# Evaluation of Raised-Bed and Conventional Irrigation Systems for Yield and Water Productivity of Wheat Crop

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**Abstract:** A study was conducted at Drainage and Reclamation Institute of Pakistan (DRIP), Tandojam in a clay loam soil. The treatments include raised-bed irrigation system ($T_1$) and conventional irrigation system ($T_2$). The experiment was laid down using randomized complete block design (RCBD) with three replications. The total area under experiment for each treatment and replication was 1004.65 $m^2$ and 334.88 $m^2$ respectively. Groundwater quality of experimental sight was slightly saline. Results of the experiment showed that there was highly significant difference in volume of water applied, yield and water productivity of wheat crop under the raised-bed and conventional irrigation systems. Both water saving (50.73%) and water productivity (54.37%) of wheat crop was higher under raised-bed irrigation system. The raised-bed irrigation system obtained 24.65% higher yield compared to conventional irrigation system. All other parameters were also higher under the raised-bed irrigation system. Thus raised-bed irrigation system is recommended to achieve higher yield and water productivity of wheat crop and to save water particularly in a clay loam soil.

**Keywords:** Raised bed irrigation system, Conventional irrigation system, Water productivity, Water saving, Yield, Wheat crop.

## 1. INTRODUCTION

Pakistan has the world's largest gravity-driven irrigation canal system; lack of maintenance is significantly decreasing its efficiency [1]. Efficiency of irrigation systems in Pakistan is around35.5%, which indicates that there is no crop which is precisely using the water being supplied [2]. It is also stated that water being used with poor quality causes reduction in yield [3]. About 70 percent of fresh water is being used for irrigating crops which is accounting to be largest. However, there has been mounting pressure to reduce water supply for irrigated agriculture, producing more food with less water [4].

Surface irrigation system also referred as flood irrigation system is the most common method being practiced throughout the world in many areas virtually unchanged, implying that the water distribution is uncontrolled and therefore, inherently inefficient [5]. In raised bed furrow method, the field is divided into narrow strips of raised beds separated by furrows. The crops are then planted on the bed surface and water is applied through furrows. Moreover, bed-furrow system once developed is not destroyed seasonally, but the beds are renovated by rotavator. Therefore, to grow crops on raised beds, simple beds shaped before planting the next crop and retain all or part of the crop residues on the surface [6]. Raised- bed planting could also prevent water logging and control weeds and also save irrigation water up to 50 percent and increases the yield of crops up to 20 percent to 25 percent over flood irrigation system [7]. There are many advantages of bed planting in wheat systems as being reported by research activities done in India and Pakistan, it has been reported that 50% seed and 30-40% of water is saved, an increase in yield, reduced lodging, facilitated mechanical weeding, a reduced loss in nitrogen and rain water conservations [8, 9]. An increase in yield with raised beds with about 30% less irrigation water was observed when compared to conventional method [10, 11]. The raised-bed planting of crops is one of the improved techniques, increasing yield, providing better nutrient management, efficient irrigation and use of fertilizer, reduced weed infestation and reducing crops lodging risk is on beds [12, 13].

Wheat (*Triticumaestivum L.*) belongs to family Poaceae contributing major world's population portion of staple food. 14.4 percent value in agriculture and 3 in gross domestic production are being contributed by wheat cultivation in Pakistan. Keeping in view the above facts, importance and necessity, the research

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work was conducted to evaluate the raised-bed and conventional irrigation systems on yield and water productivity of wheat crop under the climatic condition of Tandojam.

## 2. MATERIALS AND METHODS

### 2.1. Experimental Site and Setup

The present experiment was conducted at Drainage and Reclamation Institute of Pakistan (DRIP) Tandojam, Pakistan during the Rabi season of 2014-2015. Randomized Complete Block Design was applied with two treatments ($T_1$ = Raised-bed irrigation system and $T_2$ = Conventional irrigation system (basin irrigation method) replicated thrice. The total area for each treatment was (1004.65 $m^2$). The area of each treatment was divided into three equal blocks. The area of each block for Raised Bed and Conventional irrigation systems was 334.88 $m^2$ (18.29 m x 18.29 m) and 334.88 $m^2$ (18.29 m x 18.29 m) respectively. The source of water for the irrigation purpose of wheat crop under both systems was groundwater.

### 2.2. Preparation of Land and Sowing of Crop

The land at experimental site was prepared by disc harrow followed by cultivator and then leveled using conventional leveler. Soaking dose of 77.6 mm was applied in both experiments. Raised beds were prepared using bed planter keeping bed width 36 cm and depth as 22 cm, the width of furrow 25 cm and depth was 22 cm whereas RxR distance was 11 cm and 29 numbers of beds having 18 m length. Wheat variety (Kiran 95) obtained from Nuclear Institute of Agriculture, Tandojam was sown under raised bed using bed planter while for conventional method the farmers practice (Ghurbi) was adopted. The spacing within the rows was at 11cm; the seed rate was kept as 40 kg per acre, Waraich *et al.* [14].

### 2.3. Soil Sampling and Analysis

To determine soil texture, dry bulk density, pH, $EC_e$, SAR and ESP 72 field composite soil samples were collected for analyzing. The samples were taken at various depths (i.e. 0-15, 15-30, 30-45, 45-60, 60-75 and 75-90 cm respectively), these samples were then brought to the laboratory of Land and Water Management, Sindh Agriculture University Tandojam. pH and ECw were determined by digital meters. Soil texture was determined by Bouyoucous Hydrometer method [15], tube sampler was used for sampling of dry bulk density. The samples were then labeled and packed for determination at the laboratory. They were placed in oven for 24 hours and were then measured with weight balance. Relation described by McIntyre and Loveday was then used to calculate dry bulk density of the soil [16].

$$\text{Dry bulk density } (\rho d) = \frac{\text{Dry weight of soil sample (g cm - 3)}}{\text{Total volume of soil sample}}$$

Sodium Adsorption Ratio (SAR) of water was calculated as, Rowell [17]:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$

Sodium was determined with the help of Flame Photometer and Soluble calcium plus magnesium ($Ca^{++}Mg^{++}$) by titrating with std. versinate EDTA (Ethylenediaminetetraacetic acid) in the presence of buffer solution and Eriochrome Black T indicator methods. However, the field capacity of the soil was determined by core method [18].

### 2.4. Irrigation Scheduling and Time of Irrigation Application

The irrigation to wheat crop under raised bed irrigation and conventional system was applied after sowing at 25 days intervals through the crop period at 55% soil moisture depletion, MINFAL [19]. The crop water requirement at the root zone was calculated by the following formula, Choudhry [20].

$$R = \frac{(FC - MC)}{100} \times B \times D$$

$$M.C = \frac{(W_w - W_d)}{W_d} \times 100$$

Required depth of water applied through cut throat flume (4” x 1.5’) was installed at the center of field channel. Equation given below was used to determine the time of irrigation application to required depth [21, 22].

$$Q \times T = A \times D$$

### 2.5. Yield Components and Harvesting of Crop

Ten (10) plants were randomly selected from 1 $m^2$ area of each block to record the observations *viz*., number of plants, plant height (cm), number of spikes per plant, number of spikelet’s per spike, number of grains $spike^{-1}$, weight of grains $spike^{-1}$(g), seed index

(g) and yield (kg $m^{-2}$), Shah *et al.* [23]. Threshing was done by hand and grains were weighed by balance in grams then converted into kg $ha^{-1}$. The increase in yield (%) was computed, as under, Tagar *et al.* [24]:

$$\text{Increase in yield (\%)} = \left[\frac{Y1-Y2}{Y1}\right]\times 100$$

### 2.6. Crop Water Productivity and Water Saving

The crop water productivity (CWP) of raised-bed and conventional irrigation systems were calculated using the following formula [25, 26]:

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

The water saving for wheat crop in raised bed over conventional irrigation system was calculated by:

$$WS(\%) = \frac{(W_a - W_b)}{W_a}$$

## 3. RESULTS AND DISCUSSION

### 3.1. Soil Characteristics and Irrigation Water Quality of Experimental Site

Results for soil texture, average dry bulk density, field capacity and field capacity are presented in Table **1**. Quality of irrigation water plays a fundamental role in the growth of plants and development of salinity, therefore water samples were collected at every irrigation interval and were then analyzed (Table **2**). The results showed that irrigation water used throughout the experiment was second class (slightly saline) as criterion described by Punmia and Pande [27].

### 3.2. Irrigation Water Used

The depth and volume of water applied are presented in Figures **1** and **2**. The results showed a significant ($p<0.05$) differences under both treatments. It is apparent from the results that the total volume of water applied to wheat crop under raised-bed irrigation system was 76.01 $m^3$/block. Which was further calculated to be 1846$m^3$ $hec^{-1}$. Similarly, total volume of water applied under conventional irrigation system was 125.28 $m^3$/block. Which was further calculated to be 3747 $m^3$ $hec^{-1}$. The results revealed that total volume of water used under raised-bed irrigation system was less as compared to conventional irrigation system. The results are in line with the close conformity of findings of Hobbs and Gupta [12], they reported that the raised-bed planting of crops is one of the improved techniques for water saving.

Water saving in percentage was calculated to be 50.73 (Figure **3**). The result is in confirmation with the achievements of Jat *et al.* [28], they found that wheat

**Table 1: Soil Characteristics of Experimental Field**

| S. No. | Parameters | Soil characteristics | | |
|---|---|---|---|---|
| 1 | Soil texture | % Clay | % Sand | % Silt |
| | | 36.5 | 42.5 | 21 |
| | | Clay Loam | | |
| 2 | Dry bulk density | 1.32 g $cm^{-3}$ | | |
| 3 | Field capacity (FC) | 0.26 | | |
| 4 | Infiltration rate | 22 mm $hr^{-1}$ | | |

**Table 2: Analytical Results of Irrigation Water Samples under Raised-Bed and Conventional Irrigation System**

| Sample No. | $EC_w$ (µS $cm^{-1}$) | pH | SAR | RSC |
|---|---|---|---|---|
| 1 | 1801 | 7.9 | 4.5 | Nil |
| 2 | 1790 | 7.7 | 4.3 | Nil |
| 3 | 1798 | 8.1 | 4.0 | Nil |
| 4 | 1785 | 8.1 | 4.1 | Nil |
| 5 | 1780 | 8.2 | 3.9 | Nil |

yield was about 16.6% higher with nearly 50% less irrigation water. Similarly, Karrou *et al.* [29] found that the water savings of 1500 $m^3$/ha in wheat under raised-bed irrigation system.

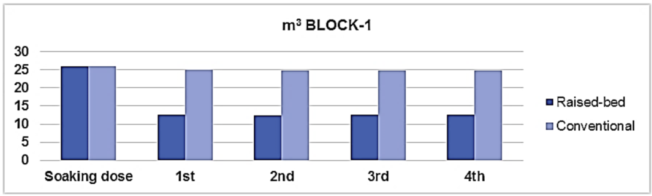


**Figure 1:** Volume of water applied to wheat crop under raised-bed and conational irrigation systems.

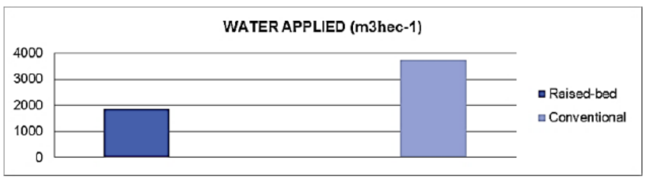


**Figure 2:** Total water used in raised bed and conventional irrigation systems.

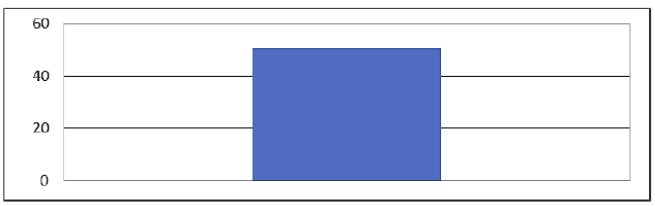


**Figure 3:** Water saving (%) under raised-bed over conventional irrigation systems.

### 3.3. Grain Yield and Yield Components

The yield and yield components parameters of wheat crop in raised bed and conventional irrigation systems are presented in Figures **4-12**. Number of wheat plants germinated $m^{-2}$, number of wheat spikes $plant^{-1}$ and wheat plant height (cm) were higher under the raised-bed over conventional irrigation system. These outcomes are affirmed by the findings of Bhuyan *et al*. [30], they as well mentioned increase in number of panicle $m^{-2}$, number of grains $panicle^{-1}$, and 1000-grain in bed planting.The same has been reported by Singh *et al.,* that wheat yield components i.e. grain spike_1 and 1000-grain were observed higher under raised bed as compared to conventional [31]. This statement further affirms the findings reported by Meisner *et al.*, that Greater biomass, longer spikes, greater number of grains per spike and plumper grains were observed with raised bed planting over conventional [32].


**Figure 4:** Number of plants $m^{-2}$of wheat crop.

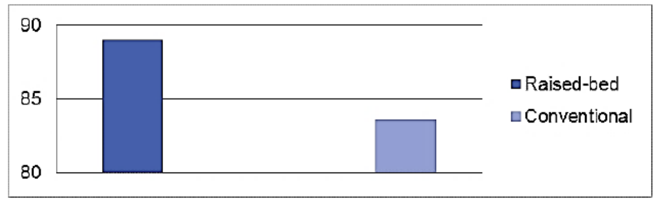


**Figure 5:** Plant heights (cm) of wheat crop.

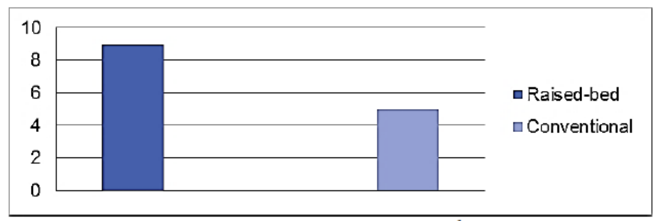


**Figure 6:** Number of spikes $plant^{-1}$ of wheat crop.

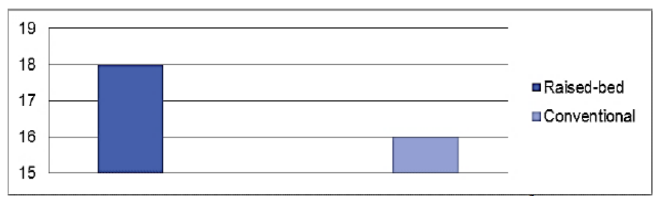


**Figure 7:** Number of spikelet's $spike^{-1}$ of wheat crop.

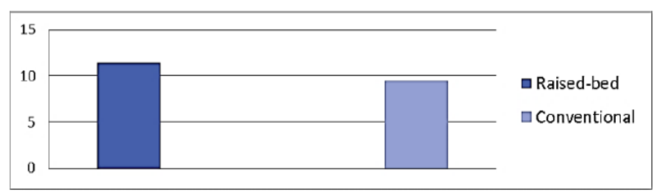


**Figure 8:** Spike length (cm) of wheat crop.

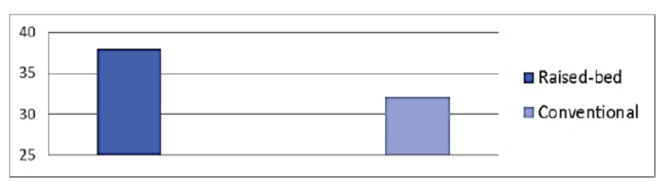


**Figure 9:** Number of grains $spike^{-1}$ of wheat crop.

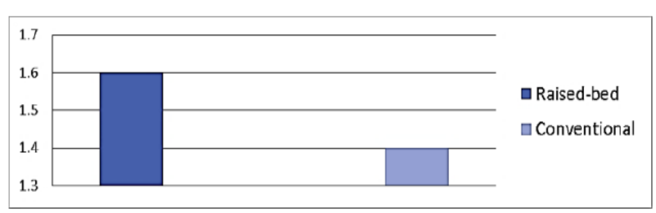


**Figure 10:** Weight of grains $spike^{-1}$(g) of wheat crop.


**Figure 11:** Seed index (1000 grains weight) of wheat crop.

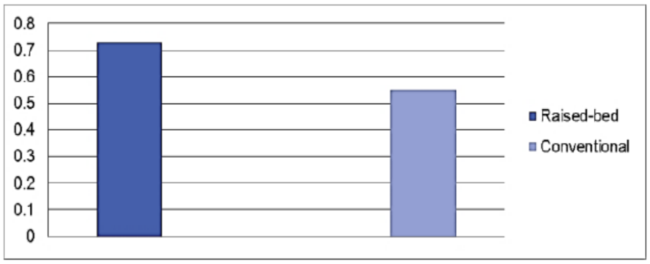


**Figure 12:** Yield (kg $m^{-2}$) of wheat crop.

### 3.4. Wheat Yield (kg $plot^{-1}$ and kg $ha^{-1}$)

The yield of wheat crop under the raised-bed and conventional irrigation systems are shown in Figure **13**. The total yield of crop under raised-bed irrigation system was 256.14 kg $plot^{-1}$ which in $hec^{-1}$ was calculated to be 7591.98 kg. Similarly total yield of crop under conventional irrigation systems was 183.94 kg $plot^{-1}$ and it was further calculated as 5451.98 kg $hec^{-1}$. These result are in agreements with the findings of Naresh *et al.* [33], they concluded from their research study that there was about 20.4% and 16.5% water saving with an increase in grain yield about 13.5% and 11.8% for wheat and maize crops with raised bed planting compared to traditional planting. However, Khoso [34] reported that crop yield increased under raised bed due to rich nutritional soil, being loose, had a better environment for aeration, water movement, root development and sufficient moisture content.

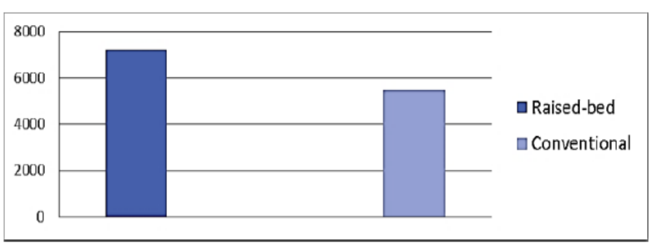


**Figure 13:** Yield of wheat crop (kg $ha^{-1}$) under raised-bed and conventional irrigation systems.

### 3.5. Increase in Yield and Crop Water Productivity

Increase in yield and water productivity are graphically represented in Figures **14** and **15**. The increase in yield was 24.65% and crop water productivity of wheat under raised-bed and conventional irrigation systems were 3.20 kg $m^{-3}$ and 1.46 kg $m^{-3}$ respectively. These results are in line with Hobbs *et al*. [35], who stated that raised-bed planting contributes in improvement of water distribution and its efficiency. Moreover, these results advocate with the findings of Bhuyan *et al*. [30], who concluded from their study that water use efficiency and crop productivity for grain production were higher in bed planting over conventional method.

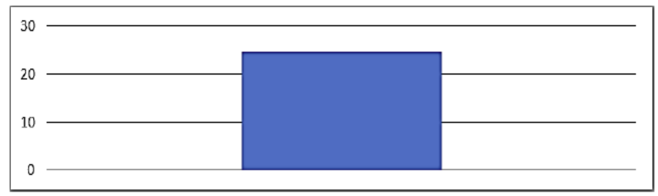


**Figure 14:** Increase in yield (%) of wheat crop under raised-bed and conventional irrigation systems.

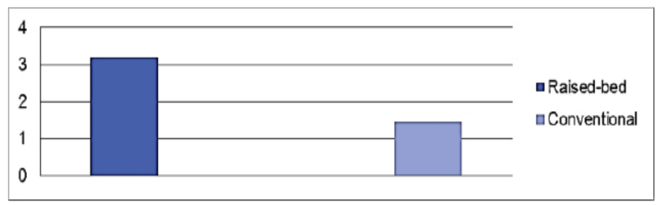


**Figure 15:** Crop water productivity (kg/$m^3$) of wheat crop under raised-bed and conventional irrigation systems.

## 4. CONCLUSIONS

The study has shown that the water saving (50.73%) and water productivity (54.37%) of wheat crop was higher under raised-bed irrigation system. The raised-bed irrigation system obtained 24.65% higher yield compared to conventional irrigation system. All other parameters were also higher under the raised-bed irrigation system.

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