ISSN 1023-1072

Pak. J. Agri., Agril. Engg., Vet. Sci., 2018, 34 (1): 57-67

EFFECT OF RAISED BED AND ALTERNATE FURROW IRRIGATION METHODS ON WATER SAVING AND YIELD OF SUNFLOWER

A. S. Soomro[1], A. Sarki[1], A. A. Tagar[2], N. Leghari[2] and H. R. Mangio[3]

[1]Department of Land and Water Management, [2]Department of Farm Power and Machinery, [3]Department of Energy and Environment, Sindh Agriculture University Tandojam, Pakistan

ABSTRACT

A field experiment was conducted at the experimental site of Faculty of Agricultural Engineering, Sindh Agriculture University Tandojam. The study assessed the effect of raised bed (RBIM) and alternate furrow (AFIM) irrigation methods on water saving and yield of sunflower. Treatments were arranged in a randomized complete block design. The raised bed and alternate furrow irrigation methods were prepared manually using hand tools. Sunflower (cv. HO-1) was planted under raised bed and alternate furrow irrigation methods. Total volume of water applied under RBIM was 1359.49 m^3 ha^{-1}, while under AFIM was 679.74 m^3 ha^{-1}. Hence AFIM saved 50% of water compared to RBIM. The water application efficiency under RBIM was 30.98%, 34.21% and 37.45%, while under AFIM was 20.95%, 77.44% and 67.66% at the depths of 0-20, 21-40 and 41-60 cm, respectively. Yield of sunflower under RBIM was 2963.59 kg ha^{-1}, while under AFIM was 2661.39 kg ha^{-1}. Total crop water productivity under RBIM was 11.771 kg m^3, while under AFIM was 21.142 kg m^3. Hence AFIM may be adopted to save water and to achieve high yield of sunflower in water scarce areas of Sindh.

Keywords: alternate furrow irrigation method, raisedbed irrigation method, water saving, yield, sunflower

INTRODUCTION

The current population of the Pakistan is approximately 170 million which will increase to 209 million by the end of 2025 at a growth rate of 1.5% per year (Shahid, 2010). This burgeoning population will expedite the demand of water in all sectors of life (i.e. agriculture, industrial and domestic). In Pakistan about 93% of water is utilized in agriculture sector, while the rest is used for drinking, domestic and industrialization purposes (WWF, 2007). Thus, agriculture sector has dominancy in water consuming from other sectors. However, water is becoming increasingly scarce worldwide (Rosegrant *et al*., 2002).

Corresponding author:abdulsaboorsoomro@gmail.com

Pakistan possesses world’s largest contiguous irrigation system, fertile soils, and favorable climatic conditions for growing crops. In spite of this crop production is usually limited (Shao *et al*., 2009). The main reasons for the crop water productivity are scarcity and miss management of water resources. The adequate and timely availability of water is important for agricultural productivity. The per capita water availability, which was about 5600 m^3 in 1947, has now reduced to about 1000 m^3, bringing the country to the brink of a water-scare condition (Abid *et al*., 2014). Therefore, it compels urgently to manage the available fresh water resources at all levels (Samdani, 2004).

Conversely farmers prefer traditional surface irrigation methods, which are responsible for considerable wastage of water and reduction in crop yields (Tiercelian and Vidal, 2006). Moreover micro irrigation methods have been avoided by farmers, because they require colossal cost of installation and maintenance. Therefore it is necessary to adopt such efficient irrigation methods that can be easily adopted by common farmers’, which not only increase production and save water but also be economically viable and can easily be operated and maintained. In this regard raised bed and alternate furrow irrigation methods have become more popular among farmers and scientists.

Raised bed technology is a land configuration where irrigation water is applied in furrows with plants on the raised beds. This technology enhances water application and distribution efficiencies and gives better crop yields (Ahmed *et al.,* 2011). Compared to the other types of surface irrigation methods, raised bed irrigation method is most efficient irrigation method as drip irrigation in pressurized irrigation methods (Naresh *et al*., 2012). This method can help in saving irrigation water and increasing crop production even in salinity affected areas and soils having low permeability (Qureshi and Lennard, 1998).

Alternate furrow irrigation is similar to the conventional furrow irrigation method. It consists of irrigation every other furrow (Irrigating odd and even furrows alternatively). According to EL-Sherbeny *et al.* (1997), the irrigation water applied through alternate furrow techniques was 23.8% to 26.7% less than traditional furrow irrigation method.

Sunflower (*Helianthus annuus* L.) is one of the potential oilseed crops that contains 39 to 49% oil in the seed in different varieties (Putnam *et al.,* 2013). Sunflower oil is quite palatable and contains many vitamins such as A, D, E and K, which is used in manufacturing of margarine (Hassan *et al*., 2000). Keeping in view the growing demand of water in all sectors of life particularly in agriculture sector owing to the rapid increase in population of the country and severe shortage of water, the present study was conducted on the effect of raised bed and alternate furrow irrigation methods on water saving and yield of sunflower.

MATERIALS AND METHODS

Experimental site

The research experiment was conducted at an experimental site of Faculty of Agricultural Engineering, Sindh Agriculture University Tandojam. The site is located at an altitude of 25° 25’ 28” N and a longitude of 68° 32’ 25” E about 26 m above sea level.

Preparation of land

The site was ploughed with moldboard plough, followed by two passes of cultivator and then leveled using traditional leveler. The treatments were arranged in a randomized complete block design (RCBD) and were replicated thrice. Total area under experiment (60 m × 35.1 m) was divided into three blocks (20 m × 11.7 m each). In each block, half portion was occupied by raised bed irrigation method (RBIM) and another half by alternate furrow irrigation method (AFIM). The RBIM was prepared by constructing 1.2 m wide 0.2 m high raised beds and 0.3 wide furrows using spade. The length of each raised bed and furrow was kept 9m. Thus total eight raised beds and 7 furrows were prepared. While AFIM was prepared by constructing 0.4 m wide and 0.2 m high beds. Hence total sixteen ridges and 15 furrows were prepared (Figure 1). In RBIM, every furrow was irrigated, while in AFIM furrows were irrigated alternately.

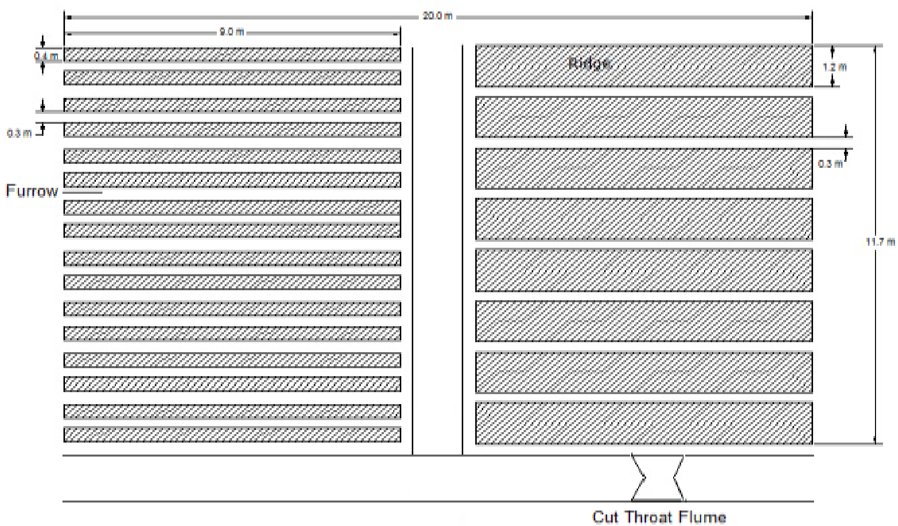

Figure 1. Layout of raised bed and alternate furrow irrigation methods.

Soil sampling

Composite soil samples were procured at the depths of 0- 20, 21- 40, 41- 60 cm to determine soil texture, ECe and pH of soil under study.

Soil physico-chemical properties

Soil texture was determined by Bouyoucous Hydrometer method (Bouyoucos, 1962), pH and ECe (1:2 soil water extract) were determined using digital pH and EC meters. Table 1 shows the depth wise soil physical properties of experimental soil.

Planting of crop

After preparation of RBIM and AFIM, a soaking doze of 100 mm was applied to each plot. As the soil turned into workable condition, sunflower seed (cv. HO-1) was drilled manually at the depth of 5 cm, keeping 70 cm plant to plant distance.

In RBIM, two rows, while in AFIM one row of sunflower seed was sown at the rate of 4 kg/acre as recommended by MINFAL (2005).

Table 1. Physico-chemical properties of experimental soil

Depth (cm)	**Sand %)**	**Silt (%)**	**Clay (%)**	**Textural Class**	**pH**	**ECe (dS m^{-1})**
0-20	72.0	27.5	0.5	Sandy Loam	8.1	1.35
21-40	84.5	15.0	0.5	Sandy Loam	8.2	1.45
41-60	80.0	19.5	0.5	Sandy Loam	8.4	1.48

Irrigation application

The irrigation water was applied to each plot under RBIM and AFIM at 50% depletion of soil moisture content at field capacity (Michael, 2008).The subsequent irrigations were applied accordingly.

The depth of irrigation water was calculated by following formula (Soomro *et al.,* 2001):

$$D = \frac{SMD}{100}\ xP_b\ xd_r$$

Where,

D = depth of water required (cm)
SMD = soil moisture deficit level
P_b = bulk density (g cm^3)
d_r = root depth (cm)

Following formula was used to identify soil moisture deficit level:

$$SMD = \theta_f - \theta_o$$

Where,

θ_f = Moisture content at field capacity (%)
θo = Moisture content at 50% SMD

Irrigation plan

Cutthroat flume (8” × 1.5’) was installed at the center of watercourse to apply the required depth of water to both plots (Skogerboe *et al.,* 1972).The time to apply required depth of water was calculated by following formula (Isrealson *et al.,* 1980):

$$QT = A\ \ x\ D$$

Where;

Q = discharge required (m^3)
T = time of application (hr)
A = area to be irrigated (ha)
D = depth of irrigation to be applied (m)

Fertilizer application

One bag of diaminum phosphate (DAP) and one bag of Urea per acre were applied to both plots at the time of planting and 1^{st} irrigation, respectively

(MINFAL, 2005). During the experiment attack of Jassids on the sunflower crop in both plots was observed. Following the pathologists instructions Amidacholopard was carefully sprayed at the rate of 250 ml/acre.

Water saving

The water saving was calculated using following formula:

$$WS\ (\%) = \frac{W_{AF} - \mathrm{W_R}}{W_{AF}}\ X\ 100$$

Where,

WS = Water saving (%)

W_{AF} = Total water used under RBIM (mm)

W_R = Total water used under AFIM (mm)

Yield and increase in yield of crop

The yield of crop under RBIM and AFIM was in kg ha^{-1}. The increase in yield (%) was computed using following formula:

$$Increase\ in\ yield\ (\%) = \frac{Y_1 - \mathrm{Y_2}}{Y_1}\ X\ 100$$

Where,

Y_1 = Total yield obtained in raised bed irrigation system (kg ha^{-1})

Y_2 = Total yield obtained under alternate furrow irrigation system (kg ha^{-1})

Crop water productivity

The crop water productivity (CWP) under RBIM and AFIM was calculated using relation:

$$\mathrm{CWP} = \frac{Y}{WR}$$

Where,

CWP = Crop water productivity (kg m^{3})

Y = Yield of crop (kg ha^{-1})

WR = Total Water consumed for crop growth (m^{3} ha^{-1})

Irrigation application efficiency

Water application efficiency was calculated by following formula:

$$\mathrm{n_a} = \frac{W_s}{W_f}\ x\ 100$$

Where,

η_a = water application efficiency

W_s = water stored in root zone during irrigation (mm)

W_f = water delivered to farm (mm)

Water stored in the root zone was calculated by multiplying moisture difference with apparent specific gravity and plant root zone depth.

RESULTS

Table 2. Statistical analysis of the data

Volume of water	Source	Degrees of freedom (DF)	Sum of squares (SS)	Means Square (MS)	F value	Significance
	Treatment	1	693097	693097	52292	0.0000
	Error	4	53	13		
	Total	5	693150			
Yield	Source					
	Treatment	1	136987	136987	8755	0.0000
	Error	4	63	16		
	Total	5	137050			
CWP	Treatment	1	131.883	131.883	43.1	0.0028
	Error	4	12.251	3.063		
	Total	5	144.134			
	Source					
WAE	Treatment	1	3146.00	3146.00	462	0.0000
	Error	4	27.25	6.81		
	Total	5	3173.25			
	Treatment					

Volume of irrigation water

Total volume of irrigation water applied under RBIM was 1359.49 $m^3 ha^{-1}$, while under AFIM was 679.74 $m^3 ha^{-1}$ (Figure 2).

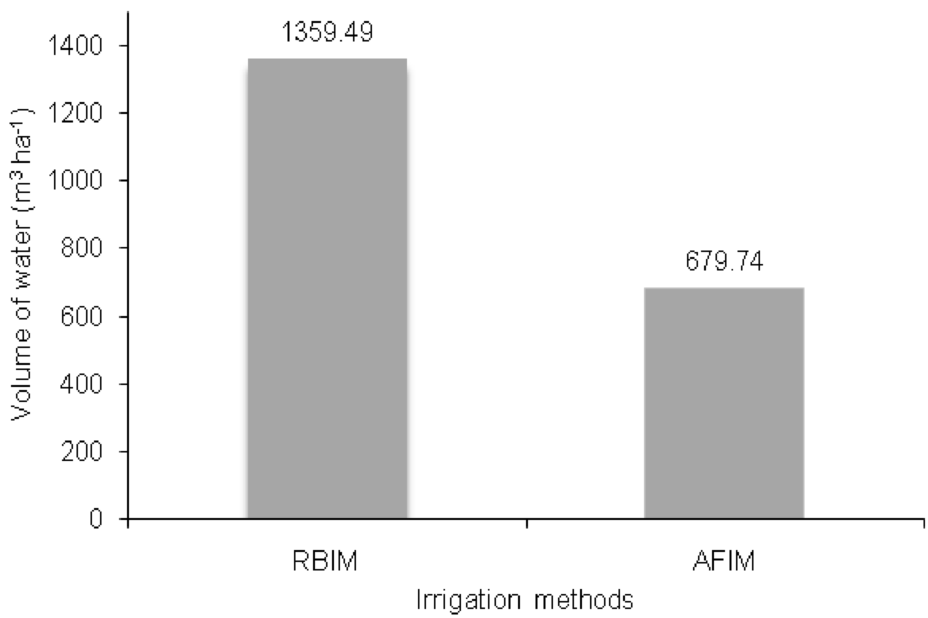

Figure 2. Volume of irrigation water applied under RBIM and AFIM

Yield of crop

The yield of sunflower was significantly increased (P<0.05) under RBIM. Total yield of sunflower under RBIM was 2963.59 kg ha^{-1}, while under AFIM the yield was 2661.39 kg ha^{-1} (Figure 3).

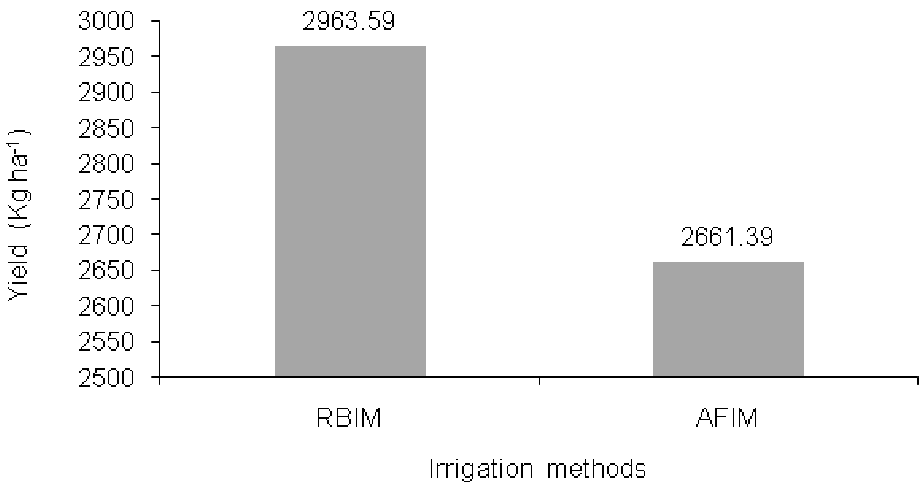

Figure 3. Yield of sunflower under RBIM and AFIM

Water saving and increase in yield

Table 3 shows the water saving and increase in yield under RBIM and AFIM. AFIM saved 50% of irrigation and increased 10.197% compared to RBIM.

Table 3. The effect of RBIM and AFIM on water saving and increase in yield.

Irrigation methods	**Water savings (%)**	**Increase in yield (%)**
RBIM	-	10.197
AFIM	50	-

Crop water productivity

Figure 5 shows the crop water productivity under RBIM and AFIM. The statistical analysis showed that the crop water productivity significantly increased (P< 0.05) under AFIM. Total crop water productivity under RBIM was 11.771 kg m^3, while under AFIM was 21.142 kg/m^3.

Water application efficiency

Figure 6 shows the water application efficiency under RBIM and AFIM at the depths of 0-20, 20-40 and 40-60 cm. The water application efficiency under RBIM was 30.98%, 34.21% and 37.45%, while under AFIM was 20.95%, 77.44% and 67.66% at the depths of 0-30, 30-60 and 60-100 cm, respectively. This demonstrates that average water application efficiency under RBIM increases as depth increases. This may be possible due to the moisture distribution improves while water application efficiency under AFIM increases at the depth of 30-60 cm but it decreases at depth of 60-100 cm due to improper moisture distribution. On average bases water application efficiency obtained with AFM was more than the RBIM.

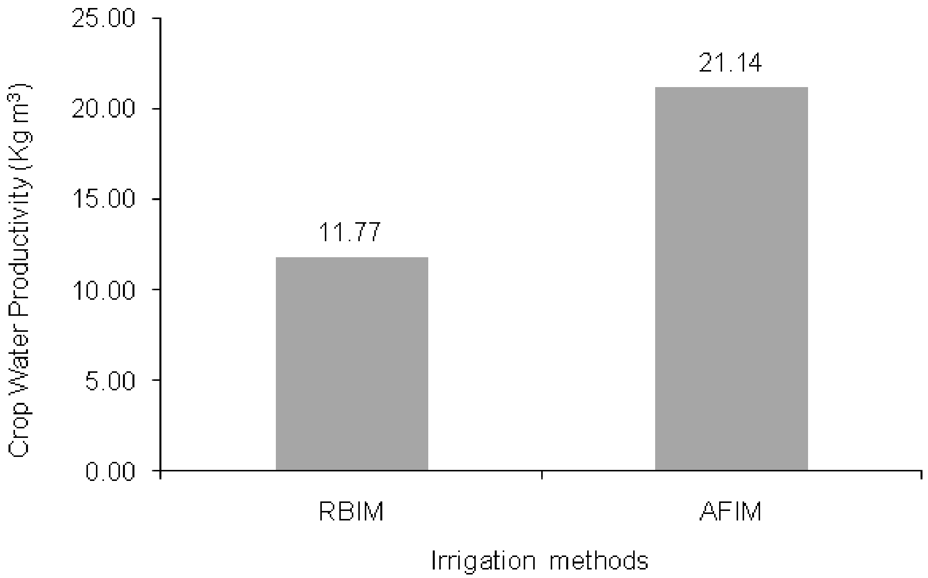

Figure 4. Crop water productivity under RBIM and AFIM

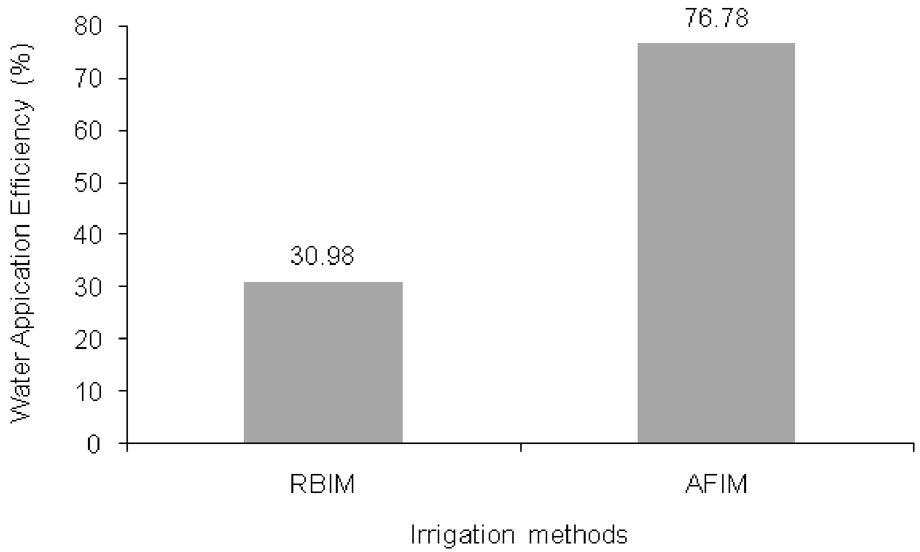

Figure 5. Water application efficiency under RBIM and AFIM

DISCUSSION

Farmers always twig with traditional flood irrigation methods. If traditional furrow irrigation methods reintegrated with efficient raised bed furrow irrigation method (RBIM) and alternate furrow irrigation method (AFIM), then these would easily be adopted by the farmers. Therefore, these technologies need performance evaluation under local soil and climatic conditions before disseminating to the farmers for future adoption. Accordingly the present study evaluated the effect of raised bed irrigation (RBIM) and alternate furrow irrigation methods (AFIM) at the experimental site of Faculty of Agricultural Engineering, Sindh Agriculture University Tandojam. The statistical analysis showed significant ($P < 0.05$) effects of both irrigation methods on water saving, yield, water productivity and irrigation water efficiency.

RBIM consumed 50% more water compared to AFIM. These results are similar to the results of Shaozhong *et al*. (2000), who reported that the AFIM used about 50% more water than that of RBIM. Similarly the yield of sunflower under RBIM was more than that of AFIM. These results are similar to the results obtained by Majeedano (2012); Bakker *et al*. (1995); Sepaskhah and Ghasemi (2008); Rafiee and Shakarami (2010) who reported the less yield of crops when irrigated with AFIM compared to RBIM. Also Crabtree *et al*. (1985) found low yield of sorghum and soybeans under AFIM even though the water use efficiency increased. In a study Stone and Nofziger (1993) found low yield under AFIM, which is attributable to the less application of irrigation water particularly during the periods of low rainfall and high evaporative demand.

AFIM saved 50% of water under AFIM when compared with RBIM. These results are similar to Slatni *et al.* (2011), who reported that large irrigation depths applied by every furrow irrigation method resulted in deep percolation losses under RBIM compared to AFIM. These results are also supported by Wankhede *et al*. (1984), who reported that furrow irrigation can save about 30% of the total water requirements compared with flood irrigation. Crop water productivity under AFIM was higher compared to the RBIM. These results are in close agreement with those of Memon *et al.* (2017), who reported that crop water productivity was higher under alternate furrow irrigation method than that of raised bed irrigation method. These results are consistent with Stone *et al.* (1982) and Slatni *et al.* (2011), who reported that alternate furrow irrigation method, obtained higher crop water productivity compared to raised bed irrigation method. Water application efficiency obtained with AFIM was more than the RBIM. These results are linked to El Tantawy *et al.* (2006) who concluded that the values of water application efficiency under AFIM were 53.44, 62.94 and 71.86%, respectively, while under RBIM were 59.67, 69.19 and 77.84%, respectively.

CONCLUSION

This study has shown that alternate furrow irrigation method offered overall better performance in relation to water saving, water application efficiency and crop water productivity compared to raised bed irrigation method. It should be adopted in the regions having severe water shortage to save water and obtain more yields and water productivity. However, in regions with adequate amount of water raised bed irrigation method may be adopted to achieve higher yields. Further studies may be conducted on different aspects of alternate furrow and raised bed irrigation methods with different crops in different soils textures.

REFERENCES

Abid, S., M. Tariq and L. Rizwan. 2014. Technologies for rain fed areas. Farming Outlook. Jan-Mar. 13 (1): 2-7.

Ahmed, R. N., M. Arshad and M. A. Shahid. 2011. Raised bed technology for crop water productivity of maize and cotton. 21st International Congress on Irrigation and Drainage, 15-23 October, Tehran, Iran. pp.173-180.

Bakker, D. M., S. R. Raine and M. J. Robertson. 1995. A preliminary investigation of alternate furrow irrigation for sugar cane production. Conference Proc. 'Clean water-clean Environment-21st Century, Kansas City, Missouri, ASAE.

Bouyoucos, J. B. 1962. Hydrometer method for making particle-size analysis of soils. Agronomy Journal, 54: 464-465.

Crabtree, R. J., A. A. Yassin, I. Kargougou and R. W. Mc New. 1985. Effect of alternate furrow irrigation: water conservation on the yields of two soybean cultivars. Agricultural Water Management, 10 (3): 253-264.

El Tantawy, M. T., A. F. El Sharkawy and M. N. Abo El Nour. 2006. Effect of laser land leveling and width between furrows on water use efficiency and yield of soybean crop. Misr Journal of Agricultural Engineering, 23 (1): 108-121.

El-Sherbeny, A. M., M. I. H. Ward and A. A. El-Behery. 1997. Evaluation of alternate irrigation technique under furrow irrigation system. Proceedings 5th Conference of Misr Soc. of Agricultural Engineering. Towards a National Strategy for Agriculture Engineering. In Egypt for the next decade. pp. 161-172.

Hassan, I., Z. Hussain and G. Akbar. 2000. Effect of permanent raised beds on water productivity for irrigated maize-wheat cropping system. ACIAR, Canberra, Proceeding. No.121. pp. 59-65.

Isrealson, O. W., V. E. Hansen and G. E. Stinger. 1980. Irrigation Principles and Practice 4th edition John Wiley and Sons, Inc, New York. Pp. 150.

Majeedano, I. 2012. Agro Digest. Agronomy Section, Agriculture Research Institute, Tandojam, Sindh, Pakistan. pp. 43.

Memon, M. S., A. A. Siyal, C. Ji, A. A. Tagar, S. A. Memon, S. A. Soomro, Khadimullah, Fahimullah and N. Memon. 2017. Effect of irrigation methods and plastic mulch on yield and crop water productivity of Okra. Journal of Basic and Applied Sciences, 13: 616-621.

Michael, A. M. 2008. Irrigation theory and practice, Second edition (revised and enlarged) Vikas Publishing House Pvt. Ltd, Delhi, India.

MINFAL. 2005. Irrigation Agronomy, Volume VI. Federal Water Management cell. Ministry of Food, Agriculture and Livestock. Government of Pakistan, Islamabad. pp.118.

Naresh, R. K., B. Singh, S. P. Singh, P. K. Singh and A. Kumar. 2012. Furrow irrigated raised bed (FIRB) planting technique for diversification of rice-wheat system for western IGP. International Journal of Life Sciences, Biotechnology and Pharmacology Research, 45: 1-12.

Putnam, D. H., E. S. Oplinger, D. R. Hicks, B. R. Durgan, D. M. Noetzel, R. A. Meronuck, J. D. Doll and E. E. Schulte. 2013. Sunflower. Alternative Field Crops Manual, University of Wisconsin Ext. Service, Minnesota (Last updated on 28th Feb. 2013), http://www.hort. purdue.edu/newcrop/afcm/sunflower.html.

Qureshi, R. H. and E. G. B. Lennard. 1998. Saline Agriculture for Irrigated Land in Pakistan. A Handbook of Australian Centre for International Agriculture Research Canbera, Australia.

Rafiee, M. and G. Shakarami. 2010. Water use efficiency of corn as affected by every other furrow irrigation and planting density. World Applied Science Journal, 11 (7): 826-829.

Rosegrant, W. M., C. Ximing and A. C. Sarah. 2002. World Water and Food to 2025: Dealing with Scarcity, International Food Policy Research Institute, Washington, D.C. USA and International Water Management Institute, Colombo, Sri Lanka. www.ifpri.org/pubs/books/ water/2025.

Samdani, Z. 2004. Watercourses lining, a popular activity. Daily DAWN (Internet Edition), 26th July, 2004. http://www.dawn.com/2004/07/26/ebr13.htm.

Sepaskhah, A. R. and M. Ghasemi. 2008. Every-other-furrow irrigation with different intervals for sorghum. Pakistan Journal of Biology Sciences, 11 (9): 1234-1239.

Shahid, A. 2010. Managing water scarcity for future agriculture development in Pakistan. Farming Outlook, Jan-Mar, 2010, 9 (1): 4-8.

Shao, H. B., L. Y. Chu, C. A. Jaleel, P. Manivannam, R. Panneerselvan and M. A. Shao. 2009. Understanding water deficit stress-induced changes in the basic metabolism of higher plants-biotechnologically and sustainably improving agriculture and the environment in arid regions of globe. Critical Review in Biotechnology, 29: 131-151.

Shaozhong, K., Z. Liang and Y. Pan. 2000. Alternate furrow irrigation for maize production in an arid area. Agriculture Water Management, 45 (3): 267-274.

Skogerboe, G. V., R. S. Bennet and W. R. Walker. 1972. Installation and field use of cutthroat flumes for water management; CUSUSWASH Water Management Technology. Report No. 19, pp 1-119.

Slatni, A., K. Zayani, A. Zairi, S. Yacoubi, R. Salvador and E. Playan. 2011. Assessing alternate furrow strategies for potato at the Cherfech irrigation district of Tunisia. Journal of Biosystems Engineering, 108 (2): 154-163.

Soomro, A., M. S. Mirjat, F. C. Oad, H. Soomro, M. A. Samo and N. L. Oad. 2001. Effect of irrigation intervals on soil salinity and cotton yield. Journal of Biology Sciences, 1 (6): 472-474.

Stone, J. F., H. E. Reeves and J. E. Garton. 1982. Irrigation water conservation by using wide-spaced furrows. Agricultural Water Management, 5: 309–317.

Tiercelin, J. R. and A. Vidal. 2006. Traite´ d'Irrigation, 2nd Ed. Lavoisier, Technique and Documentation, Paris, France.

W. W. F. 2007. Pakistan's water at rest. water and health related issues and key recommendations. Special Report. pp7.

Wankhede, N. F., S. S. Cheema and T. S. Sahota. 1984. Irrigation water management in field crops. Proceeding Regional Seminar for SAARC Member Countries on Farm Water Management. Islamabad. Pp. 83-87.

(Accepted: February 12, 2018)