The Pharma Innovation Journal 2022; SP-11(7): 322-326

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; SP-11(7): 322-326

www.thepharmajournal.com
Received: 07-04-2022
Accepted: 11-05-2022

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# Profitable drip irrigation design for sunflower-based cropping systems in Southern India

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**Abstract**
Productivity of drip irrigation was estimated in a field experiment in which sunflower was grown in the rainy season, followed by chickpea (*Cicer arietinum*), bread wheat (*Triticum aestivum*) and groundnut (*Arachis hypogaea* L.) in winter, in Dharwad in the state of Karnataka in southern India. The treatments comprised three levels of irrigation for sunflower, namely 1.0 ET0 (the reference evapotranspiration), 0.8 ET0, and surface flooding (which served as the control) and 0.6 ET0 for chickpea, 0.9 ET0 for wheat, and 0.8 ET0 for groundnut. The sunflower seed yield was significantly higher in 1.0 ET0 (2,432 kg $ha^{-1}$) than that in either 0.8 ET0 (2,172 kg $ha^{-1}$) or the control (1,847 kg $ha^{-1}$). In the winter too, yields with drip irrigation were significantly higher: higher by 21.40 percent in chickpea, 18.70 percent in wheat, and 15.58 per cent in groundnut; in terms of sunflower seed equivalent yield, groundnut (5,848 kg $ha^{-1}$) and chickpea (5,182 kg $ha^{-1}$) proved superior to wheat. The highest water-use efficiency (6.41 kg $ha^{-1}$ $mm^{-1}$) was recorded in the sunflower–chickpea combination. Sunflower–groundnut system fetched the highest returns (about 1,40,810 rupees, or $1846, per hectare).

**Keywords:** Sunflower-based cropping systems, surface irritation, flood irrigation, evapotranspiration-based irrigation, sunflower seed equivalent yield

## 1. Introduction

Water plays an important role in augmenting the growth and development of crop plants in their different stages of ontogeny. Since water is the lifeline for accruing desired yield levels, its time of application and method of application plays an important role in increasing the yield levels besides saving water. Further, water is the prime natural resource, which is often costly and limiting input particularly in arid and semi-arid regions, hence needs judicious use to reap the maximum benefit from this limiting resource. Off late, among irrigation methods, drip irrigation is receiving better appreciation, acceptance, adaption and plays an important role in saving the water in water scarce areas. It enables the efficient use of limited water with higher water use efficiency. Optimum irrigation levels with suitable method would help in enhancing the economic yield as well as water use efficiency in many field crops like sunflower crop. The efforts are now needed to harness the available quantities of water and put them to efficient use to realize higher productivity per drop of available water (Solaimalai *et al*., 2005) [13]. Therefore, greater emphasis needs to be given in improving the irrigation practices to increase the crop production and to sustain the productivity levels (Kalpana and Anita, 2014). Adoption of modern irrigation techniques that are simple, easy to operate and increase the efficiency of water usage. Among different irrigation method drip irrigation is often preferred because of its high (90-95%) water application efficiency (Rajput and Patel, 2006, Payero *et al*., 2008 and Anu and Habeeburrahman, 2015) [9, 7, 2], increased water productivity (Yenesew and Tilahun, 2009) [14] and still regulated deficit irrigation through drip technology can helps in developing practical recommendations for optimizing crop water productivity under conditions of scarce water supply (Schahbazian *et al*., 2007 and Silungwe *et al*., 2010) [11, 12].

Oilseeds play an important role in agricultural economy of India. Oilseeds are important next only to food grains in terms of area, production and value. The production of oilseeds in India is below the target levels. Among oilseed crops, Sunflower (*Helianthus annuus* L.) is an important annual oilseed crop. It is now the third largest producing oilseed in the world (47.86 m t) after soybean and rapeseed and mustard. Sunflower was introduced into India in 1969. Seeds contain up to 42 per cent of oil by weight, which is light and supplies more Vitamin E than any other vegetable oil. Owing to rich source of linoleic acid (64%), sunflower oil is good for heart patients. At world level, sunflower is cultivated on an area of 27.37 m ha and it is the third most produced oilseed crop (56 m t), representing 9 per cent of the total oilseeds production (Pilorge, 2020) [8].

India accounts for about 15-20 per cent of the global oilseeds area, 6-7 per cent of vegetable oils production, and 9-10 per cent of the total edible oils consumption (Kumar and Tiwari, 2020) [6]. The sunflower was introduced into India in 1969, though it gained importance relatively late as compared to other oilseeds, the area under cultivation had reached 2.33 m ha with a production of 1.40 m t in 2005, which then gradually declined to 0.26 m ha and 0.22 m t, respectively in 2019 (Anon., 2020) [1]. Karnataka, Maharashtra and Odisha are the major states, which account for about 75 per cent of the total area under sunflower cultivation in India. (Anon., 2020) [1].

The popularity of sunflower cultivation in India is increasing. Sunflower is a day neutral plant and has got wider adaptability to different soils, agro-climatic conditions and varied soil moisture levels. It is grown in all seasons. However, the reasons for low productivity of this crop in India are due to unavailability of adequate soil moisture.

## 2 Material and Methods

### 2.1 Land use at the site of the experiment

Malaprabha is one of the irrigation projects in Karnataka, although it offers no definite schedule or pattern for releasing water for irrigation. The quantity of water available for irrigation depends on the onset of the south-west monsoon, rainfall in the catchment area, and the capacity of the reservoir. The Command Area Development Authority regulates the schedule for releasing water. The most common cropping pattern in this command area comprises maize, sunflower (early in *kharif*, or the rainy season, typically from June to September), followed by chickpea, wheat, safflower, sorghum, or sunflower, groundnut (later in the *kharif* season), which, in turn, is followed by chickpea, wheat, sorghum, or safflower or a mixed/inter crop of chilli pepper, onion, and cotton. The main crop-growing period in the command area is from July to February: canal water for irrigation is usually available from the last week of August to December or, in a good season and if the dam is full, even up to the first half of January. Otherwise, water is available only for the winter (*rabi*) season, from September to December. In this agro-climatic zone (referred to as the Northern Dry Zone in India), it is possible to take an early crop if the area receives adequate (more than 100 mm) of rainfall from May to the first half of June; however, this is a gamble: the crops fail if the monsoon sets in late or is weak in July and August, leading to a long, dry, spell during the grand growth period of the crops—the time of peak water requirements.

Four consecutive years of such failure prompted the present experiment. The idea was to conserve the water from the early monsoon showers either *in situ* or by collecting the water in a farm pond or by pumping excess water from natural sources into farm ponds—and to use that water more efficiently, using drip irrigation, to ensure that adequate water is available to the crop throughout.

Accordingly, a field experiment was conducted in 2015/16 and 2016/17 at IWMRC, the Irrigation Water Management Research Centre (15°34′ N, 75°21′ E and 578 m above the sea level), in Belvatagi in Dharwad district of the state of Karnataka. The climate of the study site is semi-arid with annual precipitation of 560 mm and mean evaporation of 1626 mm (data on rainfall in 2015 and 2016 and the average of the past 32 years are presented in Table 1).

**Table 1:** Rainfall and number of rainy days (in 2015 and 2016 and average values) at IWMRC, Belavatagi research station, Karnataka, India

| Month | Normal rainfall | Normal no. of rainy days | Rainfall (mm) | No. of rainy days | Deficit/Excess rainfall (mm) | Deficit (%) | Rainfall (mm) | No. of rainy days | Deficit/Excess rainfall (mm) | Deficit (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1985–2016 | 1993–2016 | 2015 | 2015 | 2015 | 2015 | 2016 | 2016 | 2016 | 2016 |
| Jan. | 1.93 | 2.80 | 0.0 | 0.0 | −1.93 | 100.00 | 0.0 | 0.0 | −01.93 | 100.00 |
| Feb. | 1.36 | 0.27 | 0.0 | 0.0 | −1.36 | 100.00 | 0.0 | 0.0 | −01.36 | 100.00 |
| Mar. | 13.09 | 1.68 | 27.8 | 1.0 | 14.71 | Excess | 0.0 | 0.0 | −13.09 | 100.00 |
| Apr. | 30.20 | 3.50 | 12.2 | 1.0 | −18.00 | 59.60 | 09.4 | 1.0 | −20.80 | 68.87 |
| May | 35.10 | 5.67 | 30.1 | 4.0 | −05.00 | 14.24 | 88.2 | 9.0 | 53.10 | Excess |
| June | 86.23 | 4.44 | 120.2 | 7.0 | 33.97 | Excess | 78.2 | 4.0 | −08.03 | 9.31 |
| July | 85.83 | 6.12 | 46.0 | 3.0 | −39.83 | 46.40 | 62.7 | 10.0 | −23.13 | 26.95 |
| Aug. | 80.53 | 5.84 | 35.0 | 7.0 | −45.53 | 56.53 | 29.3 | 4.0 | −51.23 | 63.62 |
| Sept. | 128.47 | 6.88 | 156.8 | 7.0 | 28.33 | Excess | 51.4 | 4.0 | −77.07 | 59.99 |
| Oct. | 68.25 | 1.88 | 151.8 | 4.0 | 83.55 | Excess | 12.0 | 1.0 | −56.25 | 82.42 |
| Nov. | 31.06 | 0.57 | 3.0 | 0.0 | −28.06 | 90.30 | 0.0 | 0.0 | −31.06 | 100.00 |
| Dec. | 4.91 | 0.63 | 0.0 | 0.0 | −04.91 | 100.00 | 0.0 | 0.0 | −04.91 | 100.00 |
| Total | 566.96 | 4.27 | 582.9 | 34.0 | 15.94 | 2.81% Excess | 331.20 | 33.0 | −235.76 | 41.58 |

### 2.2 Soil physical and chemical properties

The experimental fields had clayey soil (24.5 per cent sand, 14.6 per cent silt, and 60.9 per cent clay) with an average bulk density of 1.4 Mg $m^{-3}$ to a depth of 90 cm, a pH of 8.5, and average electrical conductivity of 0.3 dS $m^{-1}$. The field capacity was 38.1%, the wilting point was 21.3%, and available water was 0.3 $cm^{-3}$. The organic carbon content was 0.51%, available P was 37 kg $ha^{-1}$, and available K was 791 kg $ha^{-1}$.

### 2.3 Design of drip system

The irrigation lines rested on the soil surface and the network comprised sub-lines connected to the main line and laterals connected to the sub-lines. Each lateral was 10.8 m long, connected to the sub-line at intervals of 0.6 m, and was equipped with in-built emitters (discharging 4 litres of water per hour) spaced at intervals 0.4 m on the lateral lines.

### 2.4 Experimental design and treatments

The experiment was laid out in a strip plot design with three replications. Each main plot (the irrigation treatments). The irrigation treatments for sunflower were 1.0 ET0 ($I_1$, the reference evapotranspiration), 0.8 ET0 ($I_2$), and surface irrigation ($I_3$, the farmers' method), which served as the control. After harvest of the sunflower crop, each main plot was divided into three subplots, one for each of the winter crops, namely chickpea, which was irrigated at 0.6 ET0; wheat, at 0.9 ET0; and groundnut at 0.8 ET0.

Fertilizers were applied in the recommended doses (per hectare): sunflower (90 kg of N, 90 kg of $P_2O_5$ and 60 kg of

$K_2O$), chickpea (25 kg of N and 50 kg of $P_2O_5$), wheat (100 kg of N, 75 kg of $P_2O_5$, and 50 kg of $K_2O$), and groundnut (18 kg of N and 46 kg of $P_2O_5$ and 25 kg of $K_2O$). Plant population was maintained at 100 per cent during both the years.

Each year, maize was irrigated 18 times and the winter crops were irrigated 12 times (Table 3). The total volume of water amounted (at 1.0 ETo) to 790 mm for the sunflower–chickpea system, 948 mm for the sunflower–wheat system, and 996 mm for the sunflower – groundnut system. The corresponding amounts supplied through the surface method were 875 mm, 1105 mm, and 1164 mm (pooled data). In both the yeas, the effective rainfall was 194, 92.7 mm received during *kharif* 2015 and 2016, and there was no rainfall during *rabi* seasons of both the years. Therefore, most of the rainfall received during the crop growth period was ineffective, and the crops were sustained by irrigation.

The amount of irrigation water applied through drip irrigation was calculated as follows:

$$Wa = \frac{\text{IETo}}{\text{Ea}} + \text{LR}$$

where I is the empirical irrigation level (1.0 ET0 and 0.8 ET0, respectively, for the treatments $I_1$ and $I_2$); Ea is irrigation efficiency of the system determined at the beginning of the season as 0.8; and LR is the quantity required to compensate for water lost through leaching (assumed to 10% in each round of irrigation).

The reference crop evapotranspiration (ET0) was calculated as follows:

$$\text{ET0} = \text{Ep. Kp}$$

Where EP is the cumulative evaporation to be taken into account for choosing the irrigation interval and Kp is the evaporation pan coefficient (taken as 0.75 for the experimental site). Evaporation was measured daily from the standard Class A pan evaporation tank placed close to the experimental field. The duration of irrigation was calculated as follows:

$$\text{t} = \frac{\text{Wa A}}{\text{q}}$$

Where t is the duration of irrigation in hours; Wa is the depth of applied irrigation water in millimetres; A is the area, in square metres, wetted by emitters; and q is the rate of discharge of water from each emitter (in litres per hour).

Water productivity was determined to evaluate the benefit derived from irrigation and can be defined as the amount of grain yield a cubic metre of water may produce; the values of WP (kg $m^{-3}$) were determined by dividing the grain yield (kg $ha^{-1}$) by the total amount of irrigation water ($m^3$ $ha^{-1}$) (Table 2).

**Table 2:** Total quantity of irrigation applied through drip and surface irrigation

| **Treatments** | | **Number of irrigations** | **Total amount of water (mm) (Rainfall+ Irrigation)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Sunflower-chickpea @ 0.6 ETo** | | | **Sunflower-wheat @ 0.9 ETo** | | | **Sunflower-groundnut @ 0.8 ETo** | | |
| | | | **Sunflower** | **Chickpea** | **Total** | **Sunflower** | **Wheat** | **Total** | **Sunflower** | **Groundnut** | **Total** |
| Sunflower @ 1.0 ETo | 2015 | 18 + 12 | 459 | 286 | 745 | 459 | 426 | 887 | 459 | 529 | 987 |
| | 2016 | 18 + 12 | 468 | 368 | 836 | 468 | 541 | 1009 | 468 | 537 | 1005 |
| | Pooled | 18 + 12 | 464 | 327 | 790 | 464 | 484 | 948 | 464 | 533 | 996 |
| Sunflower @ 0.8 ETo | 2015 | 18 + 12 | 409 | 286 | 689 | 409 | 428 | 837 | 409 | 528 | 937 |
| | 2016 | 18 + 12 | 403 | 368 | 771 | 403 | 541 | 944 | 403 | 537 | 940 |
| | Pooled | 18 + 12 | 406 | 327 | 730 | 406 | 485 | 890 | 406 | 532 | 938 |
| Sunflower (Surface irrigation) | 2015 | 5+5 | 690 | 300 | 900 | 690 | 480 | 1170 | 690 | 540 | 1230 |
| | 2016 | 5+5 | 499 | 360 | 850 | 499 | 540 | 1039 | 499 | 600 | 1099 |
| | Pooled | 5+5 | 595 | 330 | 875 | 595 | 510 | 1105 | 595 | 570 | 1164 |

**Table 3:** Yield of sunflower and *Rabi* crops grown in Drip method of irrigation in sunflower-based cropping system in MCA

| **Treatments (Horizontal Strip)** | **Yield (kg $ha^{-1}$)** | | | | | | | **Water use efficiency (kg $ha^{-1}$ $mm^{-1}$)** | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Sunflower** | | | **Rabi crops (Vertical strip)** | | | | **Sunflower** | | | **Rabi crops** | | | |
| | **2015** | **2016** | **Pooled** | **Crop** | **2015-16** | **2016-17** | **Pooled** | **2015** | **2016** | **Pooled** | **Crop** | **2015-16** | **2016-17** | **Pooled** |
| Sunflower @ 1.0 ETo | 2386 | 2478 | 2432 | Chickpea | 2478 | 2409 | 2443 | $5.20^{ab}$ | $5.29^{a}$ | $5.24^{ab}$ | Chickpea | 8.60 | 6.51 | 7.40 |
| | | | | Wheat | 2004 | 4551 | 3278 | | | | Wheat | 4.71 | 6.41 | 6.67 |
| | | | | Groundnut | 2547 | 2807 | 2677 | | | | Groundnut | 4.81 | 5.23 | 6.02 |
| Sunflower @ 0.8 ETo | 2217 | 2126 | 2172 | Chickpea | 2210 | 2205 | 2208 | $5.42^{a}$ | $5.28^{a}$ | $5.35^{a}$ | Chickpea | 7.73 | 5.94 | 6.75 |
| | | | | Wheat | 1854 | 4158 | 3006 | | | | Wheat | 4.33 | 7.69 | 6.20 |
| | | | | Groundnut | 2331 | 2329 | 2330 | | | | Groundnut | 4.41 | 4.34 | 4.38 |
| Sunflower (Surface irrigation) | 18.16 | 18.79 | 18.47 | Chickpea | 1998 | 1833 | 1915 | $2.63^{c}$ | $3.77^{b}$ | $3.10^{c}$ | Chickpea | 6.66 | 5.09 | 5.80 |
| | | | | Wheat | 1621 | 3674 | 2647 | | | | Wheat | 3.38 | 6.80 | 5.19 |
| | | | | Groundnut | 1922 | 1873 | 1936 | | | | Groundnut | 3.56 | 3.12 | 3.40 |
| S.Em (±) | 49 | 79 | 46 | S. Em (±) | 59 | 129 | 101 | T test | T test | T test | S. Em (±) | 0.23 | 0.40 | 0.48 |
| CD (P = 0.05) | 152 | 222 | 147 | CD (P = 0.05) | 182 | 389 | 310 | S | S | S | CD (P = 0.05) | 0.68 | 1.17 | 2.47 |

## 2.4 Statistical analysis of data

The data were subjected to analysis of variance, and mean values from the different treatments were compared using the test of least significant difference at 0.05 probability level (Gomez and Gomez 1984) [4].

## 3. Results and discussion

### 3.1 Seed yield of sunflower

Sunflower seed yield (Table 3) in 1.0 ET0 was significantly higher (2432 kg $ha^{-1}$) than that in 0.8 ET0 (2172 kg $ha^{-1}$) and the control (1847 kg $ha^{-1}$). Pooled data for the two years show that compared to the yield in the farmers' method, or the control, the yield in 1.0 ET0 was greater by 31.3 per cent and that from 0.8 ET0 was greater by 17.59 per cent. The same pattern was seen in the winter crops, the corresponding higher yields being 21.43 per cent greater in chickpea, 18.5 per cent in wheat, and 37.10 per cent in ground. The higher yields were due to easy access to moisture and nutrients enabled by the more controlled irrigation, which supplied the required quantity at frequent intervals to match the actual water needs of the crops at various stages. Although drip irrigation wetted only a small zone of the soil around the plant, the method ensured that soil moisture was always maintained close to field capacity. This continued supply also rendered ineffective most of the rainfall received during the crop growth period.

### 3.2 Water use efficiency

Water use efficiency was significantly higher with drip irrigation in both seasons. In sunflower, WUE recorded in 0.8 ET0 (5.3 kg $ha^{-1}$ $mm^{-1}$) was higher than that in the control (3.1 kg $ha^{-1}$ $mm^{-1}$). The same pattern was repeated in the winter crops. Higher WUE was recorded with sunflower (0.8 ETo)-chickpea (0.6 ETo) cropping sequence. The higher WUE was mainly due to the considerable saving of irrigation water, greater yields, and higher nutrient-use efficiency (Ramah 2008). Increase in irrigation volume not only failed to elicit any corresponding increase in the marketable yield of crops but also lowered the production efficiency of irrigation significantly. Ardell (2006) [3] reported that application of nitrogen and phosphorus usually results in higher yields, thereby increasing the crop WUE. Adequate levels of essential plant nutrients are needed for higher yields and higher WUE.

### 3.3 Sunflower seed equivalent yield and economic parameters

Overall, drip irrigation at 1.0 ET0 resulted in significantly higher Sunflower seed equivalent yield (5,069 kg $ha^{-1}$) compared to that of 4,838 $ha^{-1}$ at 0.8 ET0 and of 4,364 kg $ha^{-1}$ in the control (Table 4). The same pattern was seen among the three winter crops that followed sunflower. However, the result of the interaction between the level of irrigation and the crop showed that the highest equivalent yield (5,954 kg $ha^{-1}$) was obtained from sunflower with drip irrigation at 1.0 ET0 followed by groundnut at 0.8 ET0—this is the combination recommended for the region if water supply is limited. However, all the three winter crops are grown in the Malaprabha command area, and farmers can make their choice going by market demand and the availability of seeds and other resources, so long as they switch to drip irrigation.

The economics of drip fertigation in maize-based cropping systems are presented in Table 4. Although the initial capital investment is high for a drip fertigation system, the benefits outweigh the costs given the long life of the system. Secondly, although the cost of cultivation was generally higher with drip irrigation, so were the net returns per hectare from sunflower at 1.0 ET0 followed by groundnut at 0.8 ET0 and 14.5 per cent savings in the volume of water.

Drip irrigation is the need of the hour especially in areas with water deficit and can overcome the constraints posed by an uncertain monsoon and irregular release of water from dams. By storing water *in situ* in farm ponds and by supplying it through the drip system, farmers can grow two or three crops in a year. The drip system should not be viewed merely from the economic point of view. Given the shrinking availability of land for cultivation and the diversion of available water to non-agricultural uses, it is of paramount importance that water made available for agriculture be used as efficiently as possible by adopting such techniques as drip irrigation. In areas of acute scarcity of water, drip irrigation is the only way to enhance crop productivity.

**Table 4:** Yield, water use, and economics of sunflower in rainy season followed by chickpea, wheat and groundnut in winter (pooled)

| Treatment (ETo is reference evapotranspiration) | Sunflower seed equivalent yield (q $ha^{-1}$) | Total water use (mm) | Water saving (%) | Net returns (Rs $ha^{-1}$) | Benefit to cost ratio | Superiority over existing farmers' method |
|---|---|---|---|---|---|---|
| **Horizontal strip: maize grown in *Kharif* with different irrigation levels** | | | | | | |
| Sunflower @ 1.0 ETo | 50.69 | 911 | 15.4 | 120293 | 3.1 | Rs 24,659 additional profit with 15.41% water saving over farmers' method |
| Sunflower @ 0.8 ETo | 48.38 | 852 | 20.8 | 112207 | 3.0 | Rs 16,573 additional profit with 20.81% water saving over farmers' method |
| Sunflower (Surface irrigation) | 43.64 | 1077 | - | 100778 | 2.7 | - |
| S. Em (±) | 1.3 | | | 2713 | 0.08 | |
| C.D. (P = 0.05) | 3.9 | | | 8149 | 0.31 | |
| **Vertical strip: *rabi* crops grown after maize with different irrigation levels** | | | | | | |
| Chickpea @ 0.6 ETo | 47.82 | 798 | - | 118608 | 3.4 | Rs 28,911 profit over sunflower–wheat system |
| Wheat @ 0.9 ETo | 40.27 | 981 | - | 89697 | 2.8 | |
| Groundnut @ 0.8 ETo | 54.62 | 1032 | - | 124974 | 2.7 | Rs 30,134 profit over sunflower–wheat system |
| S. Em (±) | 1.6 | | | 2139 | 0.10 | |
| C.D. (P = 0.05) | 4.9 | | | 6419 | 0.34 | |
| **Interactions effect of *kharif* followed by *rabi* crops (H x V)** | | | | | | |
| Sunflower @ 1.0 ETo *fb* Chickpea @ 0.6 ETo | 50.62 | 790 | 9.7 | 128396 | 3.63 | Sunflower @ 1.0 ETo *fb* Groundnut @ 0.8 ETo recorded Rs. 31,113 additional net returns over sunflower–chickpea system and Rs 55,819 profit over sunflower –wheat farmers' method under drip with 14.4% – 9.7% saving of water |
| Sunflower @ 1.0 ETo *fb* Wheat @ 0.9 ETo | 41.90 | 948 | 14.2 | 95409 | 2.86 | |
| Sunflower @ 1.0 ETo *fb* Groundnut @ 0.8 ETo | 59.54 | 996 | 14.4 | 137075 | 2.92 | |
| Sunflower @ 0.8 ETo *fb* Chickpea @ 0.6 ETo | 48.64 | 730 | 16.5 | 121485 | 3.49 | Sunflower @ 0.8 ETo *fb* Groundnut @ 0.8 ETo recorded Rs. 16,770 additional net returns over sunflower–chickpea system and Rs 41,456 profit over sunflower –wheat farmers' method |
| Sunflower @ 0.8 ETo *fb* Wheat @ 0.9 ETo | 41.05 | 890 | 19.4 | 92426 | 2.80 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Sunflower @ 0.8 ETo *fb* Groundnut @ 0.8 ETo | 55.44 | 938 | 19.4 | 122712 | 2.72 | under drip with 19.4% – 16.5% saving of water |
| Sunflower *fb* Chickpea (Surface irrigation) | 44.20 | 875 | - | 105942 | 3.17 | |
| Sunflower *fb* Wheat (Surface irrigation) | 37.86 | 1105 | - | 81256 | 2.59 | |
| Sunflower *fb* Groundnut (Surface irrigation) | 48.87 | 1164 | - | 115137 | 2.40 | |
| S.Em (±) | 2.1 | | | 2103 | 0.04 | |
| C.D. (P = 0.05) | 6.5 | | | 6859 | 0.13 | |

## 4. Conclusion
Switching from surface irrigation to drip irrigation increased the income from growing sunflower in the rainy season and groundnut in winter by 37369 rupees per hectare; increased the amount of water saved by 14.5%; and earned a net profit of 137075 rupees per hectare. Growing either chickpea or wheat in winter also led to higher profits and greater savings of water. As all these crop combinations are common in the command area, the crop to follow sunflower can be chosen going by the market price to maximize profits.

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