EFFECT OF DRIP AND FURROW IRRIGATION METHODS ON WATER SAVING, YIELD AND YIELD COMPONENTS OF SUNFLOWER CROP

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ABSTRACT: *The availability of fresh water in Pakistan has become a major issue due to increasing population, urbanization and industrialization. Therefore it is mandatory to promote modern irrigation methods and to manage existing conventional irrigation methods. Present study was attempted to compare drip and furrow irrigation methods for water use efficiency, water saving, yield and yield components of sunflower. The experiments were carried out at the experimental site of Sindh Agriculture University Tandojam during 2013. The total area (12 × 6 m^2) was divided into two plots. Of which one plot (6 × 6 m^2) was used for furrow irrigation method and other for drip irrigation method. Physical and chemical characteristics of soil such as: dry bulk density (1.46 g cm^{-3}) infiltration rate (22 mm hr^{-1}) and field capacity (29 %), pH (8.2), EC (1.17 dS m^{-1}) and soil texture (Silt loam) were measured before the cultivation of the crop. The emission uniformity of drip irrigation system ranged between 87.8 to 90.8% and implies that the system was working satisfactorily according to design. Results showed that higher water use efficiency of 0.68 kg m^{-3} under drip irrigation, while lowest water use efficiency of 0.25 kg m^{-3} found under furrow irrigation method. Drip irrigation system saved 45.96% water and gave 32.7% more yield as compared to furrow rrigation system. Moreover total water consumed under drip irrigation was 54.22% less than that offurrow irrigation methods. In addition to this drip irrigation method yielded maximum plant height (215 cm), head diameter (25.2 cm), stem girth (6.56 cm), number of seeds per head (743), weight of the seeds per head (52 g), seed index (69.98 g), seed yield (09.36 kg $plot^{-1}$) and (2600 kg ha^{-1}) as compared to that of furrow irrigation method. It is concluded that drip irrigation method is better in all respects; it should be promoted all over the world particularly in developing countries where scarcity of water is the major issue.*

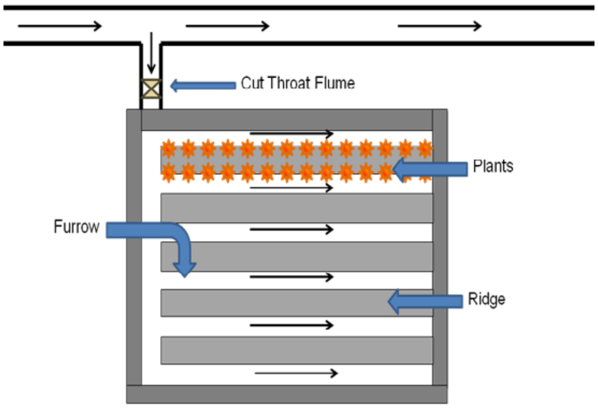
Key words: Drip and Furrow irrigation system, sunflower, seed index, water use efficiency and yield

INTRODUCTION

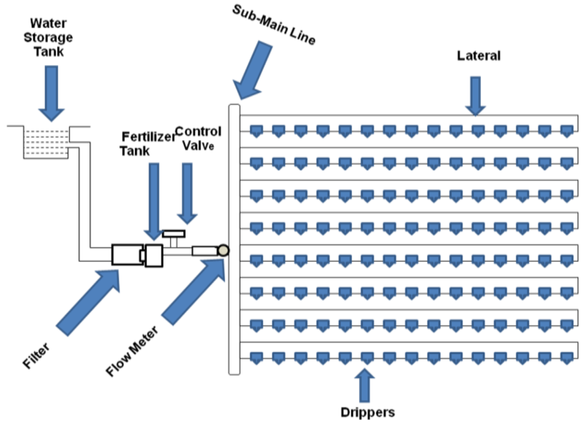
Recognizing the fast decline of irrigation water potential and increasing demand for water from different sectors, a number of demand management strategies and programs have been introduced to save water and increase the existing water use efficiency in agriculture. Water demand is increasing by every passing hour due to agricultural usage, urbanization and unsustainable utilization. Its per capita availability has tremendously decreased throughout the world. Pakistan is no exception where its per capita availability has declined by more than 5 times from 5,260 m^3 in 1951 to 1,038 m^3 in 2010 [1, 2]. If this status quo continues, then by 2020 the water availability in Pakistan would further drop to 877 m^3 per annum, which will further decrease to an extremely low level of. 575 m^3 in 2050 [2]. Pakistan has land mass of 79.61 million hectares (Mha), of which 70 Mha is located in the arid and semi-arid areas that includes 11 Mha of deserts. Currently, about 36.6 Mha land is suitable for agriculture, forage and forestry leaving 43.6 Mha unsuitable except for rough grazing in certain places. About 24.6 Mha are considered as cultivable area [3]. Out of this area, about 18.4 Mha are irrigated through canals, tube wells, dug wells, springs, streams, etc. These figures suggest that about 6.2 Mha of land still needs water for irrigation [4].

It is an established fact that agriculture sector is the major user of water and continues to dominant the overall necessities. The water availability in arid and semi-arid areas is becoming a major factor to meet the challenges of increasing population, urbanization and unsustainable utilization. Proper management of water in these areas is crucial at all levels. It is relatively expensive to manage water resources at macro level, even though it is unavoidable. While management of water at field level is relatively cheap, more feasible and easily workable that can be managed in short span of time [5].

At present, Pakistan is classified as water stress country and by the year 2025, it will turn into a water scared country. Therefore, the country will have to face a major challenge in water sector in the years to come. The problem of water shortage will aggravate further if the available water resources were not used efficiently. Farmers in Pakistan usually use conventional flood irrigation methods i.e. basin, border and furrow to irrigate their crops. In these methods complete soil surface is flooded without considering the actualconsumptive use of crops. Application efficiency of these methods ranges between 40 and 50% [6]. Due to poor application efficiency, not only huge amounts of water are lost but problems of salinity and water logging are created [7]. Therefore, implementation of modern efficient irrigation methods needs to be emphasized to save water and increase crop water production. Efficient irrigation methods like trickle, sprinkler, pitcher, and sub-irrigation are required to be familiarized in areas with water shortage. These methods may be considered expensive thus farmers are reluctant



(a)



(b)

Figure 1. Layout plans for (a) furrow and (b) drip irrigation methods

to use them. However, the acceptance of these methods depends upon their success in terms of maximum yield returns associated with minimum water use.

The aim of this research was to compare the drip and furrow irrigation system. Therefore present study considered to compare conventional method of irrigation system with the modern one in terms of emission uniformity, water use efficiency, water saving and yield related attributes of the sunflower.

MATERIAL AND METHODS

An experiment was conducted at the field experimental site of Faculty of Agricultural Engineering, Sindh Agriculture University Tandojam during the year 2013. The site is located at Latitude 25^o 25' 28" N and Longitude 68^o 32' 26'' E and at an elevation of about 26 m above mean sea level (MSL). The total area of 12 × 6 m^2 was used for this study; 6 × 6 m^2 for drip and another 6 × 6 m^2 for furrow irrigation method as shown in Figure 1 (a) and (b). The land at experimental site was continuously used for various research projects. The land was prepared to grow sunflower crop. It was ploughed using a disc plough followed by rotavator and then leveled. A soaking doze of 100 mm was applied to the entire field. Once soil came into the workable condition, it was ploughed using disc harrow followed by cultivator and afterward leveled.

Installation of drip irrigation system

The drip irrigation system was installed in the study plot. The system consists of PVC mainline with diameter of 40 mm which was connected to 16 mm diameter laterals having a discharge of 4 liter per hour (0.004 m^3 hr^{-1}) drippers. The laterals were spaced at a 70 cm distance between them while emitters were spaced at a 23 cm distance. This provided a plant to plant spacing of 23 cm as suggested by MINFAL [8] for sunflower. A total of 8 laterals each 530 cm long were laid on the ground surface along the lines of plants with 23 drippers (Figure 1 (b).

Performance of drip irrigation system

In order to determine the performance of drip system, discharge measurements through each emitter were taken and coefficient of variation and emission uniformity was determined. Containers/bowls were placed under each drippers/emitters to collect the water flowing through them. The volume of water collected in each container in a given time was then measured by a graduated cylinder [5,9]. Emission uniformity was calculated using equation described by Keller and Bliesner (1990); Soomro et al. 2012 [9,10].

$$EU = 100\left[1.0 - 1.27\frac{Cv}{n^{1/2}}\right]\frac{q_m}{q_a} \quad \text{…………(1)}$$

Where,

EU = emission uniformity, Cv = co-efficient of variation, n= number of emitters, q_m = minimum flow & q_a =average flow Co-efficient of variation determines the flow rate uniformity of the drippers. It was calculated by the following equation [9,11].

$$Cv = \frac{\sigma}{q_{av}} \times 100 \quad \text{………………………(2)}$$

Where,

C_V = co-efficient of variation, σ = standard derivation, q_{av} = average flow Standard deviation (σ) was calculated from following formula:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(q_i - q_{av})^2}{n}} \quad \text{…………………(3)}$$

Preparation of furrow and ridges

Furrows and ridges were set up manually in furrow irrigation system. Total of 6 having 450 cm length furrows with 12 ridges with same length were prepared. Like drip irrigation system, similar row to row and plant to plant distance were kept. A total of 18 plants were planted on the both ridges of each furrow.

Soil and water analysis

Soil physical properties such as: dry bulk density, infiltration rate and field capacity were measured. Composite soil samples were collected at the various depths of 0-20, 20-40 and 40-60 cm using core sampler. These samples were analyzed for physical analysis at the laboratory of Department of Land and Water Management, Sindh Agriculture University Tandojam. Soil texture was determined by Hydrometer as described by Bouyoucos [12], dry density and field capacity determined by core method as described [13, 14]; and infiltration was determined with double ring infiltrometer as described [15]. Soil samples were analyzed for chemical properties such as; pH and ECe. Soil water extract was prepared for this purpose using method described by Rowell [16]. Water samples were collected to assess the quality of irrigation water used in this study. The samples were collected from the running emitters at the beginning of irrigation, during the mid-period and at the end of experimentation. Collected samples were analyzed for EC_w, pH, SAR and RSC using methods adopted [16,17].

Water use efficiency

Water use efficiency (WUE) has been used to describe the relationship between sunflower crop production and the total amount of water used. The WUE under drip and furrow irrigation system was calculated from given expression [9, 18]:

$$WUE = \frac{Y}{W_r} \quad \ldots\ldots\ldots\ldots(4)$$

Where,

WEU = Water use efficiency (Kg m^{-3})

Y = Yield of crop (Kg ha^{-1})

W_r = Total water used for sunflower crop (m^3 ha^{-1})

Water application and crop sowing

The irrigation application was fixed at 45% soil moisture depletion as recommended [8, 19]. Subsequent irrigations were applied when the moisture dropped to fixed level. Under drip irrigation system, water was applied to soil at the rate of 4 lit per hour (0.004 m^3 hr^{-1}) through all emitters/dipper. Once soil moisture reached to field capacity, seeds of a standard commercial open pollinated sunflower variety HO-1 were sown by hand under each emitter. Just before 1st irrigation, seedlings were thinned to maintain a plant to plant distance of 23 cm. Similarly in furrow irrigation system, water was applied to all furrows, when the soil moisture reached at the field capacity, sunflower seeds were sown manually. Cutthroat flume was used to measure the irrigation water in furrow irrigation method. However, flow meter was installed in the sub-main to measure water under drip irrigation system.

The amount of water required for irrigation was based on the moisture depleted between two irrigations. The water application depths required was calculated by using following [36, 37]:

$$D = \frac{SMD}{100} \times \rho_b \times d_r \quad \ldots\ldots\ldots\ldots(5)$$

Where,

D = depth of water required (cm)

SMD = soil moisture deficit level

ρ_b = bulk density (grams cm^{-3})

d_r = root depth (cm)

Following relations were used to determine soil moisture deficit level (SMD):

$$SMD = \theta_f - \theta_o \quad \ldots\ldots\ldots\ldots(6)$$

$$\theta = \frac{(Ww - Wd)}{Wd} x100 \quad \ldots\ldots\ldots\ldots(7)$$

Where,

SMD	=	Soil moisture deficit level
θ_f	=	Moisture content at field capacity (%).
θo	=	Moisture content at 45 % SMD,
θ	=	Moisture content on dry weight basis (%)
W_w	=	Wet weight of soil (g)
W_d	=	Oven dry weight of soil (g)

A cutthroat flume (8” × 1.5’) was installed in the field channel to measure the required depth to furrow plot. The method described Skogerboe [20] was adopted to take measurements. The time of irrigation application to fill required depth of water was calculated by equation given by [20, 21]

$$QT = 28 \times A \times D \quad \ldots\ldots\ldots\ldots(8)$$

Where,

Q	=	discharge required (LPS),
T	=	time of application (hour),
A	=	area to be irrigated (hectare)
D	=	depth of irrigation to be applied (cm)

Water saving in percentage under drip irrigation compared to furrow irrigation method was determined by the following equation [5].

$$WS(\%) = \frac{(W_f - W_d)}{W_d} \times 100 \quad \ldots\ldots\ldots(9)$$

Where,

W = Water saving (%)

W_f = Total water consumed in furrow irrigation method (m^3 ha^{-1})

W_d= Total water consumed in drip irrigation system (m^3 ha^{-})

Growth and yield attributes of the crop

Plant height, head diameter, stem girth , number of seeds $head^{-1}$, seed weight $head^{-1}$, seed index (1000 seed wt.), yield (kg $plot^{-1}$) and yield kg ha^{-1} were recorded at the time of maturity as described [23]. The yied was then calculated in kg ha^{-1} for each drip and furrow irrigated plots. The increase in yield (%) was calculated as method given by Tagar et al. [5]

$$\left[Increase\,in\ yield\ (\%) = \frac{(Y_d - Y_f)}{Y_f} \times 100 \right] \ldots\ldots(10)$$

Where,

Y_d = Total yield achieve in drip irrigation method (kg ha^{-1})

Y_f = Total yield achieve in furrow irrigation method (kg ha^{-})

RESULTS AND DISCUSSION

RESULTS

Soil and water characteristics

The results in Table 1 depicted that the soil at the experimental site was silt loam with 35.2% sand, 42.7% silt and 22.1% clay. The average field capacity of soil is 29%, bulk density is 1.46 g cm^{-3}, infiltration rate is 22 mm hr^{-1}, pH 8.2 and ECe is 1.17 dS m^{-1}. However water analysis revealed EC_w was <1500 micro-S cm^{-1}, while SAR was <10 and with no RSC (Table 2). Results suggest that groundwater was suitable for irrigation. So the irrigation water can be used without any expected problems for salinity or infiltration.

Performance of drip irrigation system

Performance of the drip irrigation method was tested through **c**oefficients of variation and emission uniformity calculations/determinations. The higher values of EU will result higher values of crop production, and water use efficiency (WUE). For this purpose four laterals *viz* 1, 3, 5 and 7 were randomly selected and data was collected on these laterals. The coefficients of variation and emission uniformity were calculated and results are given in Table 3. The coefficients of variation of randomly selected laterals (i.e. 1, 3, 5, and 7) were 0.354, 0.319, 0.412 and 0.392 and emission uniformity was 89.7, 90.8, 87.8 and 88.7%, respectively.

Table 1. Physico-chemical properties of the experiment site.

S. No	Parameters	Soil characteristics	S. No	Parameters	Soil characteristics
1	Soil texture	Silt loam	4	Infiltration rate	22 mm/hr
2	Dry bulk density	1.46 g cm^{-3}	5	Soil pH	8.2
3	Field capacity	29 %	6	ECe	1.1 dS m^{-1}

Table 2. EC, pH, SAR and RSC of irrigation water

Sample #	ECw (micro-S cm^{-1})	pH	SAR	RSC
1	1356	7.7	6.67	Nil
2	1350	7.8	6.63	Nil
3	1345	7.7	6.62	Nil

Table 3. Data showing minimum discharge, average discharge, standard deviation, coefficient of variation and emission uniformity

Lateral No	Minimum discharge q_m (lit/hr)	Average discharge q_{av}	$\sum(q-q_{av})^2$	Standard deviation $\sum$	Co-efficient of variation Cv	Emission uniformity (EU) %
1	3.94	3.98	0.0041	0.0141	0.354	89.7
3	3.95	3.98	0.0037	0.0127	0.319	90.8
5	3.93	3.98	0.0062	0.0164	0.412	87.8
7	3.94	3.98	0.0056	0.0156	0.392	88.7

Table 4. Date-wise volume of water applied to sunflower under furrow irrigation method

Irrigation #	Date of irrigation	Water applied (m^3)	Irrigation #	Date of irrigation	Water applied (m^3)
1^{st}	22-02-13	1.16	5^{th}	04-04-13	5.56
2^{nd}	05-03-13	1.12	6^{th}	14-04-13	6.22
3^{rd}	15-03-13	2.27	7^{th}	23-04-13	7.09
4^{th}	26-03-13	2.23	--	**Total**	**25.65**

Table 5. Date-wise volume of water applied to sunflower crop under furrow irrigation method

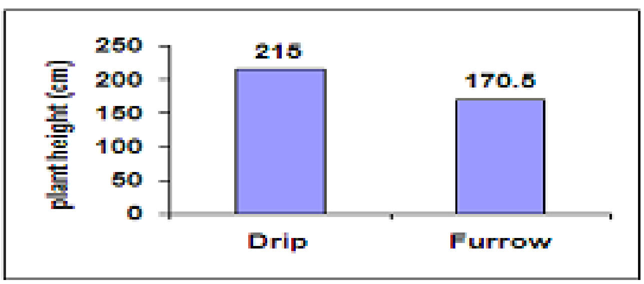
Irrigation #	Date of irrigation	Water applied (m^3)	Irrigation #	Date of irrigation	Water applied (m^3)
1^{st}	22-02-13	0.88	10^{th}	28-03-13	0.66
2^{nd}	26-02-13	0.88	11^{th}	31-03-13	0.66
3^{rd}	02-03-13	0.88	12^{th}	03-04-13	0.66
4^{th}	06-03-13	0.88	13^{th}	07-04-13	0.66
5^{th}	10-03-13	0.88	14^{th}	10-04-13	0.66
6^{th}	14-03-13	0.88	15^{th}	13-04-13	0.66
7^{th}	18-03-13	0.88	16^{th}	16-04-13	0.66
8^{th}	22-03-13	0.88	17^{th}	20-04-13	0.88
9^{th}	25-03-13	0.66	18^{th}	23-04-13	0.66
				Total	**13.86**

Total volumes of water used under two irrigation methods

Tables 4 and 5 show volume of water consumed under furrow and drip irrigation methods. Total volume o water consumed by the sunflower crop under furrow irrigation method was 25.65 m^3 that was converted into volume of water use per hectare i.e. 7125 m^3 hac^{-1}. Similarly total volume of water consumed under drip irrigation method was 13.86 m^3 that equals to 3850 m^3 hac^{-1}. These results indicate that total volume of water consumed under drip irrigation system was less as compared to furrow.

Plant height and yield related attributes of Sunflower

Plant height and yield related components of the sunflower crop under drip and furrow irrigation methods are mentioned in Figure 2 (c-h). Better and significant results were observed under drip irrigation methods over furrow. The results of the experiment revealed that the better plant height (215 cm), head diameter (25.2 cm), stem girth (6.56 cm), number of seeds $head^{-1}$ (743), seed weight $head^{-1}$ (52 g), seed index (1000 seed weight, 69.98 g) were observed under drip irrigation method. The data shows that sunflower yields were affected by irrigation methods. It is obvious from Figure 3 (i-l) that drip irrigated produced a total of 9.36 kg $plot^{-1}$ (i.e. 2600 kg hac^{-1}) while furrow irrigated plots yielded 6.30 kg $plot^{-1}$ (i.e. 1750 kg hac^{-1}). These results suggest that total yield of crop under drip irrigation method was higher by almost 1.5 times as compared to furrow irrigation method.



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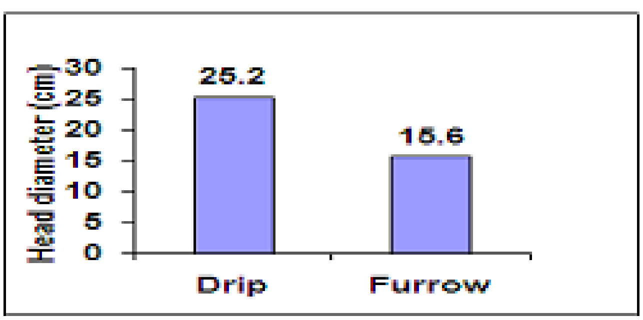

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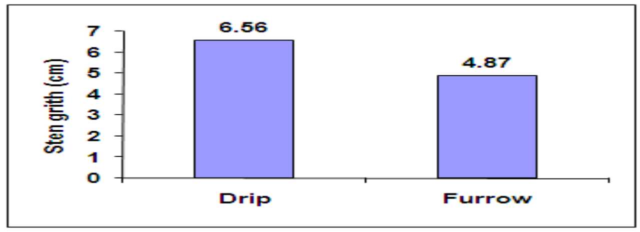

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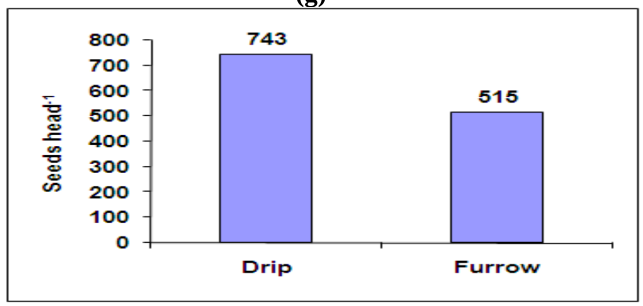

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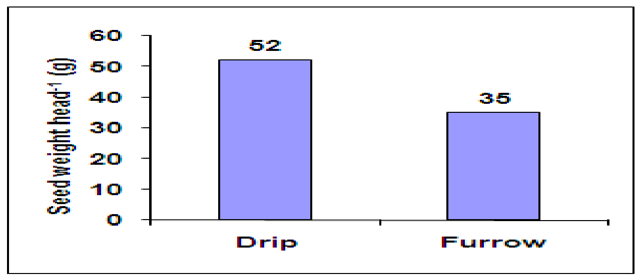

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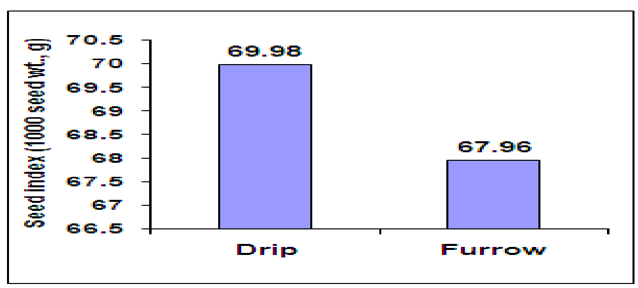
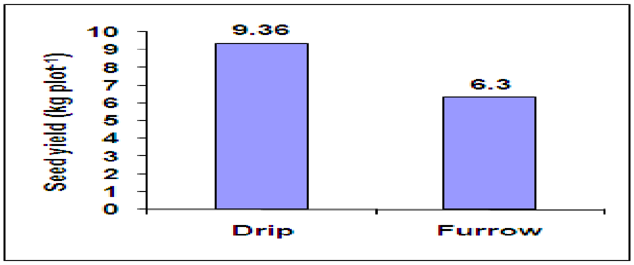
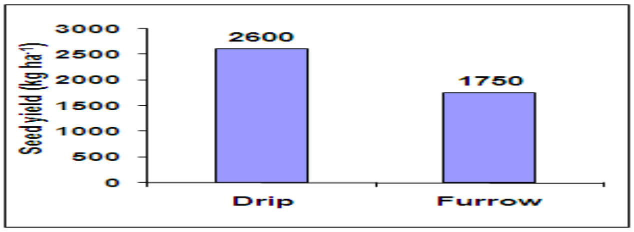


(h)

Figure 2. (c) Plant height (cm), (d) head diameter (cm), (e) Stem girth (cm), (f) no. of seeds $head^{-1}$ (g) seed weight $head^{-1,}$ (gms), (h) seed index (1000 seed wt, g)



(i)

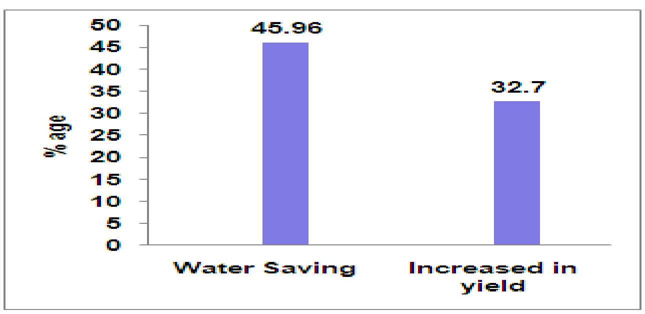


(j)

Figure 3. (i) seed weight (kg plot^{-1}), (j) seed yield (Kg ha^{-1})

Water saving, increase in yield and water use efficiency

Results on water saving, yield increase and water use efficiency under drip and furrow irrigation methods are given in Figure 4 (k-l). The results show that about 45.96% water was saved under drip irrigation as compared to furrow irrigation method. Drip irrigation produced 32.70% more yield over furrow irrigation method. Similarly, water use efficiency under drip irrigation was 0.68 kg m^{-3}as compared to 0.25 kg m^{-3} under furrow irrigation method.



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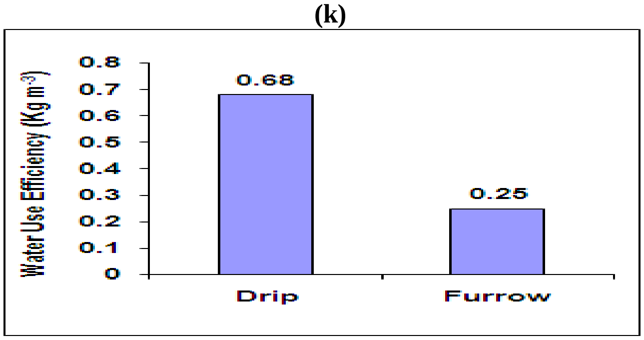

(l)

Figure 4. Effect of drip and furrow irrigation methods on (k) Water saving and increase in yield (l) water use efficiency ofsunflower (kg m^{-3})

DISCUSSION

Proper management of water in these areas is crucial at all levels. It is relatively expensive to manage water resources at macro level, even though it is unavoidable. In the present study drip irrigation system was significantly observed the most efficient in term of emission uniformity, water use efficiency, water saving, Sunflower seed yield and related components/parameters.

Performance of drip irrigation system was working satisfactorily in term of emission uniformity and results are well comparable with those mentioned [24]. Drip irrigation is the most efficient method to directly apply water and nutrients to plants. It increases yields of vegetables and crops, and simultaneously saves water [25]. The application efficiency of drip irrigation ranges between 70 and 90% as compared to flood irrigation methods where water is lost due to surface runoff, evaporation and deep percolation [26, 27]. Higher water use efficiency, greater vegetable yields and appreciable quantity of water saving i.e., 50-60% were observed under drip irrigation as compared to furrow irrigation method (28, 29, 30). It is very important to make the most efficient use of drip irrigation by scheduling water application and avoid excessive usage of water that causes stress in plants which in turn decreases yields.

The results of this study show that total yield of sunflower crop was higher under drip irrigated plots. The yield related components *viz;* plant height, head diameter, stem girth, number of seeds head^{-1}, seed weight head^{-1}, seed index (1000 seed wt.), also showed higher values under drip irrigation method as compared to furrow irrigation method. These results are in agreement with previous findings by [31, 32, 33], they reported that plant height is an important indicator of yield and its component. It has been positively related to the crop production. Muhammad et al. [34] concluded that drip irrigation method significantly increased seed cotton yield and yield components over furrow irrigation. [35] observed higher sunflower yield in drip irrigation method over furrow mode. [36, 37] conducted several experiments and observed positive responses under drip irrigation. Bilal [38] investigated that drip system improves irrigation uniformity, ensures precise use of nutrients, facilitates operations of agriculture equipment because rows are dried enough, and drip allows timely application of herbicides, insecticides, and fungicides. Further, explained that the diseases retard growth and development of plants and thus cause reduction in yield. Since drip irrigation reduces water contact with crop leaves, stems, and fruit the onset of diseases is minimized. Drip irrigation facilitates management of irrigation scheduling precisely to meet crop demands and increases yield and quality. Another reason for increasing yield was frequent application of water in the root zone. [39] reported that where precipitation and soil water supply are limited, sunflower responds positively to irrigation with respect to growth and yield.

Results of this study reveal that total volume of water consumed under furrow irrigation method was high as compared to drip irrigation method. Almost similar results were reported by [5, 29] who reported that furrow irrigation used more volume water as compared to drip irrigation method. Results further reveal that drip irrigation uses less water and gives higher yields than that of furrow irrigation method. Similarly, higher water use efficiency was obtained with drip over furrow irrigation method. This may be attributed to direct application of water in the root zone of crop through drip emitters which in turn reduces the water losses. Therefore conveyance, evaporation and percolation losses are minimized to some extent. These findings are in congruence with those found by [40 who reported that the tomato yield under drip irrigation was twice more over furrow irrigation method. Similarly, [41] observed that drip irrigation required 45% less water and produced higher tomato yield by 22% as compared to furrow irrigation. [30] reported that significantly higher yield and water use efficiency of summer and winter vegetable crops in drip over furrow irrigation mode. [42] revealed that about 49% of water could be saved with the application of drip irrigation in mango crop. [43] depicted that water use efficiency was higher by 31% in drip method as compared to furrow mode. Similarly, [34] recorded maximum water use efficiency of 7.9 kg/ha and water saving of 53.3% by drip irrigation method for cotton crop as compared to furrow irrigation method. Likewise, [39] observed that drip irrigation method saved 56.4% water and had 65% higher water use efficiency and gave 22% maximum yield over furrow irrigation method.

CONCLUSIONS AND SUGGESION

Drip irrigation method has proved to be efficient method of irrigation in all respects. Water saving, water use efficiency of sunflower crop as well as yield and yield components were comparatively higher under drip irrigation method. Therefore present study suggests the farmer's community to adopt drip irrigation method instead of old traditional flood irrigation methods (basin, furrow and border) in order to save water and obtain higher yields.

ACKNOWLEDGEMENTS

We would like to acknowledge Dean, Faculty of Agricultural Engineering and Prof. Dr. Altaf Ali Siyal Chairman, Department of Land and Water Management, Sindh Agriculture University Tandojam, Sindh Pakistan, Providing experimental field for conducting research work and laboratory facility at Faculty of Agril. Engineering, Sindh Agriculture University Tandojam.

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