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Response of lateral placement depths of subsurface drip irrigation on okra (*Abelmoschus esculentus*)

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Abstract

Subsurface drip irrigation is defined as application of water below the soil surface through emitters, with discharge rates generally in the same range as surface drip irrigation. It has many advantages over surface drip. To see the response of subsurface drip irrigation on okra yield, a study was conducted at Indian Agricultural Research Institute, New Delhi, India during 2003 and 2004. Okra (*Abelmoschus esculentus*) crop was cultivated in three sub-plots with four treatments of drip lateral depths *viz*. on the surface, and at depths of 0.05, 0.10 and 0.15 m below the soil surface. Laterals used for three sub-plots were inline drip laterals having discharge rate of 2.03×10^{-6}, 1.53×10^{-6} and 1.22×10^{-6} $m^3 s^{-1}$ per meter length. Crop was irrigated as per irrigation schedule to fulfill its water requirement. The observations were recorded on growth parameter, soil moisture content and yield of crop. The study indicated that soil moisture content under subsurface drip irrigation was more uniform as compared with surface drip. It was found that plant height, yield and water use efficiency of okra increased due to subsurface placement of laterals. The maximum increased okra yield was found to be 5.22, 13.48 and 11.56 % under 0.05, 0.10 and 0.15 m depths of lateral placement, respectively, as compared to that under surface drip. On the basis of the study, it was recommended that laterals of subsurface drip irrigation should be placed between 0.10 to 0.15 m depths below soil surface for higher okra yield.

Keywords: Subsurface drip irrigation; Placement depths of laterals; Soil moisture content; Okra yield; Water use efficiency.

Introduction

The National Water Policy of India stresses that water is a prime natural resource, a basic human need and a precious natural asset. It is vital for realizing full potential of agricultural sector in order to get food self-sufficiency and security. The demand for water is increasing both in agriculture and in particular in municipal sector at significant rates. Indian agriculture in future has to produce ever-increasing quantities of food, fiber and fuel for increasing population of the country with decreasing quantities of water available for irrigation. Therefore, optimum and efficient utilization of water in agriculture for irrigation assumes great significance. Several methods of irrigation from traditional surface flooding to modern drip irrigation systems have been evolved. The traditional surface irrigation methods pose numerous problems of soil, water and environmental degradation. These methods are supply driven rather than crop demand driven, which cause mismatch between the need of crop and the quantity supplied. A large part of irrigated agriculture employee surface application methods, which results in low water application efficiency. In contrast drip irrigation may achieve higher field level application efficiency of 80-90%, as surface runoff and deep percolation losses are minimized (Heerman et al., 1990 and Postel, 2000). Thus drip irrigation may help in producing more crop per unit applied water, and allow crop cultivation in an area where available water is insufficient to irrigate through surface irrigation methods.

Subsurface Drip Irrigation

The drip irrigation system with lateral lines laid on soil surface is the most popular application method in India. The drip irrigation can be made more applicable for irrigating a wide range of agronomic, horticultural and fruit crops by installing the laterals below the soil surface, *i.e.* subsurface placement of the laterals called subsurface drip irrigation (SDI) system. SDI offers many advantages over surface drip irrigation such as; reduced evaporation loss and precise placement and management of water, nutrient and pesticides leading to more efficient water use, greater water application uniformity, enhanced plant growth, crop yield and quality (Camp, 1998).

SDI is defined as application of water below the soil surface through the emitters, with discharge rates generally in the same range as surface drip irrigation (ASAE Std. 1999). The other advantages of SDI include less interference with cultural operations and improved cultural practices; allows field operations even during irrigation; less nutrient & chemical leaching and deep percolation; reduced weed germination and their growth; reduced pest and diseases; damage due to drier and less humid crop canopies; warmer soils; reduced exposure of irrigation equipment to damage; no soil crusting due to irrigation; well suited to widely spaced crops; and advantages of freedom from necessity of anchoring laterals at the beginning and removing it at the end of the season, and thus longer economic life (Phene, 2000).

Findings and Gap

The SDI system has been used for irrigating many crops including vegetables, horticultural and agronomic crops under different soil and climatic conditions (Camp, 1998). Many research workers have reported that, crops responded positively to SDI system under different depths of laterals placement. It has been compared with other methods of irrigation; and it was found that crop yields increased considerably under SDI (Oron et al., 1999). In India, okra (*Abelmoschus esculentus*) is one of the important vegetable crops. An okra yield of 7 to 12 Mg ha^{-1} is considered good but it has been reported to have high potential yield of 30-40 Mg ha^{-1} (Duzyaman, 1997). Response of SDI on okra was studied to achieve its potential yields in India.

Materials and Methods

The investigations were carried out at research farm of Water Technology Center, Indian Agricultural Research Institute, New Delhi. The soil is sandy loam with mean basic infiltration rate as 8.14×10^{-6} ms^{-1}. Average bulk density and saturated hydraulic conductivity of soil were found to be 1.53 Mg m^{-3} and 3.08×10^{-6} ms^{-1}, respectively.

Details of SDI System

The headwork of SDI system used for conducting field experiments consisted of a pump to develop required pressure in system and to lift and deliver water from tank to main pipeline, from main to sub- mains, and to laterals and emitters. The 100-micron recommended screen filter was used for filtering water delivered to system. One by- pass, control valve, and pressure gauge were also provided after the pump to adjust flow and monitor system pressure. The main line delivered water to three sub-mains each fitted with a valve and a pressure gauge. Each sub- main served one sub-plot of size 12 m × 19.2 m. Main and sub- main lines were buried at a depth of 0.45 m from soil surface. Laterals were connected with sub mains. Laterals with diameter 0.016 m having inbuilt emitters of 0.61×10^{-6} $m^3 s^{-1}$ discharge rate spaced at 0.30 m, 0.40 m and 0.50 m on laterals were used in the study.

The different emitters spacing (0.30, 0.40 and 0.50 m) on lateral resulted into discharge rates of 2.03×10^{-6}, 1.53×10^{-6} and 1.22×10^{-6} $m^3 s^{-1}$ per meter length of lateral used in sub-plot I, II and III, respectively (Table 1). The layout of experimental setup is presented in Figure 1. The irrigation system was operated daily as per schedule developed for applying water as per crop water requirement of okra. Water applied to crop was 0.69 m and 0.54 m during 2003 and 2004, respectively (Singh, 2004).

Table 1. Discharge rate of SDI laterals in different sub- plots.

Sub- plot	Discharge rate (10^{-6} $m^3 s^{-1}$ per meter lateral length)
I	2.03
II	1.53
III	1.22

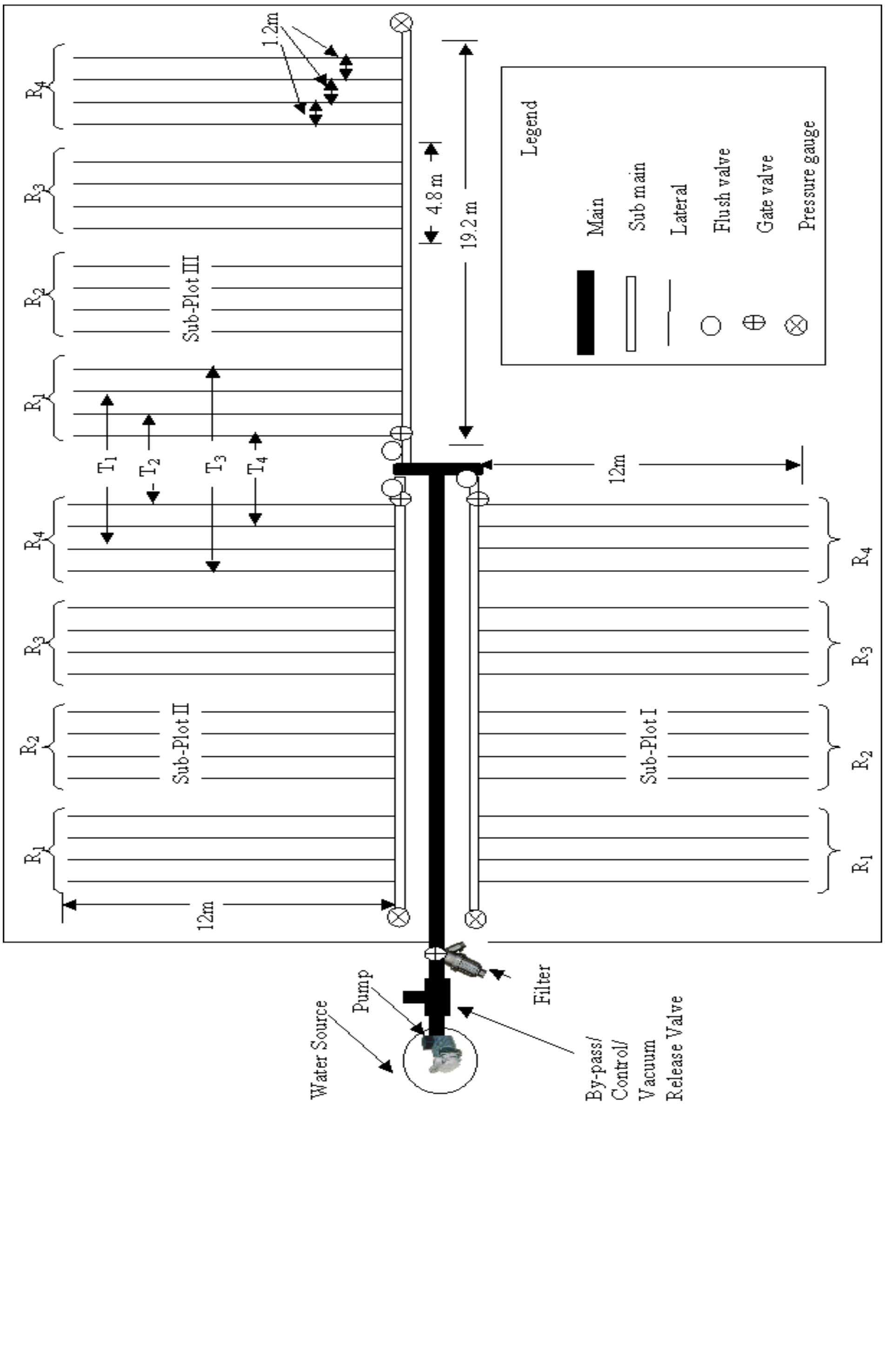


Figure 1: Layout of Experiment with Subsurface drip irrigation System

Description of Experiment

The treatment of experiment, imposed in each sub- plot was depth of placement of laterals. Laterals each of 12 m length were placed at depths of 0 m (on the soil surface) 0.05, 0.10 and 0.15 m below the soil surface which are represented as treatments T_1, T_2, T_3 and T_4, respectively, in each sub-plot. Treatments were replicated four times from R_1 to R_4 randomly in each of three sub-plots. Okra seeds were sown at 0.30 m × 0.30 m row- to- row and plant-to-plant spacing. One row of okra was kept above lateral and two rows on either sides of lateral (0.30 m away from lateral). Thus, three rows of okra crop were irrigated with each lateral. Lateral depths and rows of okra crop have been illustrated in Figure 2.

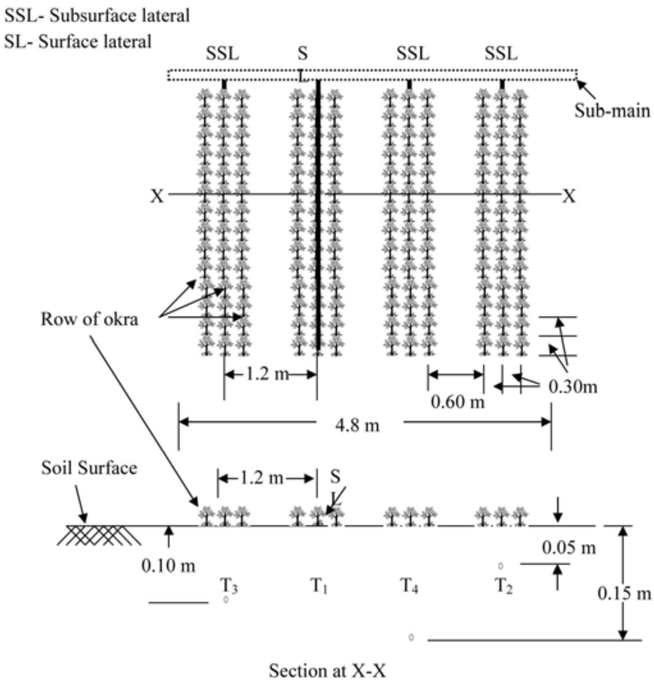


Figure 2: Replication R_2 of Sub- plot I and section at X-X to depict depth of laterals.

Response of SDI on okra

Growth, yield and water use efficiency of crop; and moisture content of experimental plots were recorded during experimentations. Tender pods of okra are its edible part. These were ready for picking after one week of flowering. Once picking started, pods were picked after an interval of every three days. In each picking pod-weight for each treatment and replication was recorded. Sum of pod-weights recorded in all pickings gave total crop production. The yield of okra was obtained for different treatments of placement depths of laterals under each discharge rate during years 2003 and 2004. One-way analysis of variance (ANOVA) was performed to analyze effect of treatments on crop yield. Okra yield under SDI was compared with that under surface drip irrigation using t- test.

Results and Discussion

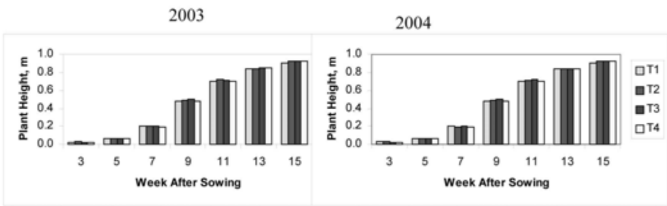
Growth of okra plant

The plant growth of okra at different weeks after sowing (WAS) has been illustrated in Figure 3. It may be observed that up to 5 WAS all treatments had equal plant height. It seems that during early growth period of okra there was not much effect of SDI. After 5-7 WAS some difference in plant heights were found. The plant growth observed under SDI was higher than that with surface placed laterals. It indicated that after 7 WAS effect of SDI was visible on plant growth. The difference in plant height continued throughout the remaining growing period of okra. The maximum okra plant height attained in different sub- plots and depths of lateral is presented in Table 2. Plant heights in all sub –plots is higher with SDI as compared with surface placed laterals (using *t*-test). However, plant height with SDI lateral placed at 0.10 m depth below soil surface was significantly highest in all sub-plots during two years of study.

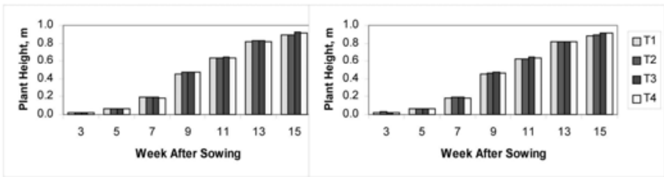
Table 2. Plant height (m) of okra under different placement depths of laterals.

Year	Sub -plots	Placement depth of laterals, m			
		0	0.05	0.10	0.15
2003	I	0.90	0.93*	0.93*	0.93*
	II	0.89	0.90	0.92*	0.91*
	III	0.88	0.88	0.90*	0.88
2004	I	0.90	0.92*	0.93*	0.93*
	II	0.88	0.89	0.92*	0.91*
	III	0.87	0.88*	0.89*	0.88*

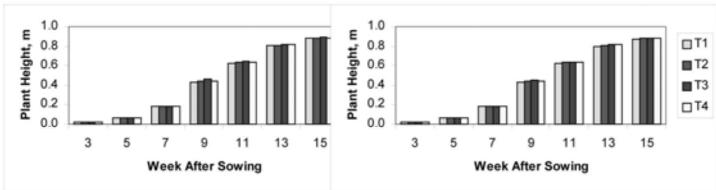
* Significantly different at $t_{0.05, 6} = 2.44$



Sub- Plot I



Sub-Plot II



Sub-Plot III

Figure 3. Okra plant growth at different WAS during 2003 and 2004 in three sub-plots.

Soil moisture in experimental plots

The moisture content of soil in experimental plots at different depths and distance from laterals were recorded. Figure 4 illustrates soil moisture content under different depths of lateral measured at 0.45 m away along lateral at different soil depths in Sub-plot I. It may be observed that variation of moisture content along depth with SDI is less i.e. more uniform as compared to that with surface drip. Similar trend was observed for all discharge rates of laterals in all sub- plots. The variation in soil moisture content was least with 0.10 m placement depth of lateral (Figure 4). Soil moisture measured at 0.45 m away from the lateral placed at 0.10 m depth with different discharge rates of lateral in all sub-plots is presented in Figure 5. It may be observed that soil moisture distribution with increasing lateral discharge was found more uniform. Similar trends were observed for other depths of lateral placement.

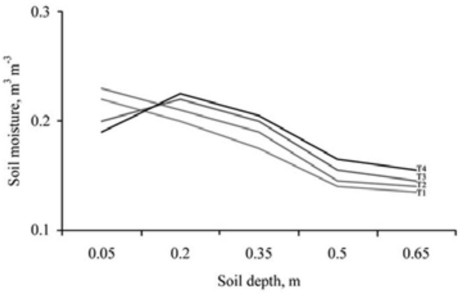


Figure 4. Soil moisture along under different placement depths of lateral in Sub- plot I.
T1: Lateral on soil surface;T2, T3 and T4: Lateral depth 0.05, 0.15 and 0.15 m below soil surface, respectively

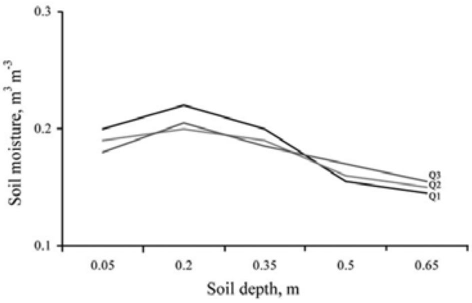


Figure 5. Soil moisture under different Sub- plots (lateral discharge) with 0.10m placement depth of lateral.
Q1, Q2 and Q3: Lateral discharge in Sub-plots I, II and III, respectively

Yield of okra

The okra yield recorded during two years of study is presented in Table 3. It may be observed from the table that yields of okra increased due to subsurface placement of laterals. ANOVA indicated significant effect of placement depths of laterals on yield.

Table 3. Yield (Mg ha^{-1}) of okra under different placement depths of laterals.

Year	Sub -plots	Placement depth of laterals, m			
		0	0.05	0.10	0.15
2003	I	30.67	31.24	33.30*	32.92*
	II	29.12	30.37	32.63*	31.28
	III	28.00	29.36	30.33*	28.08
2004	I	28.19	29.41	31.99*	31.45*
	II	26.71	27.34	29.70*	28.84*
	III	25.84	27.19	28.27*	27.84*

* Significantly different at $t_{0.05, 6} = 2.44$

Effect of lateral placement depth

The t-test indicated that yield under 0.10 m laterals placement depth of SDI during both years of experimentation was significantly higher than that under surface drip. It may also be observed that maximum yield was obtained with 0.10 m placement depth of SDI lateral. The yield under 0.15 m placement depths of SDI laterals was found higher than that under 0.05 m lateral depth, but slightly lower than 0.10 m placement depth of SDI laterals. Similar trends in mean yields were also obtained during both the years of experimentation.

Realization of higher yield under SDI as compared to surface drip irrigation is in confirmation with Rubieiz et al. (1989); (1991) and Camp (1998) who found that yields of vegetables and field crops under SDI were equal to or greater than those for other methods of irrigation. The higher yield under SDI may be due to better water utilization by crops and uniform moisture distribution in root zone, also, revealed in Figure 4.

The increase in okra yield under SDI is presented in Figure 6. Maximum increase in yield was 5.22, 13.48 and 11.56% under 0.05, 0.10 and 0.15 m placement depths of laterals, respectively as compared to yield under surface drip. Therefore, for higher okra yield under this soil, placement depth of laterals may be kept in between 0.10 and 0.15 m below soil surface.

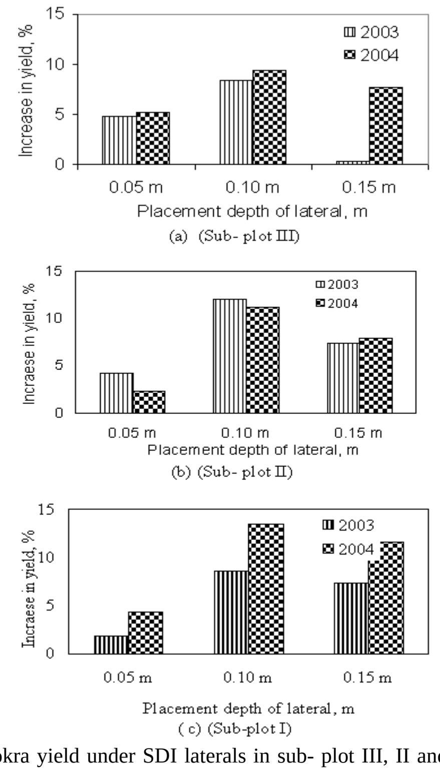


Figure 6. Increase in okra yield under SDI laterals in sub- plot III, II and I, respectively as compared to surface drip.

Effect of discharge rate of SDI laterals

It may be observed from Table 3 that discharge rates of laterals have effect on yield of okra. The mean yield of okra increased with increasing discharge rate of laterals from sub-plot I to sub-plot III (also, Table 1). The percentage increases in yield due to increase in discharge rate over 1.22×10^{-6} m^3 s^{-1} discharge rate per meter length of lateral is presented in Figure 7. For the same depths of placement of laterals, okra yield increased from 3.44 to 11.14% and 6.40 to 17.26 % under 1.53×10^{-6} m^3 s^{-1} and 2.03×10^{-6} m^3 s^{-1} over 1.22×10^{-6} m^3 s^{-1} discharge rate per meter length lateral, respectively during 2003. The similar trend of increase in yield with increased discharge rate of the lateral was also observed during 2004.

The higher discharge rate of laterals represents closer emitters spacing on lateral, which resulted more uniform application of water along the lateral (also, indicated by Figure 5 and Singh et al., 2006). Though amount of water applied in all cases was same but wider and uniform spread of soil moisture under high discharge laterals ensured adequate water supplies even to crop rows farthest from lateral. This resulted in higher okra yield under laterals of higher discharge rates.

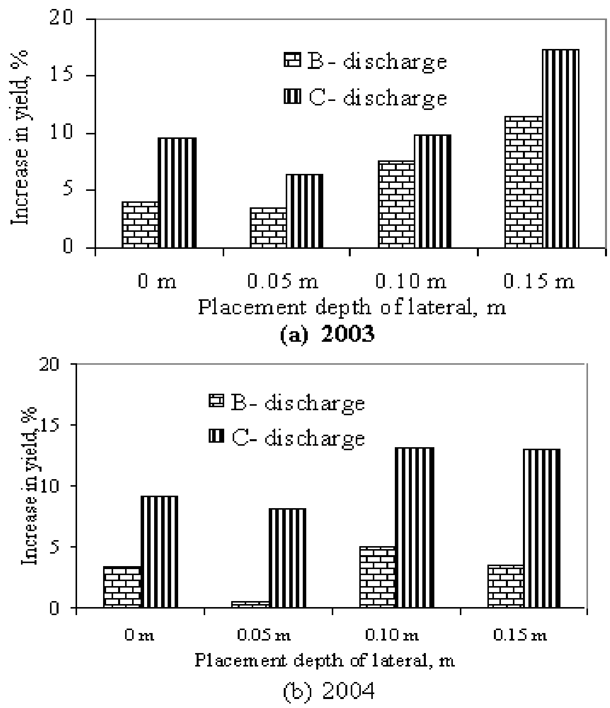


Figure 7. Increase in okra yield under per meter length lateral discharge rates of 'B' (in sub-plot II) and 'C' (in sub-plot I) as compared to 1.22×10^{-6} m^3s^{-1} discharge (in sub-plot III) during (a) 2003 and (b) 2004.

Water use efficiency

The water use efficiency of okra was calculated using mean yield and mean depths of water used during both the years of study (Table 4). It may be observed that water use efficiency was higher with SDI. The maximum water use efficiency was found with SDI of 0.10 m placement depth of lateral. The behavior of water use efficiency with placement depth of laterals for any discharge of laterals followed same trend as the yield of okra. The reason is that amount of water applied was same for all the treatments, only yield changed. That is why water use efficiency followed similar trend as yield of okra. The table indicates that water use efficiency increases with increase in lateral discharge rates (from sub-plot III to sub-plot I) for all the placement depths of laterals (Table 1).

Table 4. Water use efficiency of okra under different placement depths of laterals.

Placement depth of laterals, m	Water use efficiency (Mg $ha^{-1}m^{-1}$) in different sub-plots during different years					
	III		II		I	
	2003	2004	2003	2004	2003	2004
0	40.20	47.50	41.80	49.10	44.10	51.80
0.05	42.10	49.90	43.60	50.20	44.90	54.10
0.10	43.60	51.90	46.90	54.60	47.80	58.80
0.15	40.30	51.20	44.90	53.00	47.30	57.80

Conclusions

On the basis of present study it can be concluded that response of SDI on okra is positive with respect to its growth and yield and water use efficiency. Lateral placement depths and discharge rate of SDI system affected plant height and yield of okra. Maximum growth of plant height was observed under SDI with lateral placed at 0.10 m below soil surface. The yield increased significantly due to placement of laterals at 0.10 and 0.15 m depth below soil surface. The maximum increase in yield as compared to surface drip was 13.48% under SDI with 0.10 m placement depth of lateral below ground surface. With higher discharge rate (2.03×10^{-6} m^3 s^{-1} per meter length) of SDI yield was found 17% more as compared to yield with 1.22×10^{-6} m^3 s^{-1} per meter length discharge rate. Therefore, for higher okra yield under SDI system placement depth of lateral should be kept in between 0.10 to 0.15 m below the soil surface.

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