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WATER SAVING AND CROP YIELD UNDER PITCHER AND WICK IRRIGATION METHODS

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ABSTRACT

High-Tech efficient irrigation methods like drip and sprinkler methods require high installation cost and cannot be operated and maintained without skilled labor. Hence, there is dire need for simple, small scale, efficient, low cost and locally made irrigation methods, which can convert deserts of Pakistan into oases. The present study was thus conducted at the experimental site of Faculty of Agricultural Engineering, Sindh Agriculture University Tandojam to assess the performance of pitcher and wick irrigation methods for water saving and crop yield. Total eighteen clay pitchers with water holding capacity of about 10 liters were used in the study. Six pitchers were drilled at the bottom and wicks in the holes were fixed (W1), six pitchers were drilled around the middle of pitcher (W2) while the remaining was used without drilling and wicks (P1). They were buried randomly at a distance of 2 m in 3 rows with neck of pitchers above the ground level and then they were filled with water. The turnip seed was sown on the soil wetted around the pitchers. The experimental results revealed that the water savings were about 65.56%, 29.84% and 46.55% with P1, W1 and W2 treatments, respectively compared to conventional flood irrigation method. The crop water productivity (CWP) was about 16.9 kg m³ and 24.32 kg m³ with W1 and W2, respectively while CWP of treatment P1 was 29.2 kg m³. It is concluded that wick irrigation method performs better in terms of crop yield and crop water productivity, but it consumes more water compared to pitcher irrigation method. The farmers are suggested to adapt wick irrigation only during warm season when pitchers are incapable of meeting crop water requirements due to high evapotranspiration rates.

Keywords: pitcher irrigation, wick irrigation, water saving, crop yield, turnip

INTRODUCTION

Pakistan lies in arid and semi-arid climatic regions. About 60% of its area receives less than 250 mm of rainfall per year and 24% receives between 250-500 mm (Gadiwala and Burke, 2013). Thus, farmers rely on surface water and

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groundwater as the main sources of water to irrigate the crops. However, there is already shortage of water in the country (Tagar *et al.*, 2016). Therefore, there is a need of innovative irrigation methods for successful crop productivity. Modern irrigation methods such as sprinkler and sub-surface drip irrigation may save about half of water for irrigation, but technical, economic, and socio-cultural factors embarrass the adoption of these technologies. Thus, traditional and low cost water saving technologies need to be adapted for sustainable crop production in semi-arid and arid regions remains a major challenge for scientists. These methods include pitcher irrigation (Bainbridge, 2001), deep pipe irrigation (Bainbridge, 2006), porous capsule irrigation (Silva *et al.*, 1985) and tree shelters irrigation (Bainbridge and MacAller, 1996).

Pitcher irrigation method in its simplest form consists of unglazed backed earthen pitchers which are buried to their neck in the soil and filled with water. The water gradually oozes out through the porous wall into the root zone under hydrostatic pressure to enhance plant growth around the pitchers (Stein, 1990). Pitcher irrigation is an ancient irrigation system, which was used in Northern African and Iran (Stein, 1998). It is mostly used for water saving for the reasons of this proper tied, it has high auto regulative capabilities, which rise from the close interaction between the pitcher and its environment, including soil, climate and plants. Pitcher irrigation is used for small scale irrigation where water is either scare or very expensive and where fields cannot be irrigate without surface irrigation methods (Barthwal, 2005). It is also used for small scale irrigation where water is saline and cannot be used with surface methods for irrigation. With pitcher irrigation, deep percolation losses are negligible since water is released from smaller areas. The water requirements in a pitcher irrigated field may be less than those of drip irrigated system, due to very low hydraulic conductivity of the pitcher as well as reduce evaporation losses (Bainbridge, 2001)

Wick irrigation is a low cost alternative that may help many of the small farmers. A wet able fabric or rope is used to carry water from a reservoir or pipe to the roots of the plant. Wick irrigation has the simplest form which can be done with rags and recycled bottles at almost no cost. Wicks have also been used for watering plants in containers for decades (Editor, 1955). A well-developed wick system for irrigating window boxes is also sold in commercial kits (Editor, 2010). Wick irrigation has been demonstrated to work well and should be considered for field planting of trees and shrubs in agro-forestry system established and environmental restoration. It provides critically needed water while plants get established in micro catchments or runoff watering systems (Evenari *et al.*, 1982; Cohen, 2002). Wick can be used to help for reducing the vulnerability of drip system to clogging and blockage.

It is reported that pitcher irrigation cannot meet the plant water requirements at high temperature, when evaporative rates are high (Soomro, 2013). Hence, wick irrigation can be used in conjunction with the buried clay pot system in order to enhance the water seepage from pitcher. A hole or series of holes is drilled in the buried clay pitchers and a porous wick is inserted in the hole. The wick material allows water from the pitcher to seep into the soil and provides a slow, steady source of moisture for plant growth and hence encourages root development. Wicks can work as gravity or capillary irrigation methods. The

capillary methods are used as wick in a tube that rises above water level and water movement is limited but steady. A gravity wick is below water level and the water flow through wick (Bainbridge, 2002). Wick irrigation is most efficient and sustainable irrigation technology capable for adapting under any weather situation, area, soil type, plant species and cultural life of the plants. Wick irrigation provides steady moisture so crops flourish (Bainbridge, 2007). The wicks help to move the water further from the clay pot to enhance greater root development and wick irrigation can greatly increase water use efficiency which is specially needed in regions with severe water scarcity (Bainbridge, 2012). Keeping in view the shortage of water for irrigation, colossal wastage of water in flood irrigation methods and technical ambiguities involved in the adoption of modern irrigation methods, the simple, locally made, easy to use and operate pitcher and wick irrigation methods were employed in this study.

MATERIALS AND METHODS

Location of experimental site

The experiment was conducted at the experimental field of Faculty of Agriculture Engineering, Sindh Agriculture University Tandojam, which is located at Latitude of $25^{\circ} 25' 28''$ N and Longitude of $68^{\circ} 32' 26''$ E at an elevation of about 26 m above mean sea level (MSL) on an area of about 72 m^2 . The treatments included P_1 = Pitcher irrigation, W_1 = Wick irrigation with wicks attached at the bottom of pitcher and W_2 = Wick irrigation with wicks attached at the center (at $\frac{1}{2}$ of pitcher height). Treatments were laid down in a completely randomized design (CRD) with six (06) replications as shown in Figure 1. Six pitchers were assigned for each treatment, which were refilled when water $\frac{1}{4}$ of the pitcher emptied.

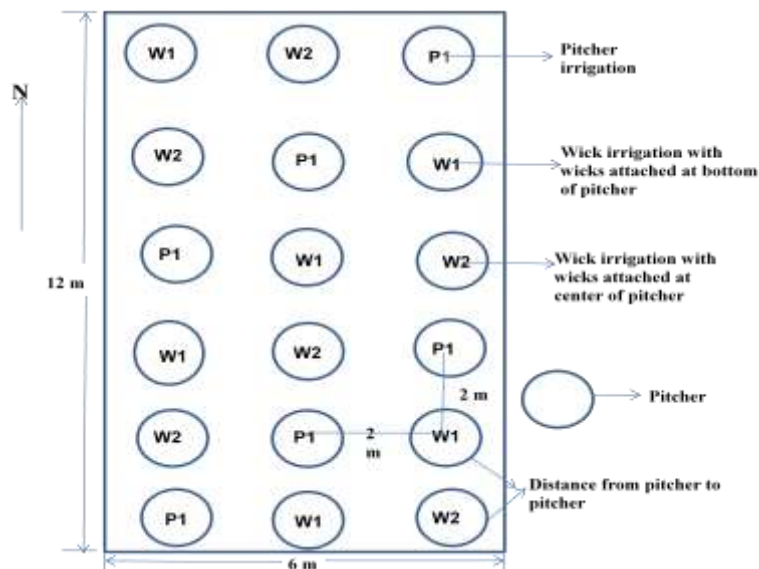


Figure 1. Layout of the experimental field



Plate 1. Physical layout of pitcher and wick irrigation methods

Soil sampling

Soil samples were taken from the four randomly selected locations of experimental plot before starting of experiment and after the harvesting of crop from soil depths of 0-15, 15-30, 30-45 and 45-60 cm. Soil texture was determined by Bouyoucos Hydrometer method (Bouyoucos, 1962), dry density was determined by core method (McIntyre and Loveday, 1974) and EC was determined by using digital EC meter (Black *et al.*, 1965) as shown in Table 1.

Table 1. Soil properties of experimental site

Sr. No.	Depth (cm)	Particle size distribution			Textural Class	Average dry bulk density (g/cm ³)	Average porosity (%)	EC _e (dS/m)
		Sand %	Silt %	Clay %				
1	0-15	56.8	37.5	5.7	Sandy Loam	1.3	53	0.97
2	15-30	49.3	42.4	8.3	Loam			0.96
3	30-45	49.4	45.0	5.6	Sandy Loam			0.95
4	45-60	49.7	44.6	5.7	Sandy Loam			0.95

Preparation of wick system

Before installation of pitcher and wick irrigation system, the land was deep ploughed using moldboard plow followed by disc harrow. Total 18 fired clay pitchers with water holding capacity of about 10 liters were purchased along with their lids from the local pottery shop. For treatment W₁, about 8 holes of size 10 mm were drilled at the bottom of pitcher using an electric drill machine. Wicks of about 20 cm length made of cotton rope of same size were passed through these holes and glued tightly. When pitchers are filled, the water seeped from pitcher wall as well as from the wicks without any leakage. Similarly, for treatment W₂ about 8 holes of 10 mm size were drilled in the pitcher wall around the periphery at about ½ of its height. Wicks made of cotton rope of about 20 cm length were passed through these holes and glued tightly.



Plate 2. Installation of Pitcher and Wick irrigation system in the field

Installation of Pitcher and Wick irrigation system

Eighteen holes in 6 rows at a distance of 2 m were excavated in the experimental plot and pitchers with treatments P1, W2 and W3 were randomly buried in these holes while keeping their neck above the ground level (2500 pitchers per hectare). Buried pitchers were filled with water and lids were put back on. The water inside pitchers seeped into the surrounding soil only from pitcher wall in treatment P1 while it seeped from the cotton wicks as well as from pitcher wall in treatments W1 and W2. The continuous seepage from pitcher wall and wicks kept the root zone moist for plant root development.

Sowing of seed

Turnip seeds were sown on the moist soil around the pitchers two days after the first filling of pitcher at the rate of 2.47-3.70 kg ha⁻¹ as recommended by MINFAL (1997). On January 03, 2013 turnip seeds were drilled within 1 to 3 cm of the outer edge of pitchers. The ideal location of the seedbed was just above the farthest boundary of the pitcher wall. A very small amount of water was added to seed spot to help in wetting the soil for establishing capillary action from the pitchers.

Refilling of pitchers

Clay pitcher filled with water then covered with a lid. Lids of clay pitcher prevented water losses due to evaporation from the mouth of pitcher and also stopped soil to be washed into them during rains or being deposited in them by wind. Pitchers were refilled with water using bucket when ¼ of pitcher was empty. The pitchers were refilled regularly with fresh water as per pitcher filling treatments and intervals using bucket. The water used in refilling was measured every time using measuring cylinder. Electrical conductivity (EC_w) of water was measured with Digital EC meter. The pitcher refilling process continued from January to Mid-March.

Table 2. Water application under pitcher and wick irrigation methods

Irrigation No.	Treatments	Total water (liters)
1	P1	1125
2	W1	2625
3	W2	1940
Total		5690

Application of nutrients

Turnip requires a balance of nutrients from organic and chemical fertilizers. Fertilizer application rates depend on soil type, soil fertility level and soil organic matter. Five grams of fertilizer was broadcasted around each pitcher. Fertilizer was applied four times around the pitchers.

Harvesting and handling

Turnip requires vital attention during harvest period. Generally it takes 60 to 70 days after sowing to be ready for harvesting. Turnip fruit was harvested after 64 days from sowing date and when it was fully mature, thick and juicy. Harvesting was done every 2nd day by pulling turnip leaves upward and then cutting leaves with sharp knife. The entire yield of turnip was placed on the safe and clean place. Every turnip was measured and weighed carefully with measuring tape and weighing balance, respectively.

Water saving

The water saving with pitcher and wick irrigation methods was compared with flood irrigation as using relations (Tagar *et al.*, 2016):

$$WS(\%) = \frac{W_F - W_P}{W_F} \times 100 \quad (1)$$

$$WS(\%) = \frac{W_p - W_w}{W_p} \times 100 \quad (2)$$

Where,

WS = Water saving in (%), W_F = Total water used for growing turnip under flood irrigation (mm) (from reference), W_P = Total water used for growing turnip under pitcher irrigation (mm) and W_w = Total water used for growing turnip under wick irrigation (mm)

Yield of crop

The yield of turnip grown with pitcher and wick irrigation systems was recorded and converted in to kilogram per hectare (kg ha^{-1}).

Crop water productivity

Crop water productivity was determined using following relation (Tagar *et al.*, 2016):

$$CWP = \frac{Y_T}{TW} \quad (3)$$

Where,

CWP = Crop water productivity (kg m^3), Y_T = Total crop yield (kg ha^{-1}) and TW = Total irrigation water used for crop production ($\text{m}^3 \text{ha}^{-1}$)

RESULTS AND DISCUSSION

Water saving

About 65.56% water saved with P1, 29.84% with W1 and 46.55% with W2 (Figure 2). Thus P1 treatment saved about 57.1% with W1 and 42.0% with W2. The results of the experiment are related to those reported by Osorio (1997) for wick irrigation method. Bainbridge (2007) found that water use efficiency (WUE) was excellent with wick irrigation system that yield of melon with pitcher irrigation system was 25 tons/hectare with application of only 2 cm of water compared to the yields of 33 tons/hectare with application 26 cm of water using the flood irrigation system. Daka (1991) reported that pitcher irrigation method was capable of saving 70% of irrigation water when compared to the conventional techniques of irrigation.

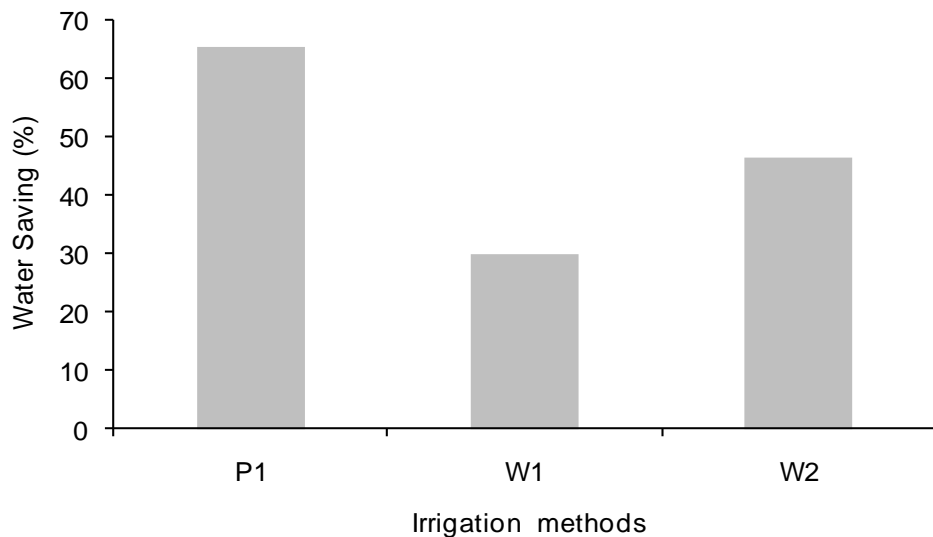


Figure 2. Water saving (%) with pitcher and wick irrigation methods compared to flood irrigation methods

Crop yield

The yield of turnip crop increased when pitcher irrigation was converted to wick irrigation methods as shown in Figure 3. It was 3.52 kg/pitcher (17600 kg ha^{-1}) for P1, 4.15 kg/pitcher (20750 kg ha^{-1}) for W1 and 4.44 kg/pitcher (22750 kg ha^{-1})

under same interval of water filling (pitcher ¼ empty). The yield of W2 was achieved higher than P1 and W1 treatments. If the full crop water requirement was not provided then the water shortage in the plant may affect crop growth and yield. Soomro (2013) reported that pitcher was incapable of meeting crop water requirements when atmospheric temperature and evaporation rate increased during summer which affected the crop yield. These experimental results were similar to those reported by Anwar *et al.* (1998) found that yield of all crops decreased significantly with increasing evaporative rates of which varied under clay loam soils, silty clay loam and sandy loam. Hence for meeting crop water requirements during warm months, pitcher irrigation method was transformed into wick irrigation method with wicks attached at middle (W2) and bottom of pitcher (W1). Greater horizontal wetting pattern with moisture content at field capacity was obtained with W2 because wicks were attached at the middle of the pitcher which boosted horizontal movement of water. Whereas, in case W1, water seeped from pitcher through wicks at the bottom of pitcher and moved more vertically then horizontally. Hence, less water and soil volume ideal for plant growth was available for vigor plant growth.

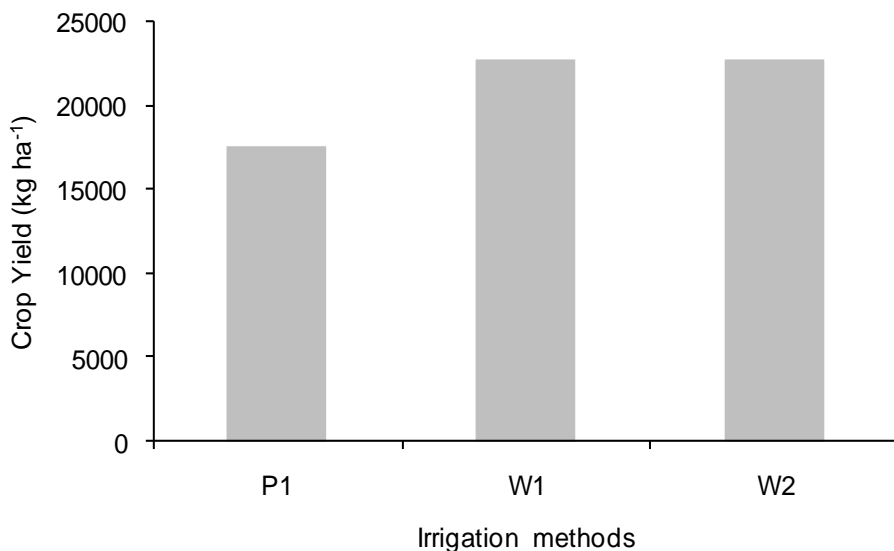


Figure 3. Yield (kg ha⁻¹) of turnip with different irrigation methods

Crop water productivity (CWP)

The crop water productivity of turnip was found 29.20 kg m³ for P1, 16.90 kg m³ for W1 and 24.32 kg m³ for W2 treatments as shown in Figure 4. Thus, the higher CWP was obtained from pitcher irrigation because it consumed less water as compared to both wick irrigation methods. The results are supported by Ferrarezi and Testezlaf (2010) who observed that wick irrigation system obtained higher crop water productivity resulting in high quality plants.

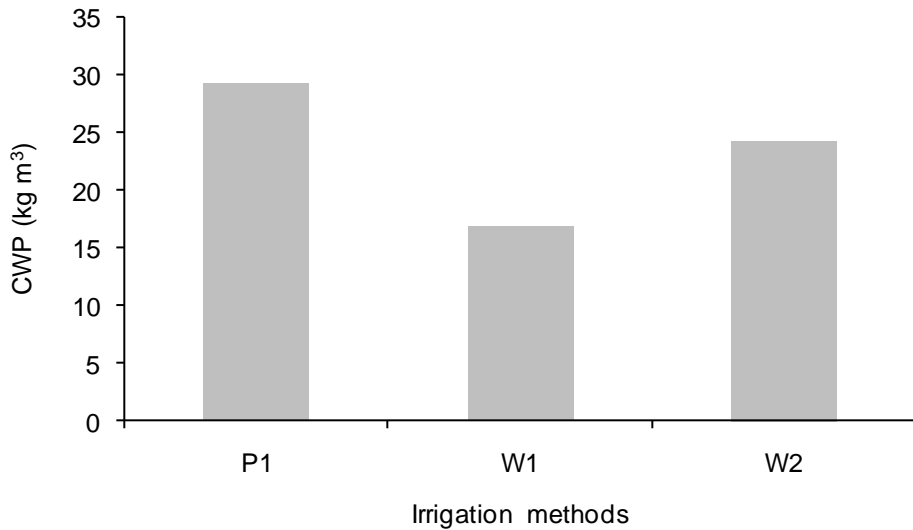


Figure 4. Crop water productivity of turnip (kg m³) with different irrigation methods

Gross income, net return and benefit cost ratio

The experimental results revealed that the cost for growing of turnip crop on hectare will be Rs. 224280 for pitcher irrigation and Rs. 273719 for wick irrigation method (Table 3). The net return yield for three treatments were Rs.479720 for P1, Rs.556281 for W1 and 636281 for W2 and benefit cost ratio (BCR) was 3.14 for P1, 3.04 for W1 and 3.33 for W2 (Table 4). The results revealed that benefit cost ratio for W2 is higher than other treatments then the findings of the study revealed that the production of selected vegetable was profitable for arid and semi-arid region in the world.

Table 3. Gross income per hectare

Sr. No.	Treatment	Average yield (kg/pitcher)	Crop yield (kg ha ⁻¹)	Rate per kg (Rs.)	Gross income per hectare (Rs.)	Total expenditure per hectare (Rs.)
1	P1	3.52 ± 0.150	17600	40	704,000	224,280
2	W1	4.15 ± 0.120	20750	40	830,000	273,719
3	W2	4.55 ± 0.110	22750	40	910,000	273,719

Table 4. Net return and benefit cost ratio

Sr. No.	Treatment	Net return (Rs.)	Benefit cost ratio (BCR)
1	P1	479,720	3.14
2	W1	556,281	3.04
3	W2	636,281	3.33

CONCLUSION

- The water saving for growing turnip was about 65.56%, 29.84% and 46.55% with P1, W1 and W2 methods, respectively compared to conventional flood irrigation method. Hence pitcher irrigation method was capable of saving 57.1% and 42.0% compared to W1 and W2 methods, respectively.
- The crop yield was 3.52 kg/pitcher (17600 kg ha⁻¹) for P1, 4.15 kg/pitcher (20750 kg ha⁻¹) for W1 and 4.44 kg/pitcher (22750 kg ha⁻¹).
- The crop water productivity (CWP) was 0.029 kg/liter for P1, 0.17 kg/liter for W1 and 0.024 kg/liter for W2 method.
- The benefit cost ratio (BCR) was higher i.e. 3.33 for W2, followed by 3.14 for P1 and 3.04 for W1 methods.

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