crop water requirements (CWR) and more specifically the design and management of the irrigation schemes. The standard values of crop coefficient (K_c) for maize crop were selected from the CROPWAT model. The irrigation scheduling was done on the basis of 6 day interval, as shown in Table 2. The total crop evapotranspiration and effective rainfall during the whole season was 651 and 120mm, respectively, so the net irrigation was 528mm, applied to the crop.

Table 2: Irrigation scheduling

Day after sowing	Rain	Depl.	Net Irr.	Deficit	Loss	Gr. Irr.	Flow
	mm	%	mm	mm	mm	mm	l/s/ha
6	0.0	6	2.9	0	0	4.1	0.08
12	0.0	7	4.2	0	0	6.1	0.12
18	0.0	7	4.8	0	0	6.8	0.13
24	0.0	10	8.1	0	0	11.6	0.22
30	0.0	8	7.1	0	0	10.1	0.19
36	1.8	12	12.0	0	0	17.2	0.33
42	0.0	15	15.8	0	0	22.6	0.44
48	0.0	21	23.9	0	0	34.2	0.66
54	0.0	21	27.0	0	0	38.5	0.74
60	1.9	24	32.1	0	0	45.9	0.89
66	2.5	26	36.3	0	0	51.9	1.00
72	0.0	28	39.3	0	0	56.1	1.08
78	0.0	29	40.9	0	0	58.5	1.13
84	0.0	30	41.9	0	0	59.8	1.15
90	4.9	27	37.7	0	0	53.8	1.04
96	0.0	35	48.9	0	0	69.9	1.35
End	0.0	80					

Depl. – Depletion , Net Irr.- Irrigation , Gr. Irr. – Gross Irrigation

RESULTS AND DISCUSSION

Germination count: Germination count of maize was calculated from the field and the average results of three replications are shown in Figure 3. The average germination count per square meter in T_1D, T_2D and T_3D was 13, 12.33 and 11.33; and in T_1RB, T_2RB and T_3RB was 11.33, 11 and 10.33, respectively. It was found that the germination was higher in T_1D, the treatment of drip irrigation with good quality water and comparative less germination in the T_3RB with poor quality water in raised-bed. The germination count of T_3D and T_1RB was found the same. In drip irrigation system more water was available to every seed as compare to raised-bed irrigation system. It was observed that the decrease in germination with in drip and raised-bed irrigation was due to low quality water.

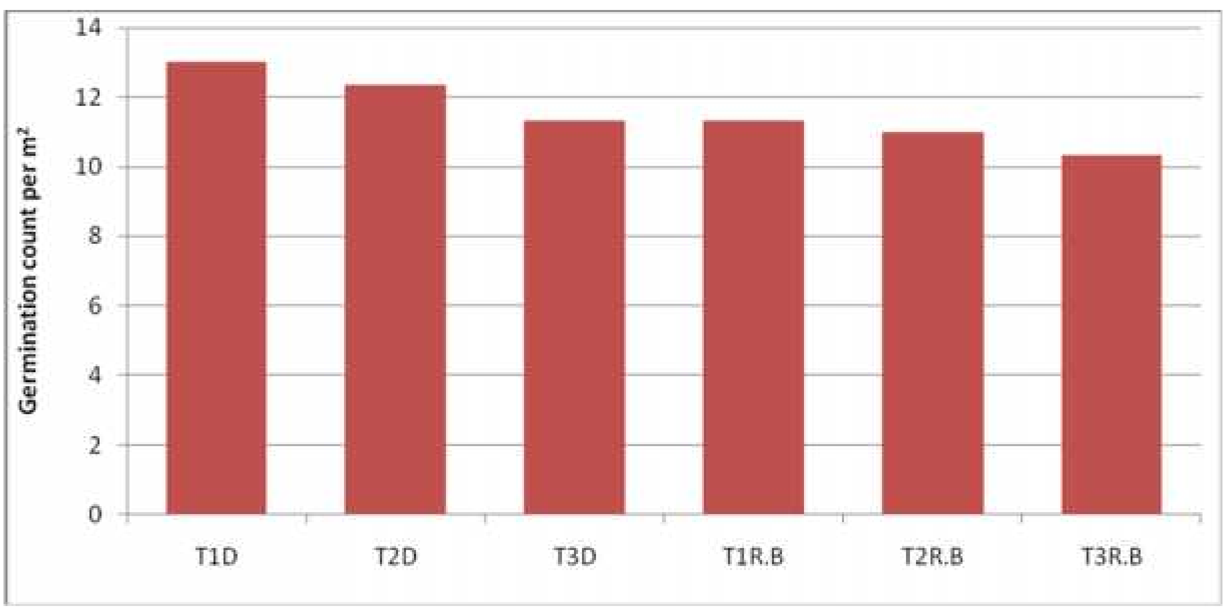

Figure 3: Average germination count

Plant height: Height of plant is very essential production component due to the photosynthetic activity. The average plant heights of maize crop for all the treatments are shown in Figure 4. The average plant heights of maize crop for T_1D, T_2D and T_3D were 2.22, 2.18 and 2.16m and for T_1RB, T_2RB and T_3RB were 2.11, 2.08 and 2.07m, respectively. The results revealed that the maximum height of plant was observed in the T_1D and comparatively low height in the T_3RB with poor quality of water.

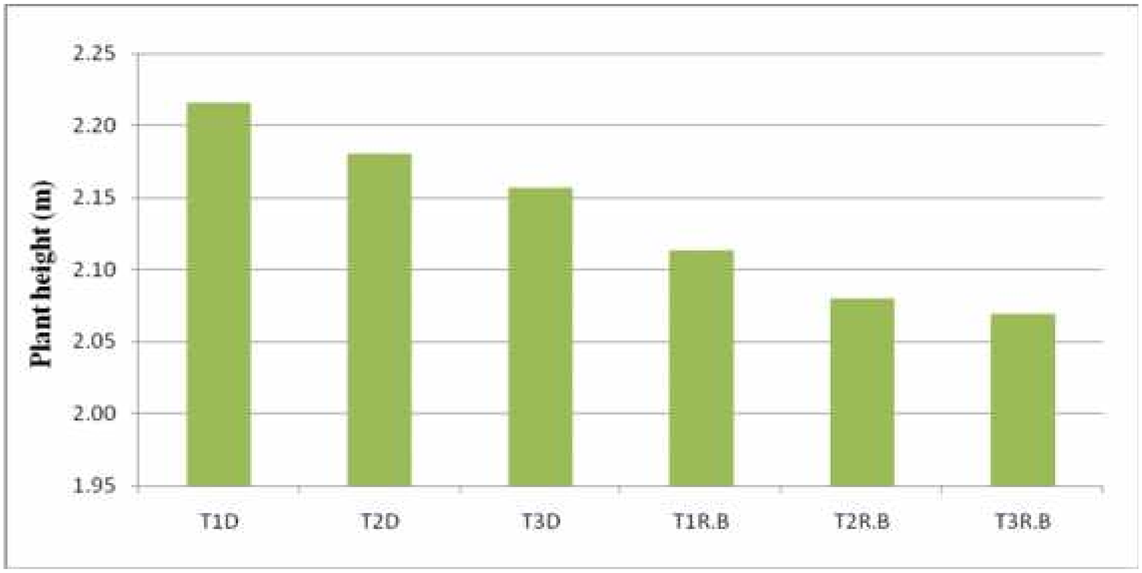

Figure 4: Average plant height

Maize crop yield: The results of average grain yield of maize crop among treatments are shown in Figure 5. The yield of crop for T_1D, T_2D and T_3D was 8487, 8083 and 7500 kg/ha and for T_1RB, T_2RB and T_3RB was 5357, 6027 and 6873 kg/ha, respectively.

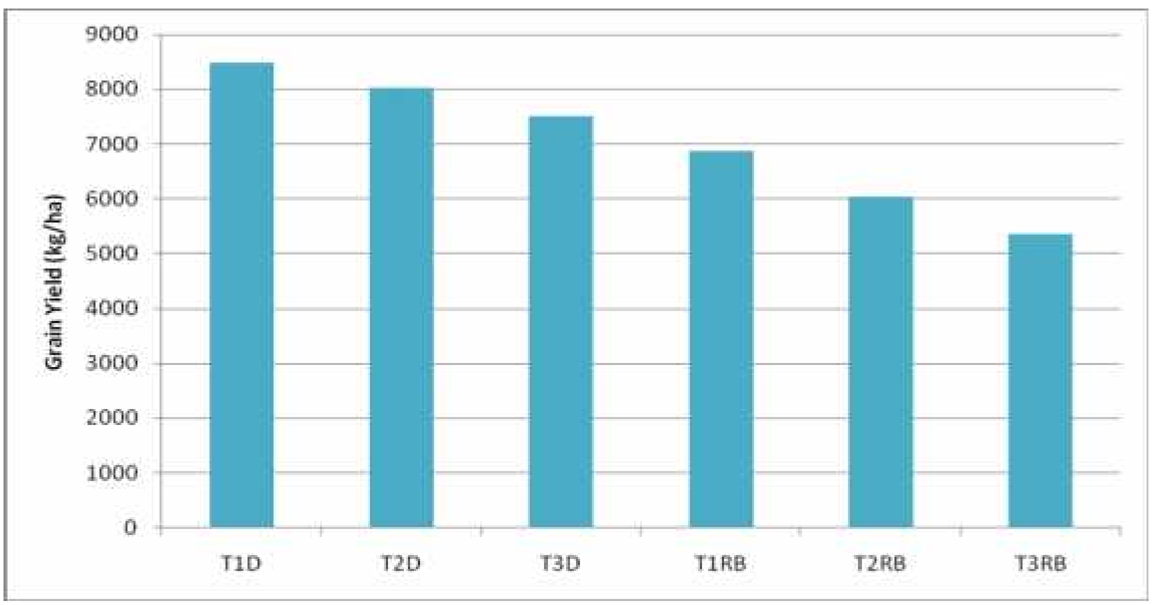

Figure 5: Average maize yield

The higher yield for all treatments in drip irrigation system over raised-bed was due to the good water distribution uniformity. The loss in crop yield within drip irrigation system due to marginal (T_2D) and poor (T_3D) quality water compared with T_1D was 453 and 987kg/ha, respectively. Similarly, in raised bed irrigation, the loss in crop yield was due to marginal

(T_2RB) and poor (T_3RB) quality water, compared with T_1RB was 847 and 1516kg/ha.

It was found that the yield of maize crop was reduced due to marginal and poor quality water in both drip and raised bed irrigation system. The low quality water affected the plant growth and soil structure directly and indirectly. This was due to the high salt concentration in poor quality water, which caused soil salinity in the soil profile. High salts concentration resulted in high osmotic potential of the soil solution, so the plants used more energy to absorb water. The higher yield of poor quality water in drip irrigation system was due to high water distribution efficiency in field in comparison to raised bed with good quality water. Kang *et al*. (2010) reported that as salinity of irrigation water increased, seedling biomass decreased, and the plant height, fresh and dry weight of waxy maize in the thinning time decreased by 2% for every 1 dS/m increased in salinity of irrigated water. Similarly, the results have good agreement with the results reported by Fadeyibi and Halilu (2011), Cetin and Bilgel (2002), Sander *et al*. (2004), Aujla *et al*. (2005), Dagdelen *et al*. (2006) and Vories *et al*. (2009).

Water use efficiency: As the water use efficiency is the relative term of crop yield and total water applied. The results of average water use efficiency had the similar trend of results as crop yield as shown in Figure 6. The average water use efficiency of T_1D, T_2D and T_3D was 13.92, 13.17 and 12.30kg/ha-mm and for T_1RB, T_2RB and T_3RB was 11.27, 9.88 and 8.78 kg/ha-mm, respectively. It was found that the high water use efficiency was in T_1D and lowest was in T_3RB.

It was also found that the results of water use efficiency in drip irrigation were high due to the high water distribution efficiency. Maximum amount of water was available in vicinity of the plant and roots because of minimum deep percolation losses in drip irrigation system. So the maximum yield and water use efficiency was obtained in drip irrigation system. The results of water use efficiency also have good agreement with the results reported by Khalid *et al*. (1999), Ahmad *et al*. (2001), Haider *et al*. (2000), Ibragimov *et al*. (2007) and Randhawa (2002).

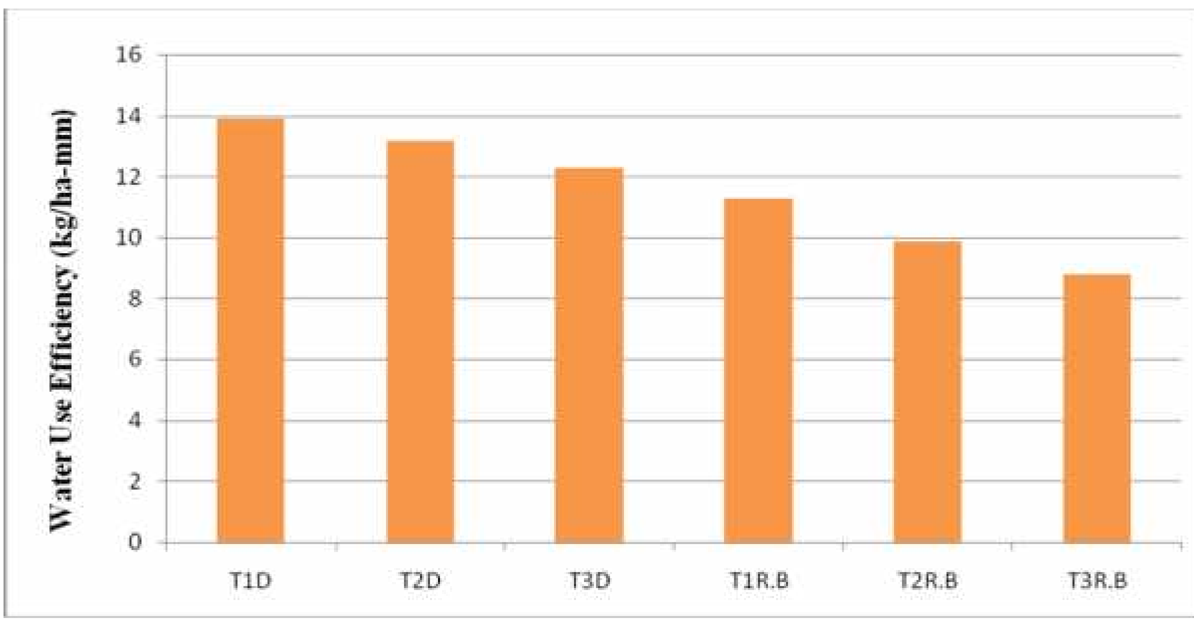

Figure 6: Average water use efficiency

Conclusions: It was concluded that irrigation method and water quality significantly affected the maize crop 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 maize crop yield and water use efficiency was high in drip system with good quality water. For good quality water, the drip irrigation system produced 19% more crop production over raised-bed irrigation system. Similarly, for marginal and hazardous water crop yield was increased by 23 and 25%, respectively. Hence, drip irrigation system was more efficient for saline water. It was also found that in drip irrigation and raised-bed the crop production was reduced due to the use of marginal and poor quality water by 5 and 12% and 10 and 17.9%, respectively. It is recommended that drip irrigation could be adopted where groundwater quality is marginal to hazardous quality to get high crop production and water use efficiency.

REFERENCES

Ahmad, M. M., S. Ahmad, M. Yasin and M. Shafiq (2001). Issues and Potential of Marginal Quality Waters for Irrigation. Proceedings of National Seminar on Drainage in Pakistan, April 18-19, 2001. Univ. Agri., Faisalabad. pp. 258-268.

Ashraf, M. (2012). Overview of drip irrigation: potential, issues and constraints. Presentation in International Center for Agricultural Research in the Dry Areas (ICARDA), Pakistan on December 31, 2012.

Aujla, M. S., H. S. Thind and G. S. Buttar (2005). Crop production and water use efficiency at various levels of water and N through drip irrigation under two methods of planting. Agri. Water Manage. (71): 167-179.

Cetin, O. and L. Bilgel (2002). Effects of different irrigation methods on shedding and yield of cotton. Agricultural Water Management 54, 1pp. 1-15.

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

Fadeyibi, A. and A. Halilu (2011). Effects of irrigation water on maize crop production atmaizube farms, Minna, Nigeria. J. Bio. & Env. Sci. 1(6)-63-68.

Ibragimov, N., S.R. Evett, Y. Esanbekov, B.s.Kamilov, L. Mirzaev and J.P.A. Lamers (2007). Water use efficiency of irrigated cotton in Uzbekistan under drip and furrow irrigation. Agri. Water Manage. (90): 112-120.

Jabran, K., A. Zahid and M. Faroo (2013). Maize: cereal with a variety of uses. http://www.agrihunt.pk/major-crops/168-maize-cereal-with-a-variety-of-uses.html

Kang, Y., M. Chena and S. Wan (2010). Effects of drip irrigation with saline water on waxy maize (Zea mays L. var. ceratina Kulesh) in North China Plain. Agricultural Water Management 97:1303-1309.

Khalid, M., M.Y. Nadeem, M. Ibrahim and A. Ali (1999). Use of Brackish Water for Irrigation by Alternating it with Canal Water. Proceedings National Workshop on Water Resources Achievements and Issues in 20th Century and Challenges for the Next Millennium. June 28-30, 1999, Islamabad. Pakistan Council of Research in Water Resources, Islamabad. pp.202-206.

Ma, W.J., Z.Q. Mao., Z.R. Yu., M.E.F. Van Mensvoort and P.M. Driessen (2008). Effects of saline water irrigation on soil salinity and yield of winter wheat –maize in north china plain. Irrigation drainage system. 22, 3-18.

Molden, D., K. Frenken, R. Barker, C. de Fraiture, B. Mati, M. Svendsen, C. Sadoff and C.M. Finlayson (2007). Trends in water and agricultural development. In: Molden, D. (Ed.), Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture. Earthscan Int. Water Manage. Inst., London and Colombo.

Qureshi, A.L., B.K. Lashari, and S.M Kori and G.A. Lashari (2011). Hydro-salinity behavior of shallow groundwater Aquifer underlain by salty groundwater in Sindh Pakistan. Fifteenth international water technology conference, IWTC-15 2011, Alexandria, Egypt.

Randhawa, H.A. (2002). Water Development for Irrigated Agriculture in Pakistan: Past Trends, Returns and Future Requirements, Investment in Land and Water, Proc. of the Regional Consultation, Bangkok, Thailand 3-5 October 2001, FAO, United Nations.

Rukhsana, A., A. Amir, U. Rahmat, M. Jahangir and M. Yousaf (2005). Effect of Soil Salinity/Sodicity on the Growth and Yield of Different Varieties of Cotton. Intl. J. Agri. and Biol. 07 (4): 606-608.

Sander, J., M. Zwart and W.G.M. Bastiaanssen (2004). Review of measured crop water productivity values for irrigated wheat, rice, cotton and maize. Agri. Water Manage. 69: 115-133.

Shaikh, I.B. (2000). Efficient and Sustainable Irrigation-Management in Pakistan. Pakistan National Committee of ICID. pp 50-57.

Tanwir, F., A. Saboor and N. Naima (2003). Soil Salinity and the Livelihood Strategies of Small Farmers: A Case Study in Faisalabad District, Punjab, Pakistan. Int. J. Agri. Biol. 05 (4):440–441.

Verhulst, N., F. Kienle, K.D. Sayre, J. Deckers, D. Raes, A.L. Ortega, L.T. Chavez and B. Govaerts (2011). Soil quality as affected by tillage-residue management in a wheat-maize irrigated bed planting system. Plant and Soil. 340:453-466.

Vories, E.D., P.L. Tacker, S.W. Lancaster and R.E. Glover (2009). Subsurface drip irrigation of corn in the United States Mid-South, Agri. Water Manage. (96): 912–916.

Wan, S.Q. and Y.H. Kang (2006). Effect of drip irrigation frequency on Radish growth and water use. Irrig. Sci. (24): 161-174.

Wang, F.X., Y.H. Kang., S.P. Liu. and X.Y. Hou (2007). Effects of soil matric potential on potato growth under drip irrigation in the north china plain . Agriculture Water Management 88, 34-42.

World Bank (2011). Land and water development division (FAO). www.fao.org.