Agricultural Water Management 173 (2016) 55–60

Contents lists available at ScienceDirect

Agricultural Water Management

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

Alternate furrow irrigation can radically improve water productivity of okra

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ARTICLE INFO

Article history:
Received 13 June 2015
Received in revised form 27 April 2016
Accepted 29 April 2016

Keywords:
Irrigation efficiency
Water use efficiency
Water savings
Deficit irrigation

ABSTRACT

Alternate furrow irrigation (AFI) is gaining interest as a means of saving water while minimising loss in crop production. Given the potential water savings of AFI, a field experiment was conducted in the Tandojam region of Pakistan by growing okra with AFI and conventional furrow irrigation (CFI) in which every furrow is irrigated. Our results show that total irrigation water applied in the AFI treatment was roughly half (248 ± 2.9 mm) that applied to the CFI treatment (497 ± 1.7 mm). Despite the very significant reduction in irrigation water used with AFI there was a non-significant ($p > 0.05$) reduction (7.3%) in okra yield. As a result, we also obtained a significantly ($p < 0.001$) higher crop water productivity (CWP) of 5.29 ± 0.1 kg m^{-3} with AFI, which was nearly double the 2.78 ± 0.04 kg m^{-3} obtained with CFI. While this reduction in yield and/or potential income may appear small, it could be critical to the welfare of individual farmers, who may as a result hesitate to make changes from CFI to AFI if they are worse off than farmers who do not adopt AFI. This situation exists because current water charges are based on crop and land area rather than the volume of water being accessed for irrigation. Transitioning from the current crop and land area based method of charging for water to a volumetric method may require investment in irrigation system changes and may take time to accomplish. These are important lessons for other countries, and particularly developing countries who are trying to improve the environmental, social and economic performance of their irrigated systems. We recommend that further studies be carried out using AFI to determine whether similar water savings and flow-on benefits can be achieved across a wide range of cropping systems in arid and semi-arid environments.

1. Introduction

Pakistan's economy is dependent on agricultural production. It is estimated that 70–80% of the total area cultivated in Pakistan is irrigated through a network of canals. About 93% of the available fresh water resources are currently utilized in the agricultural sector (Bhangar and Saima, 2008). The increasing population has resulted in demand for more food and fiber, which is met through increasing irrigated agriculture. This translates into increasing pressure on Pakistan's water resources. It is critical therefore that management and utilization of available water resources is improved at all scales; from catchment, to irrigated district, to farm and field scale. Management of water at the macro level is generally expensive, time consuming and difficult. By comparison management of water at the field scale is generally relatively inexpensive, more feasible and practical, and it can be implemented in a short period of time. It is therefore critical to improve water management at the field scale through adoption of more efficient and effective irrigation methods.

About 90% of the irrigated land of the world is irrigated using relatively inefficient surface irrigation methods (Tiercelin and Vidal, 2006). As a result about 20–30 million ha of irrigated lands globally are seriously damaged by the build-up of salts and it is estimated that the area of salt affected soils will increase by about 0.25–0.5 million ha per year (FAO, 2002). Similar trends are observed in Pakistan where traditional surface irrigation methods (basin, border and furrow) are widely used to irrigate crops. These are however inefficient methods of irrigation and are considered one of the main

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http://dx.doi.org/10.1016/j.agwat.2016.04.026

Table 1
Measurements of soil properties at four depths at the field experimental site, including soil texture, soil bulk density and soil water content at saturation (0 kPa), field capacity (33.34 kPa) and wilting point (1500 kPa).

S. No.	Soil depth (cm)	Sand %	Silt %	Clay %	Textural class	Dry bulk density ($g\,cm^{-3}$)	Saturation Capacity ($cm^3\,cm^{-3}$)	Field Capacity ($cm^3\,cm^{-3}$)	Wilting point ($cm^3\,cm^{-3}$)
1	0–20	23 ± 0.31	52 ± 0.47	25 ± 0.62	Silt Loam	1.32 ± 0.08	0.41 ± 0.03	0.33 ± 0.02	0.16 ± 0.02
2	20–40	30 ± 0.62	46 ± 0.60	24 ± 1.02	Loam	1.36 ± 0.07	0.38 ± 0.04	0.30 ± 0.04	0.14 ± 0.02
3	40–60	26 ± 0.46	48 ± 0.43	26 ± 0.57	Loam	1.33 ± 0.04	0.39 ± 0.03	0.31 ± 0.04	0.16 ± 0.03
4	60–80	28 ± 0.34	45 ± 0.47	27 ± 0.69	Loam	1.33 ± 0.02	0.40 ± 0.02	0.33 ± 0.03	0.15 ± 0.02

±Denotes confidence interval.

Table 2
A comparison of irrigation water used in alternate furrow irrigation (AFI), conventional furrow irrigation (CFI) and flood irrigation under three different irrigation methods and water savings with CFI and AFI methods.

Irrigation methods	Irrigation water used			AFI water savings (%)	
	m^3 subplot^{-1}	$m^3\,ha^{-1}$	mm	Compared with flood irrigation	Compared with CFI
AFI	50.1 ± 0.36	2480 ± 18	248 ± 2	66	50
CFI	100.4 ± 0.21	4970 ± 10	497 ± 1	–	–
Flood	–	7200[a]	720	–	–

± Denotes confidence interval.
[a] Literature values taken from Mashori (2013).

causes of waterlogging and salinisation (Burt et al., 1997). It is because of these sorts of problems that the use of modern, high-tech and efficient micro irrigation methods (drip, bubbler, sprinkler etc.) are advocated worldwide. However, farmers are often reluctant to adopt these high-tech methods, especially in Pakistan and other developing countries, due to their high cost of installation, operation and maintenance. As a result these methods have not yet been widely adopted by farming communities in developing countries. There is a need therefore for more efficient irrigation methods that are economical, easy to install and operate, and which are readily acceptable to the farming community.

Furrow irrigation, reported to be one of the least efficient methods compared with other irrigation methods (Burt et al., 1997), is still one of the most widely used forms of surface irrigation. It involves water flow through narrow channels (furrows) spaced regularly across the field (with row spacing often between 1.0–2.0 m), instead of flooding water over the whole field. Despite its application efficiency remaining relatively low (Ampas and Baltas, 2009), not enough effort is being made to keep improving its management and efficiency. Because furrow irrigation is a well-known, simple and economical method of irrigation, farmers are likely to be ready adopters of new approaches that are practical improvements of their current practices and that result in improved water use efficiency.

It has been suggested (Kang et al., 2000a; Du et al., 2010; Horst et al., 2005) that the efficiency of conventional furrow irrigation (CFI), referred to by some as every furrow irrigation, can be improved by converting it to alternate furrow irrigation (AFI). The AFI method is essentially the same as CFI, except that instead of irrigating every furrow, irrigation is applied to alternate furrows, while the in-between furrows remain dry. This means each ridge receives water from only one side, and the side receiving irrigation water could be changed with each irrigation if the field is set up to facilitate this change. Irrigating just one side of the ridge means there is significant potential to save irrigation water compared to CFI. There is however, also potential in some cases for a reduction in crop yield (Samadi and Sepaskah, 1984; Crabtree et al., 1985; Mashori, 2013). It has been observed that farmers prefer to stick with traditional flood irrigation methods due to their simplicity, ease of operation and maintenance and low installation/construction cost. If the conventional furrow irrigation method (CFI) is transformed into alternate furrow irrigation (AFI) then it might be readily accepted by farmers. However, before introducing and advocating this method to local farmers for adoption, the method needs to be evaluated under soil and climatic conditions representative of the areas being targeted for its introduction.

The objective of this study is to report on an experiment in which okra (*Abelmoschus esculentus* L.), also known as Lady's finger, was grown using CFI and AFI. Okra is an important vegetable crop grown throughout Pakistan, and the aim of the experiment was to assess the water savings and water productivity improvements that could be achieved with AFI compared with CFI. While we report on benefits of AFI for growing okra in Pakistan, this paper provides lessons for furrow irrigators in general, and particularly for irrigators in developing countries who do not have access to high tech irrigation methods such as pressurised drip irrigation.

2. Materials and methods

An experiment with conventional furrow irrigation (CFI) and alternate furrow irrigation (AFI) methods was conducted at a field site with an experimental plot that was 1260 m^2 (36.5 m × 34.5 m) located in the district Hyderabad, Sindh, Pakistan, at Latitude of 25°25′28″N and Longitude of 68°32′6″E. The elevation at the site is about 26 m above mean sea level (Fig. 1).

The experimental plot was deep ploughed with a moldboard plough and the resulting clods were pulverized with a disc harrow. The whole plot was levelled before demarcation into six subplots, each with a size of 202 m^2. The remaining area (48 m^2) was used for construction of the water supply canals and bunds between the subplots. The selection of subplots for testing the CFI and AFI methods was completely randomized. Furrows were manually constructed using spades. The furrow to furrow and ridge to ridge distance were 0.8 m. The furrow depth was 0.2 m. The total length of each furrow was 18 m, and there were a total of 14 furrows in each subplot. There were therefore 3 subplots and 42 furrows under each treatment. Subplots were irrigated through a field channel passing through the center of the plot.

Seventy two (72) soil samples were collected from 3 randomly selected locations in each subplot at depths of 0–20, 20–40, 40–60 and 60–80 cm for determining soil texture and soil dry bulk density. Soil texture was determined using the hydrometer method (Bouyoucos, 1962). Soil bulk density was determined using the core method (Grossman and Reinsch, 2002). Soil water contents