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Effect of Drip and Furrow Irrigation Systems on Sunflower Yield and Water Use Efficiency in Dry Area of Pakistan

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Abstract: Surface irrigation is commonly used in Pakistan and will continue to be used as a traditional method of irrigation with water application efficiency not more than 40%, whereas yields are way below those of other countries. The use of available water resources therefore warn to use limited irrigation water efficiently to save not only loss of water but provide adequate root zone moisture for increasing crop production. A field experiment was conducted in the year 2007 on sandy loam soil of dry area of Pakistan to study the effect of drip and furrow irrigation methods on sunflower crop yield and water use efficiency. As sunflower is one of the most cultivated crops in the World and its cultivation in Pakistan is increasing due to its short duration (90-120 days) with high oleic acid, higher oxidative stability and better dietary property. Comparison of results under drip and furrow irrigation methods revealed that drip irrigation produced 26 percent more sunflower yield with 56 percent less water compared to furrow irrigation method. Water use efficiency of drip irrigation was about three times higher than furrow irrigation method. With one cubic meter volume of water drip and furrow irrigation produced 0.55 and 0.19 kg of sunflower yield, respectively. The results revealed that drip irrigation has the potential to increase the area under cultivation due to water saving and increase in crop production for food security and poverty alleviation.

Key words: Comparative effect · Drip irrigation · Furrow irrigation · Sunflower yield

INTRODUCTION

Sindh province of Pakistan is an arid region and is heavily dependent on surface irrigation resource. With a growing population, this vital resource has become water scarce resulting food insecurity. Due to scarce water resources and inefficient traditional surface irrigation practice, agriculture is faced with intensifying pressure to improve and manage the available water resources efficiently by increasing the efficiency of water for food production. As cropping land and water resources are becoming more limited, conservation is becoming an increasingly important topic. Researchers are interested to develop or study highly efficient application methods to use scarced water resources efficiently and have the capability to provide effective root zone moisture for increased crop yield. There are, however, also other technical and economical reasons, sunflower is an excellent preceding crop for wheat; all cropping practices can be easily mechanized; the high price of grain, at least until recent years [1].

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Sunflower (*Helianthus annuus* L.) is one of the most important oil crops which grown on over 22 million hectares worldwide, with a production of 26 million tons/year [2]. Sunflower was introduced in Pakistan during the 60s which has now become a major oilseed crop of Pakistan besides; other oilseed crops include cottonseed, rapeseed/mustard, canola, etc. It was sown on an area of 457.30 thousand hectares during the year 2007-2008, which resulted seed production of 683 thousand tons and oil production of 264 thousand tons (Anonymous, 2008). Pakistan is deficit in vegetable oil production. The imported edible oil budget is growing into billions of dollars; and is a big drain on our foreign exchange reserves. Demand of edible oil is increasing at a rate of 5.4% annually, [3].

Sunflower is generally considered drought-resistant, but significant reduction in yield has been observed due to water stress. This is because too much and too little water is detrimental that can influence the production and quality of sunflower oil [4]. Therefore adequate root zone moisture and drainage are essential for maximum sunflower production [5].

Effective use of irrigation with the aim to increase the productivity at least to double the existing level is prerequisite. Under these circumstances, the micro irrigation systems, such as drip irrigation can be more useful than surface irrigation (furrow irrigation method) for cultivation of crops in the areas where fresh groundwater is available. In such areas, drip irrigation is good option [6]. This innovative irrigation technique is well known for high water application and water use efficiency along with appreciable water saving over traditional methods of irrigation (i.e. like flood irrigation).

Many reports have been published for higer yield of vegetables under drip irrigation method. An appreciable water saving can be achieved and higher water use efficiency can also be noted in drip irrigation over surface irrigation (furrow method). In addition, it can be used in combination with saline water [7]. There is possibility of increasing efficiency of furrow irrigation method by selecting proper combination of spacing, length and slope of furrows and suitable size of irrigation stream and duration of water application [14], but efficiency may not be higher than the drip irrigation method [6].

The main objective of conducting this study was to investigate comparative effect of drip irrigation and furrow irrigation systems on the water use efficiency and subsequent sunflower production in the arid region of Thana Boula Khan, district Jamshoro, Sindh province, Pakistan.

MATERIAL AND METHODS

Study Area: The study was conducted at Muhammad Khaskheli farm, which is located in deh Desvi, taluka Thana Boula Khan of district Jamshoro, Sindh, Paksitan. The farm is located at a distance of about one kilometer in the north of Thana Boula Khan town i.e. at the right side of Thana Ahmed Khan road (Fig. 1). At this Farm, Pakistan Agricultural Research Council, Hyderabad has established a field station and installed drip irrigation system under National Research and Development Project (NRDP) on water management of spate irrigation systems in Rod-Kohi areas of Pakistan.

Drip Irrigation System: The field experiment was designed for drip irrigation method on plot measuring 10 m x 30 m (i.e. 300 m^2 or 0.03 hec). The drip irrigation system was designed and installed in such a way to maintain required pressure at the end of the plot so that uniform water distribution at each emitter head is obtained. The lateral polyethylene pipes of 15 mm diameter were installed in 11 rows of 30 m length into 10 m long sub main of 25 mm diameter at the head of the plot. The distance between two laterals/rows was 90 cm. The pressure compensating emitters were fixed into laterals with punch hole at a distance of 30 cm. Each lateral contained 100 emitters. A total of 1100 emitters were used in a drip plot. The water into drip plots was delivered by pumping water from reservoir through m long main PVC pipeline of 50 mm diameter which was connected with sub main. Fertigation tank was connected with mainline for direct application of liquid fertilizer with water at the recommended rate for efficient plant nutrition requirement. Water meter was also fixed in a mainline for measurement of water delivered in drip plot. Under drip irrigation system, water was delivered to the plant root zone directly at a slow and low pressure rate in small amounts through emitters for watering the plants. The water was applied at the interval of two days based on the soil type and the water holding capacity determined before the design and installation of drip irrigation system. The soil of experiment plots was sandy loam with low water holding capacity. The layout of drip irrigation system at farm is shown Fig, 1 (for details refer Gadehi, [8]).

Preparation of Furrows and Ridges: Under furrow irrigation plot measuring 10m x 30m (0.03 ha), furrows and ridges were prepared to give 30 cm x 30 cm x 30 cm dimension of furrow bed width x ridge width x height of the ridge cm. Length of each furrow was kept 30 m.

Fig. 1: Study area

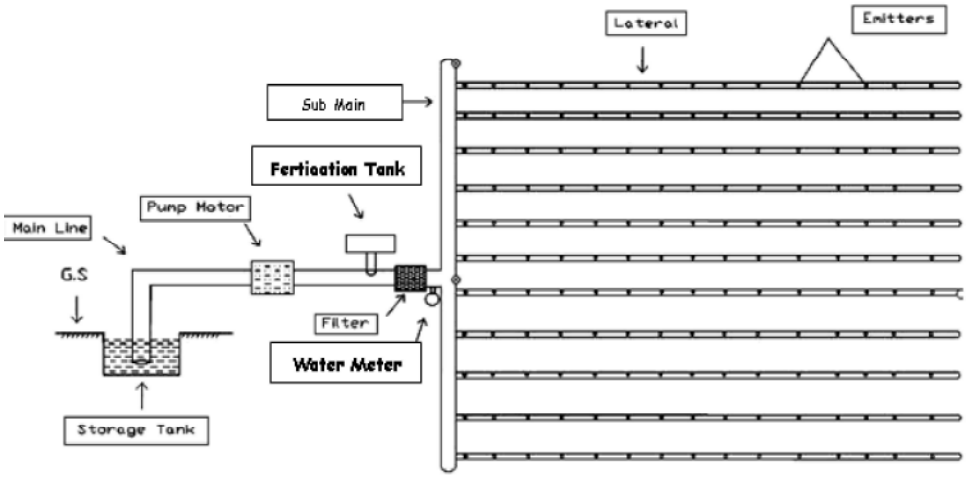

Fig. 2: Layout of Drip Irrigation System

There were 11 numbers of furrows and 12 numbers of ridges. Water into furrow plot was applied through ditch prepared at the head of furrows. The layout of furrow irrigation system at farm is shown in Fig. 2.

Crop Cultivated: The sunflower was sown under drip and furrow irrigation systems. For this purpose, the land under experiment (0.06 ha) was ploughed thoroughly and divided equally having dimension of 10 m x 30 m.

In drip plot, a soaking dose of 5.4 m^3 was then applied through emitters. When the soil came in workable condition, the diammonium phosphate (DAP) fertilizer at the rate of one bag (123.5 kg) per hectare was applied in the plot as recommended. Sunflower (Hybrid Australian Variety) seeds were sown on both sides of the laterals at a plant to plant distance of 30 cm and row to row distance of 90 cm. A total of 200 seeds were sown on a single row and total of 2,200 plants in drip plot having 11 rows. Drip lateral line was installed in middle of the two rows on a ridge with emitters supplying water to two plants each. Water meter installed at mainline was used to record the volume of water applied in drip plot.

Similarly, furrows were prepared in furrow plot keeping same row-to-row and plant-to-plant distances as those in the drip irrigation method. The soaking dose 38.125 m^3 was applied in the furrows. For the measurement of water, a cutthroat flume (4" x 8" size) was installed in the watercourse that supplied water to the farm ditch.

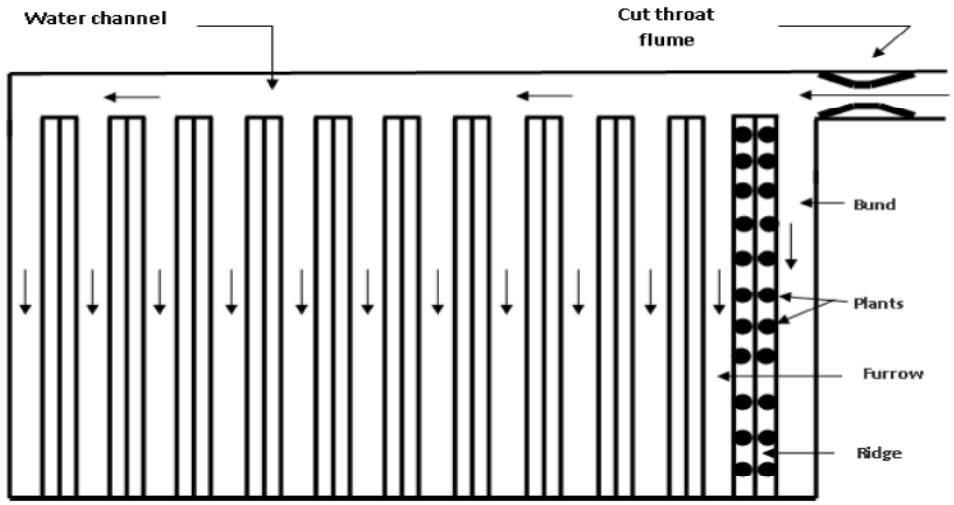

Fig. 3: Layout of Furrow Irrigation System

The furrows were filled with water at half of the height of the ridges. The water applied was recorded accordingly. When the soil came in workable conditions, DAP fertilizer at the recommended doze was applied and sunflower seed was sown on either side of the 11 ridges keeping the same plant-to-plant distance and row to row distance to that of drip irrigation system in order to maintain same plant population in both the drip and furrow irrigation plots. All the other cultural practices, such as weeding, inter-culturing, fertilization, tenting of birds etc were carried out as per the recommendations of Agricultural Research Institute (ARI), Tandojam, Pakistan. The crop was sown on April 15, 2007. On maturity, the sunflower crop was harvested and air dried under the sun for record of sunflower yield in both drip and furrow plots.

Computation of Water Use Efficiency and Water Saving

Water Use Efficiency (WUE): Water use efficiency (kg/m^3), ratio of crop yield to total water delivered, is given by Majumdar [15]:

$$WUE = \frac{Crop\,Yield\,in\,Kg\ per\ Hectare}{Total\,Water\,Delivered\,in\,the\,Plot\,in\,m^3 ha^{-1}} \quad (1)$$

Water Saving (%): The water saving in drip irrigation method over furrow irrigation method can be calculated as under:

$$WS(\%) = \frac{(Wf - Wd)}{Wf} * 100 \quad (2)$$

where

WS = Water Saving (%)

Wf = Total water used in furrow method of irrigation (m^3 ha^{-1})

Wd = Total water used in drip irrigation method (m^3 ha^{-1})

Actual water delivered in each plot under drip (Wd) and furrow irrigation (Wf) was computed after determining the effective rainfall in the site area from the rainfall data recorded using rain gauge installed at the experimental site during crop growing season in the months of June and July 2007. The effective rainfall was calculated using method of Doorenbos and Pruitt [9]. The calculated effective rainfall was added to total water delivered under each irrigation method.

RESULTS AND DISCUSSION

Irrigation Application: Irrigation application data recorded in both drip and furrow irrigation during crop duration was 139.7 and 357.77 m^3, respectively (Fig. 4), whereas effective rainfall was computed as 31.11 m^3 using the method described by Doorenbos and Pruitt [9]. Hence, actual irrigation application in both drip and furrow irrigation methods was 170.81 and 388.88 m^3, respectively. On hectare basis, it comes 5,694 m^3/ha in drip irrigation and 12,963 m^3/ha in furrow irrigation (Fig. 4). It is evident that furrow irrigation method consumed twice as high water than that used by drip irrigation system. Thus, there was saving of 56% water in drip irrigation over the furrow irrigation method. These results are in agreement with those obtained for vegetable crops on

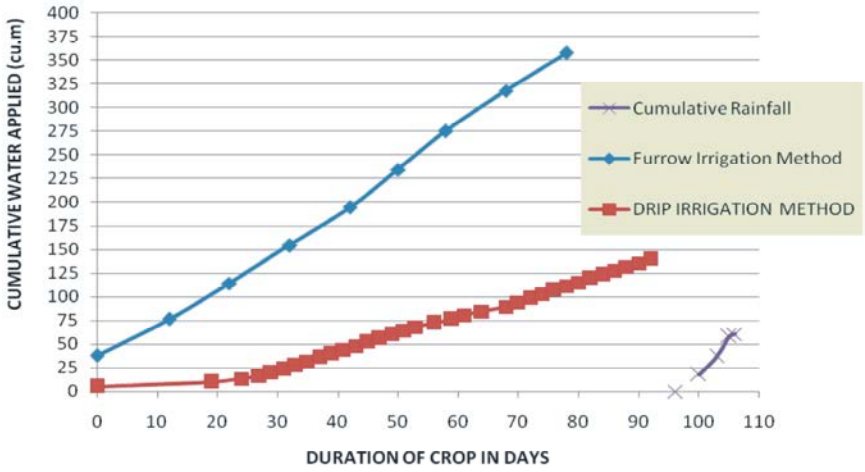

Fig. 4: Irrigation applied to Drip and Furrow plots for whole crop duration and rainfall data

Table 1: Water use efficiency of drip and furrow irrigation methods

Yield (Kg/ha)		Water Used (m^3/ha)		Water Use Efficiency (WUE) (Kg/m^3) (Crop yield/ Water used)	
Drip	Furrow	Drip	Furrow	Drip	Furrow
3,098.36	2,467.21	5,600	12,750	0.55	0.19

drip irrigation system [refer. Chandio, *et al.* [10]] for cotton crops by Ibragimov *et al.* [11], for wheat crops [Yaseen *et al.* [6]] and show better performance in terms of yield for sunflower crop on treated wastewater [Asgari *et al.* [12]].

Crop Yield: The record of yield of sunflower in both drip and furrow irrigation plots is shown in Table 1. It can be seen that drip irrigation and furrow irrigation methods yielded 3,098 kg/ha and 2,467 Kg ha^{-1}, respectively showing an increase of 26% increase in yield with drip irrigation over the furrow irrigation method. The increase in sunflower yield in drip irrigation was due to precise irrigation management that produced radial distribution pattern and effective utilization of nutrient fertigation in the wetted soil volume where most of the roots are concentrated near the emitter or along each lateral line.

Water Use Efficiency: Water use efficiency is used as another basic indicator to evaluate the performance of the irrigation methods. From the given crop yield and total volume of water consumed, water use efficiency (WUE) as defined earlier was calculated for both drip and furrow irrigation methods and is also presented in Table 1. The table shows that the performance of drip irrigation method in terms of WUE was 0.55 Kg m^{-3}, whereas performance of furrow irrigation was 0.19 Kg m^{-3} of water. The results indicated that the drip irrigation is more water use efficient producing about 3 times more sunflower yield than furrow irrigation from one unit of volume of water.

Expansion of drip irrigation method in Pakistan depends on economic cost of drip material and its affordability, consistent management to ensure long life, crop prices and water scarcity. Due to increasing demand of edible oil of sunflower and high price, the cultivation of sunflower in Pakistan is increasing every year. At present Pakistan is producing only 24% of the total demand and rest of the 76% demand is met from import which consumes billion of rupees in foreign exchange. Thus, there is need to increase not only the area under cultivation of sunflower, but to increase per hectare yield as well. The results of study revealed that drip irrigation method has potential to increase area and production of sunflower in minimizing the gap between demand and supply and saving the country's foreign exchange [13]. At present sunflower is grown on 343,308 hectare of land with very low average yield of 1,810 Kg/ha and oil production 211 tons [13]. With the intervention of drip irrigation, cultivation of sunflower crop may be increased to about 535,560 hectares with increasing sunflower production to 1,659,762 tons by using drip irrigation method. The current oil production of 211 tons may be increased to 664 tons which is 3 times higher than the current sunflower oil production. As a result there would be significant increase in food and economy with direct benefit to farmers.

CONCLUSIONS

The field study on sandy loam soil revealed that drip irrigation has the potential to save 56% water and increase sunflower yield by 26% over furrow irrigation.

Drip irrigation system is efficient method having 3 times more water use efficiency than furrow irrigation system and can successfully be adopted in Pakistan for increase in sunflower cultivation and yield. Based on high performance of drip irrigation over furrow irrigation method, there is potential to increase current area under sunflower in Pakistan and production to 1½ times and 3 times respectively. Further expansion of area is possible if drip irrigation is adopted at economic cost and consistent management.

There is however need to conduct further long term studies on different soils at different locations of Sindh to see the performance of drip irrigation system and its adoptability with respect to economic material cost, payoff and consistent management to ensure long life, crop prices and water scarcity that requires water conservation.

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