AGRICULTURAL WATER MANAGEMENT 87 (2007) 292–298

available at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/agwat

# Water use efficiency and economic feasibility of growing rice and wheat with sprinkler irrigation in the Indus Basin of Pakistan

*Muhammad Akram Kahlown*[a,*], *Abdur Raoof*[1,b], *Muhammad Zubair*[1,b], *W. Doral Kemper*[a]

[a] *Pakistan Council of Research in Water Resources (PCRWR), Khyaban-e-Johar, H-8/1 Islamabad, Pakistan*
[b] *Regional Office, PCRWR 6 km, Thokar Niaz Baig, Main Raiwind Road, Lahore, Pakistan*

ARTICLE INFO

*Article history:*
Accepted 27 July 2006
Published on line 26 September 2006

*Keywords:*
Rice
Wheat
Sprinkler irrigation
Indus Basin
Pakistan
Water saving
Evapotranspiration
Water productivity
Economic feasibility

ABSTRACT

With a population of more than 150 million, Pakistan cannot meet its need for food, if adequate water is not available for crop production. Per capita water availability has decreased from 5600 $m^3$ in 1947 to 1000 $m^3$ in 2004. Water table has gone down by more than 7 m in most parts of the country. Present need is to identify and adopt measures, that will reduce water use and increase crop production. This study was conducted in farmers' fields during 2002–2004 to evaluate the water use efficiency and economic viability of sprinkler irrigation system for growing rice and wheat crops. Yields and water use were also measured on adjacent fields irrigated by basin flooding, which were planted with the same crop varieties. Sprinkler irrigation of rice produced 18% more yield, while reducing consumption of water to 35% of that used in the traditional irrigation system. Sprinkler irrigation of wheat resulted in a water use efficiency of 5.21 kg of grain per cubic meter of water used compared to 1.38 kg/$m^3$ in the adjacent flooded basins. Benefit–cost analysis showed that adoption of rain-gun sprinkler irrigation for rice and wheat is a financially viable option for farmers. While these findings show large potentials for improving water use efficiency in crop production they also indicate that a large portion of the water applied in traditional flooded basin irrigation is going to groundwater recharge, which has high value near large cities which draw their water from the aquifer.



## 1. Introduction

Irrigated agriculture produces about 40% of all food, and consumes 69% of all freshwater resources (FAO, 2000). Global population growth is expected to increase the demand for cereals including rice and wheat by 1.27% annually between 2000 and 2025 (Rosegrant and Cai, 2000). To meet the projected demand for food, irrigated agriculture will require an increase of 17% in freshwater resources (Seregeldin, 1999). In many arid and semi-arid countries where population growth is high, and freshwater is in short supply, there is pressure on the agricultural sector to reduce its water consumption and make it available for the urban and industrial sectors. This drives the demand to produce cereals, especially rice and wheat, using

* Corresponding author. Tel.: +92 51 9258959; fax: +92 51 9258963.
E-mail addresses: pcrwr@isb.comsats.net.pk, kahlown@hotmail.com (M.A. Kahlown), ropcrwr@lhr.comsats.net.pk (A. Raoof), ropcrwr@lhr.comsats.net.pk (M. Zubair), pcrwr@isb.comsats.net.pk, kahlown@hotmail.com (W.D. Kemper).
[1] Tel.: +92 42 5320484; fax: +92 42 5321067.
0378-3774/$ – see front matter 
doi:10.1016/j.agwat.2006.07.011

lower amount of irrigation water. Pakistan is no exception to this challenge.

In Pakistan, farmers generally apply water to unleveled bunded units, resulting in long irrigation events, poor water uniformity and over-irrigation (Kahlown and Kemper, 2004). Rice growers in particular tend to believe that it requires standing water during the growing season to maximize yields. These practices result in very low irrigation efficiencies. Studies within Pakistan indicate that 13–18 cm water is applied per irrigation event, which is considerably higher than the consumptive use between two irrigation events, i.e. approximately 8 cm (Kahlown et al., 2001). On-farm irrigation efficiencies range between 23 and 70% (Clyma and Ashraf, 1975; Kalwij, 1997; Kijne and Kuper, 1995; Kahlown et al., 1998).

Recently, there have been attempts to adopt pressurized irrigation methods to grow rice and wheat in various countries (Spanu et al., 1996). Sprinkler systems such as portable rain-guns can be used to apply a desired depth of water during pre-sowing and subsequent irrigations. The application of irrigation water with sprinklers has improved on-farm irrigation efficiencies up to 80% under the prevailing climatic conditions in the Indian sub-continent (Sharma, 1984).

The potential for the adoption of sprinklers to irrigate rice and wheat has not been evaluated in the Indus Basin of Pakistan, where water is delivered to farms by watercourses based on *warabandi*, a rotational method for equitable allocation of available water, by turn, with a fixed day, time and duration of supply to each irrigator. *Warabandi* provides a continuous rotation of water in which one complete cycle of rotation generally lasts 7 days. The duration of supply to each farmer is proportional to the size of the farmers' land holding (Bandaragoda, 1998). This practice poses an additional constraint on the adoption of pressurized irrigation methods, which require water to be available for irrigation when soil moisture is in deficit. Therefore, there is a need for on-farm storage of water if sprinkler irrigation is to be adopted in this area. Consequently, farmers would incur additional expenses to pay for sprinkler irrigation system and on-farm storage.

In this study, the potential for improving water productivity of rice and wheat by adopting rain-gun sprinklers for irrigation in the Indus Basin of Pakistan was evaluated. In addition to sprinkler irrigated fields, basin irrigated fields were also monitored for comparison. The specific objectives of the study were to apply irrigation water with a portable rain-gun above and below the evapotranspiration ($ET_c$) requirements for rice and wheat and to compare crop water productivity of rice and wheat with crops grown under basin flooding; and to estimate whether the water savings resulting from sprinkler irrigation can pay for the additional costs incurred.

## 2. Materials and methods

### 2.1. Layout and treatments for rice (2002) and wheat (2002–2003)

Trials in (2002–2003) were carried out on Monoo Farm, 6 km from the Regional Office of the Pakistan Council of Research in Water Resources (PCRWR) at Lahore. Clay loam soil is dominant in this area. Three different irrigation treatments were evaluated each with three replications and having size of plots, each 36.6 m × 36.6 m. Circular areas within these plots covered by rain-gun water were taken as the actual experimental areas while the remaining area was used as a buffer area (Fig. 1). A reservoir (2 m × 2 m × 2 m) was constructed near the trial sites to store water. A 16 HP diesel operated pump was installed to operate the rain-gun system. Pan evaporation and rainfall data were recorded, and daily crop evapotranspiration requirement ($ET_c$) estimated (Eq. (1)) using daily pan evaporation data ($E_{Pan}$), a pan coefficient ($K_{Pan}$) of 0.7 (Khan, 2001) and a crop coefficient ($K_c$) (Kaleemullah et al., 2001).

$$ET_c = E_{Pan} \times K_{Pan} \times K_c \quad (1)$$

Water flow meters were installed on the supply lines of each rain-gun to measure the cumulative volume discharged. Irrigation was applied twice a week for sprinkler irrigated plots, as a percentage of crop evapotranspiration demand. Adopted irrigation treatments are summarized in Table 1. Water used in the basin irrigation plot was measured with a cut-throat flume.

For the rice (2002) crop, the seedbed was prepared by two disc ploughings and four simple ploughings followed by two plankings and puddling (process of breaking down soil aggregates into uniform mud, accomplished by applying mechanical force to the soil at high water content). The rice variety Super Basmati was transplanted in the first week of June and harvested in last week of October. Fertilizers applied included 155 kg/ha of diamonium phosphate at the time of transplanting and after 25 days urea and zinc sulphate at the rate of 124 and 12.5 kg/ha, respectively. Wheat was sown in second week of November 2002 and harvested in second week of April 2003. Seed-bed preparation included one disc ploughing followed by two cultivations and two plankings. A seed rate of 123.5 kg/ha of Inqlab-91 of wheat variety was used. Fertilizers added were 75 kg/ha nitrogen and 70 kg/ha phosphorus at the planting time.

### 2.2. Layout and treatments for rice (2003) and wheat (2003–2004)

Trials on rice and wheat were again conducted (2003–2004) at the Inam Ilahi Farm, at Mouza Sheikh Da Kot, about 13 km from the Regional Office of the PCRWR at Lahore. Clay loam soil is dominant in the area. Three different irrigation treatments were evaluated each with three replications. Since variations among yields of (2002–2003) treatments were small, it was decided to minimize the variation in water applications among sprinkler irrigated treatments (2003–2004). In addition to this, moisture stress condition was also considered for rice trials. Nine plots, each covering one of the half circle areas shown in Fig. 2, each measuring 561 $m^2$ (18.9 m radius) were prepared for the trials. The irrigation supply was same as in the previous year. Adopted irrigation treatments are summarized in Table 1.

Crop water requirements were usually met using canal water with private tubewell water used when canal water was not available. Irrigation volumes were measured with flow meters for sprinkler irrigated plots, and with a cut-throat flume for surface irrigated plots. Water savings were calculated by