ISSN 1023-1072

Pak. J. Agri., Agril. Engg., Vet. Sci., 2010, 26 (1): 16-29

WATER USE EFFICIENCY AND SAVING THROUGH PITCHER AND POLYETHYLENE BAG OVER FURROW IRRIGATION

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ABSTRACT

A field study was carried out at the Muhammad Khaskheli Farm, located at Taluka Thana Boula Khan, District Jamshoro during the year 2008. The pitcher, polyethylene bag, and furrow irrigation methods were compared on the basis of water use efficiency, yield, and water saving. The experimental setup for three irrigation methods was established. Irrigation to furrows was supplied through a watercourse and quantity of water was measured through a cutthroat flume. While a measured quantity of water to the pitcher and polyethylene bag methods was manually supplied.

The results indicate that the water holding capacity of the pitchers ranged between 7.9 and 9.0 liters, whereas the seepage rate was between 1.1 and 1.5 l/day. The wetting front vertically moved to a maximum of 13.4 cm depth and it reached to a distance of 22.6 cm laterally.

The results further suggest that the highest yield and WUEs were achieved under pitcher irrigation method as compared to furrow and polyethylene bag methods. The pitcher method had the higher WUE. It was higher by 90% and 40% as compared to polyethylene and furrow irrigation methods, respectively. An overall yield increase under pitcher over furrow was about 58% while, it was 18% over polyethylene bag method. The yield increase under polyethylene bag over furrow irrigation was calculated to about 49%.

Pitcher irrigation method saved water by about 75.4% as compared to furrow irrigation method while it saved water by about 26.5% as compared to polyethylene bag method. Similarly, the polyethylene bag, saved 66.5% compared to furrow method. Thus, the highest water saving was achieved under pitcher irrigation method as compared to both under furrow and polyethylene bag irrigation methods.

Keywords: Pitcher, polyethylene, furrow, irrigation systems, water use efficiency, water saving.

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INTRODUCTION

Water is a key input for agriculture and is made available to farmers through irrigation network. The water availability at canal heads is 103.5 million-acre feet (MAF) (all canals on National level). The overall (both for Kharif and Rabi) water availability has been less in the range of 5.9 percent (2003-04) to 20.6 percent (2004-05) (Economic Survey of Pakistan, 2009). However, it remained less by 2.5 percent in 2005-06 against the normal availability. Relatively speaking, Rabi season faced more shortage of water than Kharif during 2007-08. During the fiscal year 2007-08, the availability of water for Kharif 2007 (for the crops such as rice, sugarcane and cotton) has been 5.5 percent more than the normal supplies and 12.2 percent more than year 2008 of Kharif (MINFAL, 2009). The water availability during Rabi season (for major crop such as wheat), as on end-March 2008 was, however, estimated at 27.9 MAF, which was 23.4 percent less than the normal availability, and 10.5 percent less than last year's Rabi, adversely affecting the wheat crop, production of which has decreased by 6.6 percent over the last year (Economic Survey of Pakistan, 2009).

The Pakistan is located in arid and semi arid climatically conditions, water availability is decreasing with the increasing demand for crop to fulfill human needs. Various approaches are formulated to solve the problem, but due to limitations of cost and time, none is found fruitful (Alam and Khan, 2006). A number of irrigation systems have been developed and most of them are very successful in effective water management with special reference to saving water without affecting potential crop productivity. These specifically include pitcher irrigation, furrow irrigation and polyethylene bag irrigation.

Pitcher irrigation consists, in its simplest form, of unglazed baked earthen pitchers which are buried to their neck in the soil and filled with water. The water gradually seeps out through the porous walls into the root zone under hydrostatic pressure and/or suction, to maintain plant growth around the pitchers. Pitcher irrigation is an inexpensive small-scale irrigation method practiced in the semi-arid areas. When the pot is filled with water, the natural pores in the pot's walls allow water to spread laterally in the soil, creating the moist conditions necessary for plant growth. Pitchers are filled as needed, maintaining a continuous supply of water directly to the plant root zone. Pitcher irrigation is used for small-scale irrigation where, water is either scarce or expensive, fields are difficult to level such as under uneven terrain, water is saline and cannot be normally used in surface methods of irrigation and in remote areas where vegetables are expensive and hard to come by (Barthwal, 2005).

Polyethylene bag irrigation is also a simple irrigation method. Under this method of irrigation suitable size of white polyethylene bags of suitable

thickness are used for crop cultivation. The polyethylene bags are filled with soil and are watered manually. Before filling of soil in the bags some small holes are made in their bottom to facilitate the drainage conditions otherwise, the salts (from irrigation water) would be accumulated in the soil which would adversely affect the plant growth (Barthwal, 2005).

Furrow is an old traditional irrigation method which is being practiced for centuries like in India, USA, England and Pakistan. This is a row crop method under which most of the crops can be irrigated except those grown in ponded water. Efficient irrigation by furrow method is obtained by selecting proper combination of spacing, length and slope of furrows and suitable size of irrigation stream and duration of water application. The method is designed to suit the soil and topographic features of the field. Spacing and size of furrows depend on the type and size of the crop to be grown also on soil texture. The length of furrow varies from 3.0 m to 500 m for field crops. The common lengths of furrows are kept as 100 to 200 m. The general slope provided for furrow may vary from 0.2 to 0.5 percent. To obtain the most uniform irrigation, the large stream of water that may not cause erosion is used in each furrow at the beginning of irrigation (Bainbridge *et al.* 2000).

The field experiment was carried at Muhammad Khaskheli farm, Deh Desvi, Taluka Thana Boula Khan, District Jamshoro (Sindh). Thana Boula Khan Taluka is spread over western mountainous tracts of Sindh and is known as a part of Lower Kohistan, and it is also last Taluka Head Quarter of Kohistan Region. This is the only Taluka Head quarter where the Agriculture is not practiced by canal irrigation system because of its high elevation and unavailability of canal water (SAZDA, 1991). The present research was conducted to investigate the water use efficiency and water saving under pitcher and polyethylene bag irrigation as compared to furrow irrigation method.

MATERIALS AND METHODS

Description of experimental site

The field experiment was carried at Muhammad Khaskheli Farm, Deh Desvi, Taluka Thana Boula Khan, District Jamshoro (Sindh) during 2008.The experimental site is shown in the location map of the area in Figure 1. The farm is located at a distance of about one kilometer in the northwest of Thana Boula Khan town at the right side of Thana Ahmed Khan road. The area is locally called as ‘Kohistan’ as it is situated in hilly tracts. The area is located at higher elevation in the hilly tracts of mountains and it is out of canal commanded reach hence the area is cultivated by water carried out by the hill torrents generated by the torrential rains. The agriculture practiced in these areas is rain-fed and called as Barani agriculture.

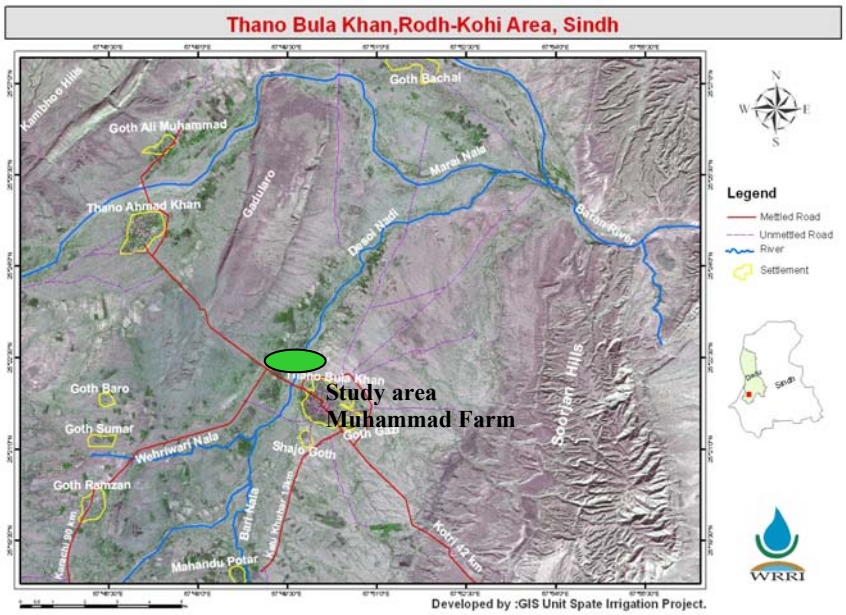

Figure 1: Location map of study area Muhammad Khaskheli Farm Thana Boula Khan

The climate of the area is arid to semi arid. In summer, the maximum temperature ranges between 35 and 44 ^{0}C, whereas the minimum temperature ranges between 15 and 25 ^{0}C in the winter. Mean annual rainfall is about 250 mm, whereas the evaporation ranges from 1750 to 3000 mm. The top soils are mainly alluvial in character and composition. They are homogenized silty sand soils under-lain by coarser layers of conglomerates (sand, pebbles, and boulders) and soils, hard & compact lime and sand stones. The loess (wind blown) silt and fine sand are also traced in the piedmont and cover flood plains. The residual soils, and those deposited by the hill torrents, are found in the piedmont plain and at the foothills of the western mountains. The texture is rather coarse, with about 50% sand (Soomro, 2007). The area is considered as a water scarce area, where micro irrigation techniques such as pitcher and polyethylene bag are well suited. After rains, the land is cultivated through spate irrigation and dug wells irrigated where wheat, sorghum, sesame, melons, jujube, onion and other seasonal vegetables are grown in the area by using traditional methods i.e. flooding or furrow irrigation methods where about 30-40% water is lost (PARC, 2004).At the experimental site Pakistan Agricultural Research Council (PARC) has established a research station under “National Research and Development Project (NRDP)” where research continues on Water

management of spate irrigation system. This research facility and equipment were used to conduct this study.

Description of pitcher irrigation method

Ten baked clay pitchers, each about 8-9 liter capacity along with their lids were purchased from a local potter's shop. The pitchers were checked for cracks/holes. The height of pitcher ranged from 31 to 33 cm from bottom to its mouth. A field plot measuring 6 m x 2.5 m beside the polyethylene bag irrigation plot was earmarked. Ten pits (5 in a row) were excavated and pitchers were buried. The pitchers were buried at in distance of 120 cm. The layout plan of pitcher irrigation method is shown in Figure 2. After installation and filling water the pitchers, seepage rate and the wetted zone around the them were measured.

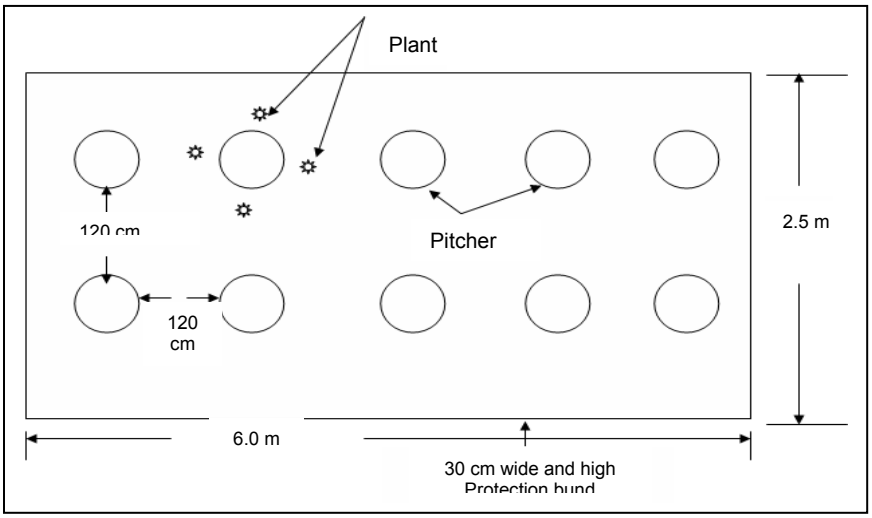

Figure 2.A layout showing a pitcher irrigation method

Seepage rate and wetted zone under a pitcher

Ten pitchers were used to determine seepage rate and wetted zone. Each pitcher has a maximum diameter of about 105 cm is 30 cm deep. The pits were dug and soil pulverized and homogenized. Each pitcher was placed in the middle of the pit and buried in such a way that its neck remained outside of soil. The pitchers were buried in two rows (5 in each row). The pitchers were installed in a square plot of 120 x 120 cm which covered a total area of 15 m^2. The water was then filled in each pitcher up to its neck and volume was recorded. The width and depth of wetted zone of these pitchers were measured by digging a side of each pitcher (in cm). Whereas the seepage rate was recorded as:

(1)

where,

Q=Seepage rate from pitcher (l/day),
Vw=Volume of water consumed (liter)
T=Time (day).

Description of polyethylene bag irrigation method

Polyethylene bag irrigation is considered as a high water use efficient method (Memon, 2009).Ten polyethylene bags with 25 micron thickness and 61 cm x 91 cm size were obtained. A field plot measuring 170 cm x 75 cm was dug up to a depth of 81 cm. The excavated soil was pulverized and filled in the polyethylene bags leaving 10 cm empty at the mouth for watering. After filling the soil, the diameter of a bag was measured which turns to be approximately 30 cm. Four to five tiny holes were made at the bottom of each bag before filling it with the soil. The holes served as drainage outlets to avoid salt accumulation in the soil. The polyethylene bags were buried in the plot in two rows (5 bags in one row) keeping a distance of 30 cm between them. The installation of polyethylene bags is shown in Figure 3.

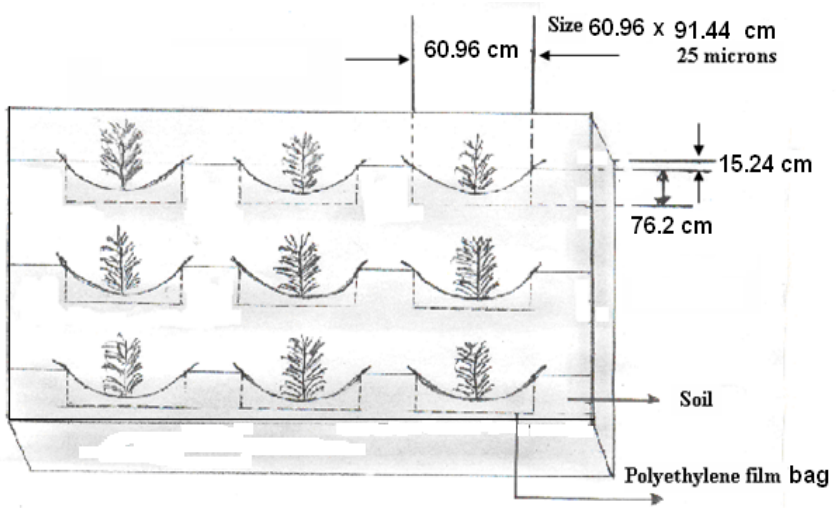

Figure 3.A Layout showing polyethylene bag irrigation method

Description of furrow irrigation method

A plot measuring 96 m^2area (10 m x 9.6 m) was selected near the main water channel. Eight furrows with ridges were prepared in a properly ploughed and leveled land. The 60 cm wide and 15 cm deep furrows were spaced at a distance of 60 cm between them. Each furrow was 8 m

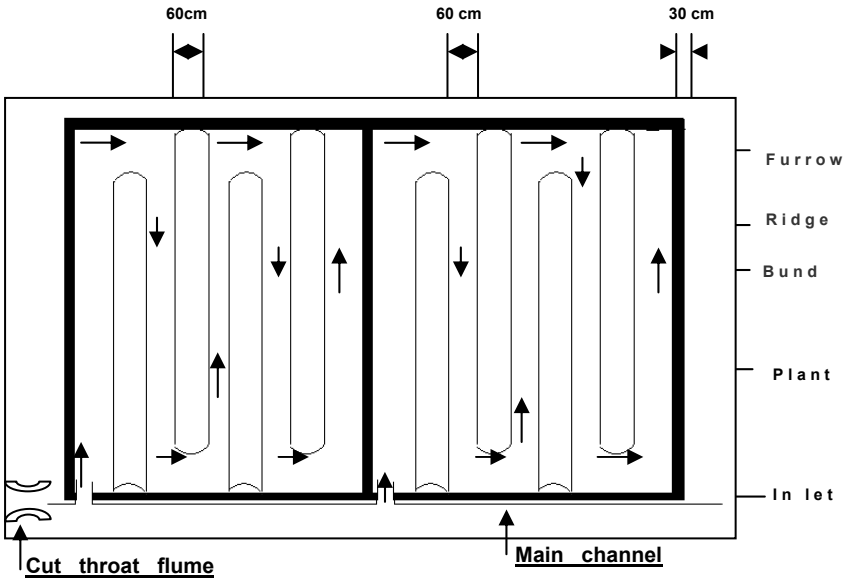

Figure 4.Layout plan of furrow irrigation method

Crop cultivation

Okra/Lady Finger (Abelmoschus esculentus) which is locally known as 'Bhindi' was grown under pitcher, polyethylene bag, and furrow irrigation methods. In furrow irrigation method, the seeds were sown at a row to row distance of 60 cm and were spaced at a 30 cm as recommended by On Farm Water Management Cell (1997). A total of 27 seeds were sown in 80 m long furrow with a 30 cm recommended spacing. Since, both ridges were used for sowing that required 54 seeds for each furrow. This combination required a total of 432 seeds for eight furrows.

Under pitcher irrigation method, four seeds were sown around each pitcher at an equal distance between plants. For ten pitchers, a total of 40 seeds were sown under this method. Likewise, under polyethylene bag irrigation method, one plant per bag was kept. Thus in all10 polyethylene bags 10 seeds were sown.

Water use efficiency

The water use efficiency (WUE) has been computed by using the formula given by Majumdar (2002):

(2)

where,

Y = Crop yield (Kg/ha)

WR = Total water used (m^3/ha)

WUE =Water use efficiency (Kg/m^3)

Water saving

Water saving obtained under pitcher and polyethylene bag irrigation methods over furrow irrigation was computed using the following formula given as:

(3)

where,

WS =Water saving (%)
Wa =Total water used in furrow irrigation (m^3)
Wb =Total water used in pitcher / polyethylene bag (m^3).

RESULTS AND DISCUSSION

It can be seen from Table 1, that capacity (volume of water) of the pitchers under study ranged between 7.9 and 9.0 liters, whereas the average seepage rate (after burying in the soil up to crop harvest), ranged between 1.2 and 1.4 liters/day. However, the average capacity and seepage rate of 10 pitchers under study were computed as 8.42 liters and 1.3 liters per day respectively. Thus, the amount of water seeped daily from the pitchers in to the soil was sufficient to meet the crop water requirement of 4 okra plant sown around each pitcher.

Seepage rate under a pitcher

The average seepage rate observed on daily basis (24 hours)and water holding capacity of the pitchers are presented in Table 1. Result suggest that the water holding capacity (volume of water hold by a pitcher) of the pitchers ranged between 7.9 and 9.0 liters, whereas the average seepage rate (after first water filling of pitcher to crop harvest), ranged between 1.2 and 1.4 liters/day. The average water holding capacity and seepage rate of 10 pitchers under study were 8.42 liters and 1.3 liters per day, respectively. The results on amount of water seeped from the pitchers in to the soil was sufficient to meet the crop's water requirements of okra plant sown around each pitcher.

Wetting front under a pitcher

The wetting front of the pitchers was measured vertically and horizontally for a week before crop sowing. The results on average wetting front are shown in Figure 5. Whereas, the radius of the wetting front from the neck of the pitcher along with daily seepage and volume (water holding capacity of the pitchers are given in Table 2.The wetting front (radius) around the pitchers ranged between 21.4 c mand 22.6 cm, with an

Table 1. Water holding capacity and average seepage rate of a Pitcher

Pitcher No.	Capacity (liters)	Average Seepage Rate (liter/day)
1	8.4	1.3
2	8.8	1.2
3	8.0	1.5
4	8.3	1.3
5	9.0	1.4
6	8.2	1.1
7	8.2	1.4
8	8.8	1.2
9	7.9	1.4
10	8.6	1.2
Average	8.42	1.3

average of 21.9 cm laterally (it has maintained after 4 to5 days and then it was constantly maintained itself due to continuous seepage). Whereas, vertically, the depth of wetting front ranged between 12.2 cm and 13.4 cm from the bottom of the pitchers with an average of 12.82 cm. Thus, an appreciable quantity of water seeped into the soil which wetted it too considerably. This was due to the fact that soil was light in texture i.e. sandy loam and has high seepage potential.

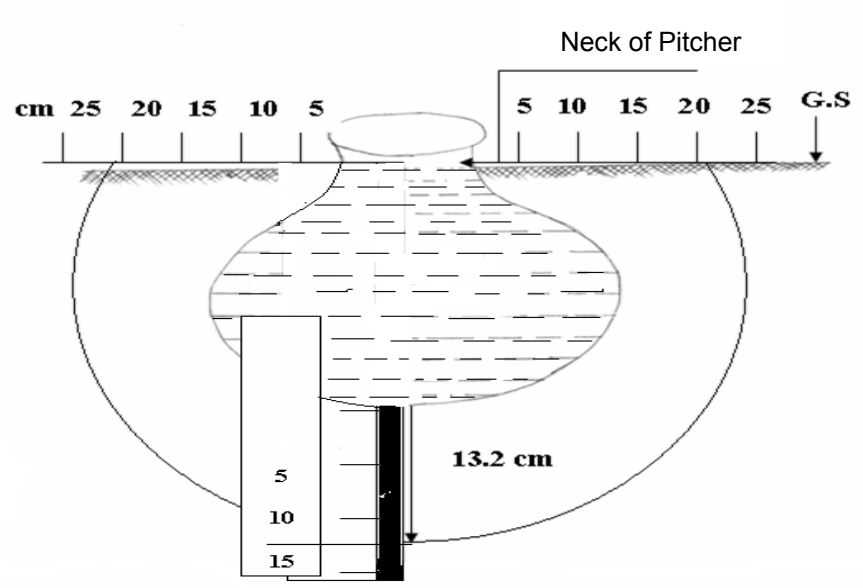

Figure 5. Schematic diagram of the wetting front of Pitcher

Table 2. Wetting front under Pitchers

Pitcher No	Water holding capacity (l)	Seepage rate (liter/day)	Wetting front, cm (Horizontal)	Wetting front, cm (vertical)
1	8.4	1.3	21.4	12.8
2	8.8	1.2	21.7	12.3
3	8.0	1.5	21.1	13.1
4	8.3	1.3	22.0	12.7
5	9.0	1.4	22.1	12.2
6	8.2	1.1	21.8	13.2
7	8.2	1.4	21.9	13.4
8	8.8	1.2	22.4	12.9
9	7.9	1.4	21.4	13.1
10	8.6	1.2	22.6	12.5
average	8.42	1.3	21.9	12.82

Table 3.Irrigation water applied under furrow irrigation method

Irrigation event	Irrigation application date	Quantity applied (m^3)	Remarks
1^{st}	01.04.2008	1.92	Soaking dose
2^{nd}	08.04.2008	0.96	Rainfall on 3 & 4/4/2008
3^{rd}	13.04.2008	0.96	
4^{th}	18.04.2008	0.96	
5^{th}	26.04.2008	1.92	
6^{th}	30.04.2008	0.96	
7^{th}	04.05.2008	0.96	
8^{th}	07.05.2008	0.96	
9^{th}	11.05.2008	0.96	
10^{th}	14.05.2008	0.96	
11^{th}	17.05.2008	0.96	
12^{th}	20.05.2008	0.96	
13^{th}	23.05.2008	0.96	
14^{th}	26.05.2008	0.96	
15^{th}	20.05..2008	0.96	
16^{th}	01.06.2008	0.96	Rainfall on 3/06/2008
17^{th}	05.06.2008	0.96	
18^{th}	09.06.2008	0.96	
19^{th}	14.0620.08	0.96	
20^{th}	19.06.2008	0.96	
Total	80 days	19.20	
Effective. rainfall	-	6.38	
Grand total	-	27.00	

Area of furrow 10 x 9.6 m = 96 m^2

Water use efficiency

Water use efficiency (WUE) is an important parameter and defines the ratio between the total yield produced to the total volume of water

consumed. The WUE of Okra computed for three irrigation methods i.e. pitcher, polyethylene bag, and furrow is presented in Table 4.

Table-4 Water Use Efficiency of Okra under Three Methods of Irrigation

Irrigation method	Yield (Kg/ha)	Water Used (m^3/ha)	WUE (Kg/m^3)
Pitcher	5606.7	691.9	8.1
Polyethylene Bag	4611.1	941.7	4.9
Furrow	2339.6	2812.5	0.8

Table 4 indicates that the highest yield of okra i.e. 5606.66 Kg/ha was obtained under pitcher irrigation method. Whereas the minimum quantity of water i.e. 691.9 m^3/ha was used under it. Thereby highest water use efficiency (WUE) i.e. 8.1 Kg/m^3 were achieved under pitcher followed by 4.9 Kg/m^3 and 0.8 Kg/m^3 under polyethylene bag and furrow irrigation methods.

Percentage increase in the yield and water use efficiency

The increases in yield of okra and water use efficiency (WUE) in pitcher over furrow and polyethylene bag and in polyethylene bag over furrow are presented in Table 5.

Table 5. Yield Increase and WUEunder three irrigation methods

Irrigation Method	Yield (Kg/ha)	WUE (Kg/m^3)	Increase in Yield (%)			Increase in WUE (%)		
			In P over F	In P over Pb	In Pb over F	In P over F	In P over Pb	In Pb over F
Pitcher	5606.7	8.1	-	-	-	-	-	-
Polyethylene bag	4611.1	4.9	-	-	-	-	-	-
Furrow	2339.6	0.8	58	18	49	90	40	83

P (pitcher), F (Furrow), and Pb (Polyethylene bag) irrigation methods

The percent yield increase and WUE between three irrigation methods are given in Table5. The results suggest that the highest yield and WUE was achieved under pitcher irrigation method both over furrow and polyethylene bag methods, whereas the lowest yield and WUE was achieved under furrow irrigation method as compared to both under pitcher and polyethylene bag methods. An overall yield increase under pitcher over furrow was about 58% while, it was 18% over polyethylene bag methods. The method yielded an increase of 90 and 40% in WUE over polyethylene and furrow irrigation methods, respectively. However, the yield increase under polyethylene bag over furrow irrigation was about 49% whereas the WUE increased by about 83%. These results are in agreement with those by Chang and Marri (1988), Brain bridge (2000), Siyal *et al* (2007) and Baber *et al* (2008).

Water saving

The water saving in micro irrigation methods varies from method to method and crops grown under them. Since under present study, two micro irrigation methods i.e. pitcher and polyethylene bag are studied and compared against furrow method of irrigation, therefore water saving in pitcher and polyethylene bag irrigation methods over furrow mode and also water saving in pitcher over polyethylene bag method of irrigation for okra crop is computed which is presented in Table- 6.

The results on water saving are shown in Table 6. An appreciable water saving was achieved in pitcher irrigation over furrow and polyethylene bag irrigation methods. Similarly, the polyethylene bag had higher water saving over furrow method. Pitcher irrigation method saved about 75.4% as compared to furrow irrigation method while it saved about 26.5% compared to polyethylene bag method. Similarly, the polyethylene bag, saved 66.51% compared to furrow method. Thus highest water saving was achieved under pitcher irrigation method as compared to both over furrow and polyethylene bag methods. It is therefore inferred that pitcher and polyethylene bag methods also referred as micro irrigation methods are highly efficient methods in term of water use. The saved irrigation water either could be used to bring more area under cultivation or could be used for reclamation of salt affected lands. Almost, similar results were observed by Siyal, *et al* (2007) and Baber, *et al* (2008).

Table 6. Water saved under different irrigation methods.

Total water used (m^3/ha)			Water saving (%)		
In P	In F	In Pb	In P over F	In P over Pb	In Pb over F
691.9	2812.5	941.7	75.4	26.5	66.5

P (pitcher), F (Furrow), and Pb (Polyethylene bag) irrigation methods

CONCLUSION

The results suggest that the highest yield and WUEs were achieved under pitcher irrigation method over furrow and polyethylene bag methods, whereas the lowest yield and WUEs were achieved under furrow irrigation method as compared to both pitcher and polyethylene bag methods. The WUE was 8.10 Kg/m^3, 4.90 Kg/m^3, and 0.83 Kg/m^3 under pitcher, polyethylene bag, and furrow irrigation methods, respectively. The pitcher method yielded an increase of 90% and 40% in WUE over polyethylene and furrow irrigation methods, respectively.

An overall yield increase under pitcher over furrow was about 58% while, it was 18% over polyethylene bag methods. However, the yield increase under polyethylene bag over furrow irrigation was about 49%.

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(Received 28 May, 2010; Revised 22 June, 2010)