Research Article

Pitcher Irrigation as a Viable Solution for Water Conservation Under Water Scarce Condition

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Abstract |Under the current scenario of climate change, water shortage is considered a main hindrance in sustainable food production. Exploring various technologies to improve desert food production at lowest possible water use is the cry of the day. The current study was conducted on the irrigation system whereby pitchers were used for water saving. Experiment was conducted at the Agriculture Farms at Main Campus, University of Swabi, Pakistan during the summer 2021 and repeated in 2022. The Apple trees (*Pyrus malus)* grown in novelty gardens were tested at two type of irrigation systems (Flood and pitcher) using RCBD with four replications. The average data taken during eight months (March to October of the year 2021 and 2022 showed that maximum increase in plant height (0.75 feet), maximum number of new leaves (52.5), maximum new branches produced (2.5), maximum leaf length (0.081cm), maximum leaf width (0.55cm) was recorded in the plants irrigated using flood irrigation which was at par with the Apple trees attributes irrigated with pitcher irrigation system such as increase in plant height (0.63 foot), number of leaves (87.75), number of branches (1.5), leaf length (0.046cm) leaf width (0.0525cm). According to the data, pitcher irrigation system saves 122.78 liters of water per day per apple tree as compared to flood irrigation. In spite of huge difference in water consumption, there is no significant difference among various parameters. Therefore, pitcher irrigation system is highly recommended for arid land agriculture particularly in those areas where water scarcity prevails.

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Introduction

Irrigation is one of the most important aspects of growing crops. Irrigation is defined as the use of water by humans for agriculture, providing the appropriate amount of water as the plants require. As we know, today's population is increasing, putting pressure on existing food resources. Global food production requires a lot of land and water. Owing to population growth and climate change, water availability is a key issue for human beings on earth (Zamin *et al*., 2025; Khalid *et al*., 2022). Many countries also suffer from low rainfall and water scarcity. Thus, we have to focus on water conservation so that we may be able to overcome the prevailing challenge of water shortage (Zamin *et al*., 2020). Under these circumstances, we must develop technologies that save water and deliver high-quality products in different ways. In recent years, hightech irrigation systems have been increasingly used to save water and reduce pressure on drinking water (Abu-Zreig, 2006). Although modern irrigation methods combined with underground drip irrigation structures can store half of the irrigation water, many technical, financial, and cultural factors hinder the adoption of these technologies (Abu Zeirg *et al*., 2006; Siyal *et al*., 2009). Taking these conditions into consideration, it becomes important to develop irrigation systems that can reduce soil evaporation more effectively (Batchelor *et al*., 1996). Most international development programs ignore this fact (Bainbridge, 2001). However, the cost of modern water pipes may preclude the use of high-tech systems in many arid and semi-arid countries. Thus, we need to adopt a technology which can serve the purpose of drip irrigation system but should be economical and sustainable in terms of cost. Pitcher irrigation is an ancient technique which is adopted by several countries among the arid zones such as but not limited to Iran, India, African and South American countries (Mondal, 1997; Stein, 1997). The technology is simple, inexpensive and has great potential for water conservation (Mondal, 1978; Bainbridge, 2001). Watering a jug is mentioned in a book written in China about 2000 years ago (Sheng, 1974). This method has been reported to irrigate watermelons in India and Pakistan (Mondal, 1974; Soomro, 2002); horticultural crops in Brazil, Germany, and Indonesia (Mondal, 1997; Setiawan *et al*., 1998); Corn, tomato, and autumn crops in Zimbabwe. Sunflower (Batchlor *et al*., 1996). The design of pitcher irrigation and its comparison with conventional irrigation systems is illustrated in Figure 1.

In pitcher irrigation, water retention is the key factor. Watering the pot keeps the soil moist. By using pitchers, soil moisture is maintained around the roots, and the salinity of the soil around the roots is reduced. The holes in the clay pot allow water to seep into the soil and create moisture for crop growth. The pot is checked weekly and filled with water as needed, thus maintaining a constant supply of water to the plants. Slurry irrigation technology is a water conservation system that saves 50% to 70% of water compared to conventional irrigation systems. When burying the jar in the ground, farmers have to place the jar properly so that the rainwater is not lost from the jar, otherwise, pores of the jar will be clogged due to sand deposition. The threads installed at the bottom is used to make the water penetrate into the soil and send the water directly to the roots of the plant. The amount of water flowing from the bottle depends on the type of plant, soil and weather. Usman, (1986) and Stein, (1997) indicated that seepage rate of pitchers buried in the soil is affected by evapotranspiration

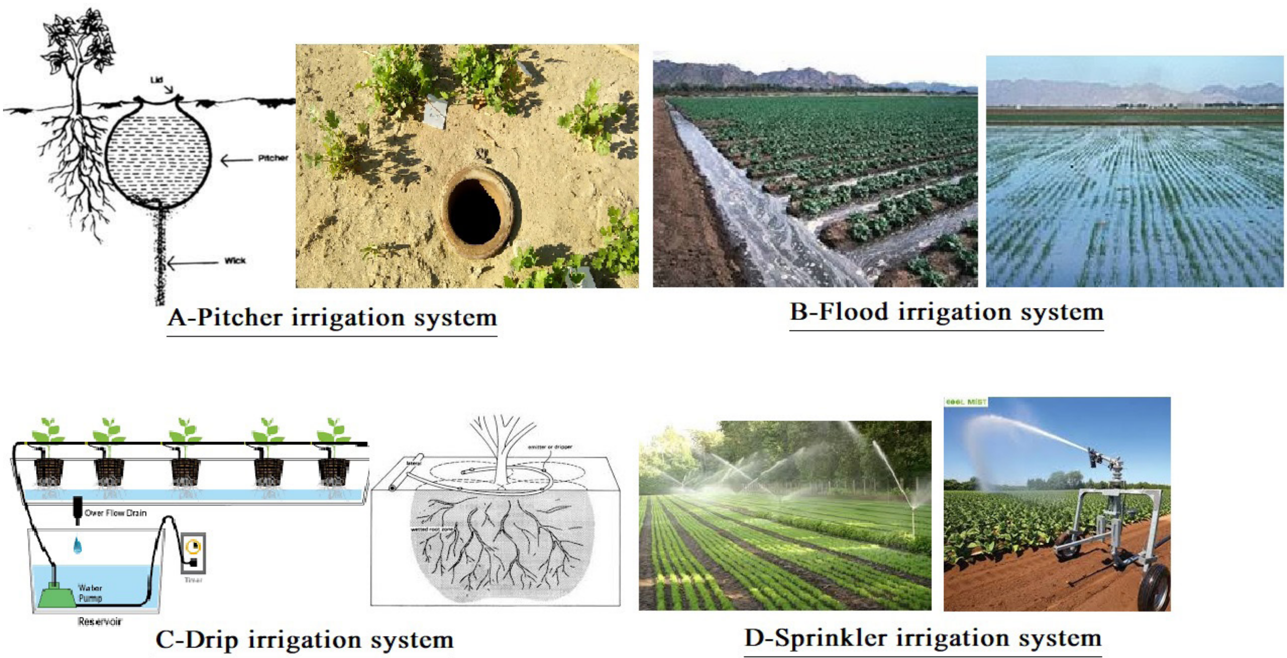

Figure 1: *Illustrated images of the pitcher irrigation in comparison to traditional irrigation systems.*

rate, hydraulic conductivity at saturation of pitcher wall material and pitcher surface area. Stein, (1998) indicated that in some cases a 200% increase in pitcher's seepage has been observed due to increased evapotranspiration demand. As the water level in the soil rises and the soil becomes saturated, the water will flow back into the pot and fill it again. The system is self-regulating and water loss is negligible. The number of terracotta pots needed per hectare varies depending on the type of crop. Creeping vegetables such as cucumber and bitter gourd along with okra and brinjal require 2,000-2,500 pots per hectare, while upright and umbrella crops such as beans, tomatoes, leeks, and watermelon require 4,000-5,000 pots per hectare.

The amount of water that comes out of the jug depends on the age of the plant, the soil and the climate. Though, pitchers are commonly used in the arid zones of India on limited scale. However, in some areas it has been used successfully for annual plants and vegetables. This system has special application under high salinity, severe drought and limited water supplies conditions.

Water use in an irrigation system depends on many factors including soil type, crop type, weed competition, and local climate. Pitcher irrigation facilitates rapid establishment and rapid growth of plants. A controlled water supply can quickly reduce tidal and drought problems. Pitcher irrigation facilitates rapid establishment and rapid growth of plants. It can be used to establish vegetation on steep slopes and areas with rapid drainage where conventional irrigation is impractical. Since water is limited for agriculture in the Swabi, especially in sandy area like Swabi University Campus soil, a comparison was made between the usual flood irrigation with a view to finding the water loss. The current study was designed to identify water losses through conventional furrow flood irrigation system and to find out ways to reduce water loss.

Materials and Methods

The research on Pitcher Irrigation System was carried out in Agriculture Farm at the University of Swabi, Pakistan during the year 2021 (growing season-March to October) under the desert climatic conditions. The experiment was repeated during the same months of the year 2022. The experiment was designed in Randomized Complete Block Design (RCBD) with one factor; water application methods (pitcher/pots and flood irrigation).

The pitcher/earthen pots were placed in the first week of March 2021 and data were recorded for all the parameters as mentioned below. Pots (9 liters capacity) were buried at the root zone of Apple trees, variety Anna, at the depth of 1 foot. The pitcher/pots were covered by plastic to avoid evaporation. One row of apple trees with four numbers (considered replication) of apple trees were irrigated with flood irrigation system while the next similar row was applied with pitcher irrigation whereby all other means of water were disconnected. Water was applied based on the plant requirement and weather conditions using flood irrigation. While pitchers were frequently observed for water once a week and filled with calculated water. Then the cumulative water applied per month was determined for each tree using pitcher irrigation which was divided by 30 days to get per day tree water used. The data was taken for the whole growing season starting from March till October. Then the average data were obtained by dividing by 8 to get average monthly water used. Similarly, on each flood irrigation total time taken for the whole row was identified and water flowing through the water channel was also calculated using flow meter at the entry point. Thus, monthly water consumed was determined for the whole row which was divided by total number of trees in the row to get water used by each tree using flood irrigation system. Then dividing by 30 days, daily water consumed was recorded. The monthly average was measured as mentioned above. The experiment was repeated during the same growing season in 2022 and Data was recorded. Thus, the average of two years was considered for analysis.

Parameters

The following parameters were studied during different stages of experiment.

Water quantity used

Water quantity used by flood irrigation and Pitcher irrigation system were measured and compared. The water quantity was measured at the entry channel to the field and the time taken to reach the end of tree row.

Plant height (feet)

The height of the plant was measured with the help of a measuring tape from the base to the tip of each plant at the beginning of the experiment and again at the end of the experiment. The difference was the total plant heigh achieved during the experiment and was compared with both type of irrigation system.

Number of leaves per plant
The total number of leaves of each plant was counted at the beginning of experiment and then at the end, thus the difference was the total number of leaves produced because of respective irrigation.

Number of main branches per plant
The total number of main branches in each plant was counted at the beginning of the experiment and then at the end of experiment, the difference was considered as new branches obtained at specific irrigation method.

Number of shoots per Plant
The number of shoots were also recorded as mentioned above.

Leaf width (cm)
The leaf width of randomly selected 10 leaves in each plant was measured with the help of measuring tape and their average was taken at the end of experiment.

Leaf length (cm)
Leaf length was also taken as mentioned above for leaf width.

The above data were subjected to analysis of variance using statistical software statistix version 8.1 and the means for each factor were separated using the LSD technique (Steel and Torrey, 1997).

Results and Discussion

Plant height (feet)
The data recorded on plant height (Table 1) reveals that the effect of irrigation methods on the height of Apple plants was found non-significant ($P \geq 0.05$). Mean data show that maximum (0.75feet) plant height was observed in flood irrigation which was at par with pitcher irrigation (0.63 feet). A huge difference between two methods was found as far as the water consumption is concerned. As indicated in Table 1 and 2, there is a significant difference between two methods for water consumed while the increase in agronomic characters of Apple tree is negligible, therefore, pitcher irrigation proved to have advantage over flood irrigation system whereby huge amount of water is saved. Pitcher irrigation system is proved to be the best way for water conservation (Yousaf *et al*., 2007, Tripathi *et al*., 2017).

Number of branches per plant
The irrigation methods had non-significant ($P \geq 0.05$) effect for number of branches per plant (Table 1).Mean data show that maximum (2.5) number of branches were observed in flood irrigation followed by pitcher irrigation (1.5). Branches development is an agronomic parameter which is directly related to plant growth and development. Since water is affecting the overall well being of a plant body, therefore, its quantity directly improve the number of branches as indicated in Table 1. Though, there was no significant difference between number of branches, however, a significant difference was found in water usage (Fereres *et al*., 2003).

Water consumed
The data recorded for water consumed during the whole experiment are given in Table 1. The statistical analysis reveals that irrigation methods such as flood method and pitcher irrigation were found significant ($P \leq 0.05$). Mean data show that maximum (123.75) liters of water was consumed through flood irrigation followed by pitcher irrigation system (0.97 liters) indicating that pitcher irrigation consumes very less water as compared to flood irrigation. Mean data show that a significant difference was found between flood irrigation and pitcher irrigation as far as water consumption is concerned. Hence pitcher irrigation consumes very less water as compared to flood irrigation. Our findings are similar with the results of Ansari *et al*. (2015) and Malekinezhad, (2015) who also observed a huge difference in water consumption during similar experiment.

Table 1: *Effect of different irrigation methods on plant height, Number of branches and quantity of water by apple trees.*

Type of irrigation	Plant height (feet)	Number of branches per tree	Water consumption per day per plant (ltrs)
Flood	0.75 a	2.5a	123.75 a
Pot	0.63 a	1.5a	0.97 b

Data with similar letters are non-significant

Number of leaves per plant
As shown in Table 2 irrigation methods had a non-

significant effect (P≥0.05) on the number of leaves per plant. Data indicate that a maximum (87.25) new leaves were produced on the apple tree during the trial period as compared to the pitcher irrigation system where 52.5 leaves were produced. Though, plants irrigated via flood irrigation method produces higher number of leaves and maximum leaf area (length and width) was observed, however, the difference was non-significant and it could not attribute to plants overall vigor and growth (Memon *et al*., 2010; Naik *et al*. (2013).

Leaf length (cm)

The statistical analysis reveals that irrigation methods had non-significant (P≥0.05) effect on leaf length of apple trees (Table 2). Means data show that maximum (0.081cm) leaf length was observed in flood irrigation which was followed by pitcher irrigation (0.046cm). leaf lengthis also affected by water supply and adequate water provision to plants guarantee a healthy growth (Fereres *et al*., 2003).

Number of shoots per plant

The data on the number of shoots per plant is given in Table 2. The statistical analysis reveals that irrigation methods had a non-significant (P≥0.05) effect on number of shoots Plant^{-1}. Means data show that maximum (2.5) number of shoots were observed in flood irrigation which was at par with pitcher irrigation (1.25). Number of new shoots/branches is another main parameter of fruit plants, which was also not affected significantly (P≥0.05) by irrigation methods. Number of shoots belong to vegetative growth of a plant. During vegetative growth profuse watering is required to maintain plant growth and development. Since pitcher irrigation used minimum water but all was used by root zone while in case of flood irrigation a large quantity of water consumed but the growth parameters such as number of shoots had no significant difference. Thus, pitcher irrigation is better than flood irrigation (Yousaf *et al*., 2007; Siyal *et al*., 2009).

Leaf width (cm)

Data on sheet width are given in Table 2. Statistical analysis showed that different irrigation methods had a non-significant effect (P≥0.05) on leaf width. Means data show that maximum (0.054cm) leaf width was observed in pitcher irrigation followed by flood irrigation where a leaf with 0.036cm width was produced. As shown in Table 2 wider leaves were found on apple trees irrigated using flood irrigation. Adequate water supply results into better growth. Leaf width data resemble with leaf length (Fereres *et al*., 2003).

Table 2: *Effect of different irrigation methods on leaf length Leaf, Width, Number of shoots and number of leaves per apple tree using irrigation methods.*

Type of irrigation	Leaves numbers	Leaf length(cm)	Number of shoots per plant	Leaf width (cm)
Flood	52.50a	0.081a	2.50a	0.036a
Pots	87.75a	0.046a	1.25a	0.054a

Data with similar letters are non-significant

Conclusions and Recommendations

There is no significant difference between Pitcher Irrigation system and conventional flood irrigation system as far as various growth parameters ae concerned, however, a huge quantity (122.78ltrs) of water can be saved in case of pitcher irrigation system per tree per day. Therefore, pitcher irrigation system is recommended for water conservation.

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Novelty Statement

Global water shortage and food security are the two main concerns of the world growing population. Exploring technology to save water will contribute to food security under world food crisis.

Author's Contribution

Muhammad Zamin: Contributed in conceptualization, supervision, investigation and manuscript drafting.
Hayat Zada: Contributed in data collection and processing.
Muhammed Abdul Mohsin Salim Alyafae: Contributed in analysis and discussion of results.
Moudassir Habib: Played role in interpretation of results.
Muhammad Shakur: Contributed in review of literature and helped in analysis.

Muhammad Adnan: Contributed in data collection and processing.
Hassan Zaman: Contributed in review of literature and helped in analysis.

Generative AI or AI assisted technology statement
The authors declare that no Genrative AI was used in the creation of this manuscript.

Conflict of interest
The authors have declared no conflict of interest.

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