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Response of spring season grown okra (*Abelmoschus esculentus*) to drip irrigation and fertigation

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Abstract

A field experiment was conducted during 2015 and 2016 on loamy sand soil to study the effect of drip irrigation and fertigation as compared to surface furrow irrigation on the fruit yield, water use efficiency of Okra (*Abelsmoschus esculentus* var Punjab 8).The treatments comprised of three levels of drip irrigation in combination with three levels of fertigation and surface furrow irrigation was considered as control treatment. The results showed that best drip fertgation treatment I_3F_2 (2015) and I_2F_3 (2016) recorded 27.0 and 24.3 per cent higher fruit yield as compared to conventional furrow irrigated crop. The averaged values of water use efficiency was enhanced from 26.1 kg $ha^{-1}mm^{-1}$ under control plot to 42.2 kg $ha^{-1}mm^{-1}$ under I_3 and 52.8 kg $ha^{-1}mm^{-1}$ under I_2 irrigation treatment.The maximum water use efficiency of 60.4 kg $ha^{-1}mm^{-1}$was obtained under I_1 (0.6 ETc) which gave same fruit yield as under conventional furrow irrigated crop and saved irrigation water to the extent of 55.4 percent as compared to control plot. The net returns obtained under drip fertigation were higher to the extent of 25.6 per cent as compared to furrow irrigated control plot.

Key words: Drip irrigation, Fertigation, Okra, Water use efficiency, Yield

Introduction

Okra (*Abelmoschus esculentus* L.) commonly known as '*Bhindi*' is one of the important fruit vegetables grown during spring and summer/rainy season in India. India is the global leader in the okra production of 5,74,000 tonnes of fresh fruit weight from an area of 4,98,000 ha with average productivity of 11.6 t/ha (Anonymous 2018). Okra has a prominent position among vegetable fruits due to its high nutritive and medicinal value, wider adaptability to varying weather conditions, year-round cultivation, high yield, resistance to various diseases and pests and export potential (Reddy et al. 2012; Meena et al. 2017). Okra fruit is generally picked at a tender stage of maturity and yield of okra is directly correlated with the length and thickness of fruits at time of harvest. These fruits are rich in vitamins and minerals.The nutritional composition of fresh okra comprises of 7.4 g carbohydrates, 1.48g sugars, 3.2 g fiber, 0.2 g fat, 2.0 g protein, 90.2g water, 36 µg Vitamin A, 0.2 mg Thiamine (B_1), 0.06 mg Riboflavin (B_2), 1 mg Niacin (B_3), 23 mgVitamin C, 31.3 µg Vitamin K, 8.2 mg Calcium,0.62 mg iron,57 mg Mg,299 mg potassium and 0.58 mg Zn per 100 g of edible portion of fruit. The energy value is 33 Kcal/100 g fresh weights of the fruit (Kumar et al. 2013). In Punjab okra was grown on an area of 5,010 ha with production of 52,360 tonnes with average fruit yield of 10.44 t/ha during 2019 (Anonymous 2019). Okra contains special fiber which takes sugar levels in blood under control, providing sugar quantity acceptable for bowls. Mucilage found in the okra is responsible for washing away toxic substances and bad cholesterol which loads the liver (Kumar et al. 2013). Water and fertilizers are two most important inputs essential for crop production. However, during the last 2-3 decades due continuous growing of paddy-wheat crops, the water table is falling in many blocks of the Punjab state. During the last decade, the average decline of water table was 45-50 cm per year in the central districts of Punjab (Minhas et al. 2010). In the present-day context improvement in irrigation practices are needed to increase water use efficiency, while maintaining crop yields with sustainable productivity levels. Furrow irrigation is conventional method widely used to irrigate most vegetable crops. Many researchers have reported higher application efficiency of drip irrigation over conventional irrigation methods. In study conducted at Anand, Gujrat, Patel et al. (2009) reported 46.3 percent higher yield of okra with water saving of 18 percent under drip irrigation as compared to conventional furrow irrigation. Nair et al. (2017) also reported that drip fertigated (100% water soluble fertilizers) crop of okra

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recorded 46.0 percent higher fruit yield as compared to drip irrigated crop with basal application of fertilizers. Keeping these points in view an experiment was planned to study the effect of drip irrigation and fertigation on the fruit yield of okra.

Materials and Methods

A field experiment was carried out at the research farm of Department of Soil and Water Engineering, Punjab Agricultural University, Ludhiana, during Spring/summer season of 2015 and 2016. The region is characterized by a sub tropical and semi arid climate. Average annual rainfall is approximately 700 mm of which about 70% is received during monsoon. The soil of experimental field was sandy loam with pH 8.0, low in available nitrogen (272 kg/ha) and organic matter (0.40%) and high in available phosphorus (28.0 kg/ha) and medium in available potassium (258.0 kg/ha). The experiment was laid out in randomized block design with three replications with plot size of 27 m^2. There were total ten treatments including combination of three drip irrigation levels (0.6, 0.8- and 1.0-times crop evapotranspiration (ET_{crop}) i.e. I_1, I_2 and I_3 respectively) and three fertigation levels (60%, 80% and 100% of the recommended dose of N(90 Kg N/ha) i.e. F_1, F_2 and F_3 respectively). The tenth treatment was a control plot with furrow irrigation and manual application of fertilizer by broadcasting ½ at time of sowing as basal dose and ½ after first picking by top dressing, after irrigation was considered as conventional treatment (Control). P and K were not applied considering the soil inherent nutrient status and recommendations for the crop. A basal dose of well rotten F.Y.M @ 25 tonnes/ha was applied in all the plots. The drip system installed consisted 16 mm inline drip lateral with dripper discharge rate 2.2 lph, when operated at a pressure of 1.5 kg/cm^2. The drippers were spaced at 30 cm. Irrigation to different drip treatments was given on every 3rd day for the whole season. Drip irrigations frequency was adjusted if amount of effective rainfall received was equal to or more than Etc requirement of the crop during the interval. The time of irrigation was varied as per the calculation based on Etc values during crop season. The daily ETc values for the crop season were calculated using modified Penman method based upon daily meteorological data collected from the School of Climate Change and Agricultural Meteorology, Punjab Agricultural University, Ludhiana, located in radius of about 1.5 km from the experimental site. Fertigation was done at weekly interval throughout the crop season starting from two weeks after sowing of the crop and it was stopped 15 days before termination of crop season. The fertilizer N fertilizer was applied in the form of Urea by using venturi system. The recommended dose of nitrogen (N) 90.0 kg per ha was applied. The beds were prepared with tractor drawn be planter having bed top width 37.5 cm and 30 cm furrow. Paired row planting was used under drip irrigation treatments. The Punjab-8 variety of okra was sown on 18th March, 2015 and 6th March 2016 at inter row space of 30 cm on bed top and plant to plant spacing of 15 cm in bed furrow system under drip irrigation and in ridge furrow system for control treatment at spacing of 45× 10 cm. The observations on plant height were recorded from five tagged plants in each plot at periodic interval till the final harvesting. The leaf area index was recorded by Delta –T sun scan during noon hours between 12.00-14.00 hrs by first calibrating sensor with incoming radition above the canopy and subsequently it was placed below the canopy. After 20 minutes solar radiation coming at top of the canopy was again recorded before taking subsequent readings. The fruits were picked at tender stage when attained length of around 10-12 cm and two/three pickings were done per week depending on fruit load. Other management practices like weed and insect pest control were followed as per package of practices for Vegetables crops PAU. The crop was harvested in 26 pickings (30.04.2015 to 06.07.2015) and 22 pickings (03.05.2016 to15.07.2016). Data was analysed using ANOVA procedure in CPCS-I software.

Results and Discussion

Growth Parameters: Data on plant height recorded during 2015 revealed at 30 DAS except I_1F_1 treatment all other drip fertigation treatments recorded significantly higher plant height as compared to conventional furrow irrigated crop, but during the second-year differences were non-significant among the different treatments. At 60 DAS 2015 season I_1F_1 treatment recorded plant height statistically at par with control plot, but all other drip fertigation treatments recorded significantly higher plant height than control. However, during the second year all the drip fertigation treatments recorded significantly higher plant height as compared to control

Table 1: Weather conditions during okra crop growing season in 2015 & 2016

Month	Monthly rainfall (mm)			Maximum temperature (ºC)			Minimum temperature (ºC)		
	2015	2016	N*	2015	2016	N*	2015	2016	N*
March	85	41	26	26	28	27	13	15	11
April	29	03	18	33	37	34	20	20	17
May	17	25	22	40	40	39	24	25	22
June	18	86	66	38	40	39	26	29	26
July	125	130	217	34	34	34	27	27	26
Total	274	285							

Normal (N*) = Long term average

plots. During first year at 90 DAS, all the drip fertigation treatments recorded significantly higher plant height than control plot but during 2016 season I_1F_1, I_1F_2, I_1F_3 and I_2F_1 treatments were statistically at par with control plot and remaining treatments recorded significantly higher plant height than control (Table 2). The final plant height attained at maturity in all the drip fertigation treatments was significantly higher as compared to surface furrow irrigated control plot in both the years of study. Under drip fertigation treatments maximum plant height 99.2 and 90.0 cm was obtained under I_3F_3 and I_3F_2 treatments during 2015 and 2016 respectively. Further, it was found to be statistically at par with all other drip fertigation treatments during first year except I_1F_1, while during second year of study it was statistically at par with I_3F_3 and I_2F_3 only. Mintu *et al* 2018 also observed significant increase in plant height with drip fertigation as compared to furrow irrigated control.

Leaf area index: Leaf area index (LAI) recorded at 30 DAs was significantly influenced by different treatments. The drip fertigation treatments I_2F_2, I_2F_3 I_3F_1, I_3F_2 and I_3F_3 recorded significantly higher LAI as compared to control plot during both the years. However, during second year in addition to the above treatments I_1F_3 also recorded significantly higher LAI than control plots. At 60 DAS during the first year I_2F_2, I_2F_3, I_3F_1, I_3F_2 and I_3F_3 recorded significantly higher LAI than control while during second year the differences in LAI were found to be non-significant.

Yield attributes and fruit yield: The data presented in Table 3 on yield attributes and yield of Okra showed that fruit length varied from 10.2 to 11.8 cm during the crop seasons, however it was not significantly influenced by different drip fertigation treatments during both the years.The fruit width also did not vary significantly among different treatments. The values varied between 1.30 to 1.47 cm during the two growing seasons. Similarly, the individual fruit weight was not significantly influenced by different drip irrigation and fertigation treatments or the conventional furrow irrigation. This may be attributed to the reason that fruit weight is directly related to fruit length and fruit width which did not varied much due to picking at regular intervals. All the drip fertigation treatments except I_1F_1 during 2016 recorded significantly higher number of fruits per plant as compared to conventional furrow irrigated crop. Further, it was observed that drip fertigated crop gave first picking earlier by 10-12 days than the conventional furrow irrigated crop.

During the first year of the study, all the drip fertigated treatments except I_1F_1, I_1F_2, I_1F_3 and I_2F_1 recorded significantly higher fruit yield than the furrow irrigated

Table 2: Effect of different drip irrigation and fertigation levels on plant height of okra plants

Treatments	Plant height(cm)						Leaf area index					
	30 DAS		60 DAS		90 DAS		30 DAS		60 DAS		90 DAS	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
I_1F_1	20.7	19.5	50.6	37.6	83.6	61.2	85.1	78.0	1.25	1.32	2.76	2.44
I_1F_2	22.7	20.0	51.4	40.9	89.9	68.9	89.7	79.9	1.35	1.38	2.95	2.50
I_1F_3	23.5	21.1	53.3	41.8	92.4	70.4	94.1	81.9	1.45	1.48	2.98	2.81
I_2F_1	23.0	20.8	51.7	38.9	87.9	66.8	91.9	77.9	1.41	1.40	2.91	2.63
I_2F_2	23.5	21.7	54.7	40.4	90.0	72.9	93.5	80.8	1.61	1.50	3.38	3.14
I_2F_3	23.9	23.2	56.5	41.7	94.4	76.3	96.7	87.5	1.73	1.70	3.54	2.84
I_3F_1	23.2	22.2	54.0	42.9	90.0	72.6	93.6	85.1	1.87	1.74	3.11	2.86
I_3F_2	23.9	22.9	55.3	43.5	92.5	76.3	96.5	90.0	1.98	1.81	3.37	2.88
I_3F_3	24.3	23.0	56.3	44.0	95.3	76.5	99.2	88.9	2.18	2.03	3.69	3.03
Control	18.7	19.9	44.2	27.5	68.8	64.6	74.2	70.3	1.30	1.15	2.58	2.20
CD 0.05%	2.27	NS	6.54	8.0	8.23	5.91	9.56	4.63	0.17	0.26	0.42	NS

Table 3: Effect of different drip irrigation and fertigation levels on yield attributes and yield of okra

Treatments	Fruit length (cm)		Fruit width (cm)		Fruit weight (g)		Fruits/plant (No)		Fruit yield (q/ha)	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
I_1F_1	10.4	10.8	1.40	1.33	12.0	11.4	24.2	20.3	155.3	145.9
I_1F_2	10.4	10.5	1.43	1.37	12.3	12.0	26.4	21.9	174.9	151.0
I_1F_3	10.5	11.4	1.43	1.37	12.9	12.6	26.6	22.5	179.2	165.3
I_2F_1	10.4	10.5	1.43	1.37	11.5	12.0	25.4	21.7	160.7	158.8
I_2F_2	10.7	10.6	1.37	1.37	11.7	12.0	27.2	23.4	206.6	170.8
I_2F_3	10.8	10.3	1.43	1.40	12.0	12.2	28.9	25.3	194.8	182.1
I_3F_1	11.1	10.4	1.37	1.33	10.9	12.0	27.5	22.2	189.4	161.9
I_3F_2	11.4	10.7	1.33	1.30	11.6	12.0	29.3	23.4	211.6	171.3
I_3F_3	11.8	10.2	1.40	1.40	12.5	12.8	29.1	24.5	197.4	177.5
Control	10.9	10.5	1.47	1.40	11.2	12.8	18.4	18.6	166.6	146.3
CD at 0.05%	NS	NS	NS	NS	NS	NS	3.6	2.8	22.3	18.4

control. Similarly, during the second year also all the above treatments except I_1F_3 recorded significantly higher fruit yield than control plot. Among the drip fertigation treatments maximum fruit yield was obtained under I_3F_2 (221.6 q/ha) during 2015 which was statistically at par with I_3F_3, I_3F_1, I_2F_3 and I_2F_2 but significantly higher than all other treatments, while during 2016 maximum fruit yield of 182.1 q/ha was obtained under I_2F_3 which was statistically at par with I_1F_3, I_2F_2, I_3F_2 and I_3F_3 but significantly higher than all other treatments. Relatively lower yield during 2016 may be attributed to increased maximum and minimum temperature by 1-3°C (Table 1) during different months particularly during fruiting period which might have affected net photosynthesis thereby resulting in reduced yields. The rainfall was relatively on higher side than normal in Months of May-June which caused increased load of insect-pests. Results corroborate the findings of Patel et al. (2009) where it is reported that drip irrigation with fertigation resulted in yield increase of 46.25 percent as compared to surface irrigated crop.

Water use and Water use efficiency: The total depth of irrigation water applied was 282 and 254 mm in I_1 treatment which was less than I_2 (376 & 306 mm) and I_3 (471 & 401 mm) for 2015 and 2016 crop seasons respectively. Further, in conventional treatment, the depth of irrigation water applied was 650 and 550 mm for the respective years (Table 4). The results in maximum percentage of water saving over conventional irrigation was in I_1 treatment (56.6 & 53.8 %) followed by I_2 (42.2 & 34.2%), I_3 (27.5 & 26.4 %) respectively for

Table 4: Comparison of irrigation water applied in different irrigation treatments

Irrigation treatments	Total depth of irrigation water applied (mm)		Percentage of saving water over conventional irrigation			Mean yield (q/ha)		WUE kg ha^{-1} mm^{-1}	
	2015	2016	2015	2016	Mean	2015	2016	2015	2016
I_1	282	254	56.6	53.8	55.4	169.8	154.1	60.2	60.6
I_2	376	306	42.2	34.2	34.2	187.4	170.6	49.8	55.8
I_3	471	405	27.5	26.4	26.4	199.5	170.2	42.4	42.0
Conventional furrow irrigation(cm)	650	550	--	--	--	166.6	146.3	25.6	26.6

Table 5: Economic analysis of drip irrigation system in okra with subsidy and conventional method

Sr.No.	Description	Drip irrigation	Conventional method
1	Main, submain & venturi etc.		
	a) Fixed cost (Rs)	41,898.00	
	b) Accessories[10% of a] (Rs)	4189.80	
	c) Total (Rs)	46,087.80	
	d) Life in years	20	
	e) Depreciation on capital by taking two crops per year (c/40)	1152.19	
	f) Interest @ 8% per crop taking two crops per year (c × 0.08/4)	921.76	
	g) Total (e +f)	2073.95	
2	Pump		
	a) Fixed cost (Rs)	20,000	20,000
	b) Life in years	20	20
	c) Depreciation on capital by taking two crops per year(c/40)	500	500
	d) Interest @ 8% per crop taking two crops per year(c × 0.08/4)	400	400
	e) Total (c+d)	900	900
3	Laterals and installation		
	a) Cost of laterals with inbuilt emitters @ Rs10.45 per meter for 1 ha (approx.14850 m)*	1,54,815	--
	b) Cost of installation (Rs)	15,481.5	
	c) Total (Rs)	1,70,298.3	
	d) Total cost with subsidy (With maximum subsidy of Rs.80812.50 based upon the maximum subsidy provided by the government on vegetable crops per hectare)	89485.75	
	e) Life in years	8	
	f) Depreciation on capital by taking two crops per year (d/16)	5593.0	
	g) Interest @ 8% per crop taking two crops per year (d × 0.08/4)	1790.0	
	h) Total (f + g)	7383.0	
4	Cultivation cost of Okra (Rs)	78,600	78,600
5	Total cost of production (Rs)	88,920	78,600
6	Average Produce (q/ha)	190.0	156.5
7	Selling price (Rs/quintal)	1500	1500
8	Gross income (Rs)	2, 85,000	2,34,750
9	Net income (Rs)	1,96,080	1,56,150

the first and second year. Maximum water use efficiency of 60.2 & 60.6 kg $ha^{-1}mm^{-1}$was recorded higher in I_1 irrigation level treatments followed by I_2 49.8 & 55.8 kg $ha^{-1}mm^{-1}$.Among the drip fertigation treatments the lowest WUE of 42.4 and 42.0 kg $ha^{-1}mm^{-1}$ was recorded under I_3, which was 65.6 and 57.9 % higher as compared to conventional furrow irrigated control.

To calculate the net returns for drip irrigated okra the cost of different inputs and outputs were taken from the department of Agricultural Economics, PAU Ludhiana. These values were used for calculating the net income for okra. Table 5 depicts the cost of different components for the drip irrigation system and net returns from the crop. It shows that net seasonal income from okra was Rs 1, 96,080 and 1, 56,150 per hectare for bed planted drip fertigated okra and furrow irrigation method of irrigation. In okra, the increase in net income by drip fertigation method was 25.6 percent more as compared to furrow method of irrigation.

From the above results it is concluded that best drip fertgation treatment I_3F_2 (2015) and I_2F_3 (2016) recorded 27.0 and 24.3 per cent higher fruit yield as compared to conventional furrow irrigated crop. The maximum water use efficiency of 60.4 kg $ha^{-1}mm^{-1}$was obtained under I_1 (0.6 ETc) which gave same fruit yield as under conventional furrow irrigated crop and saved irrigation water to the extent of 55.4 percent as compared to control plot. The net returns obtained under drip fertigation were higher to the extent of 25.6 per cent as compared to control plot.

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भिण्डी (*एबलमास्कस इस्कुलेन्टस* वार. पंजाब–8) की बलुई दोमट मिट्टी में टपक सिंचाई तथा उर्वरक (फर्टिगेशन) के प्रयोग का तुलनात्मक अध्ययन सतही मेड़–नाली सिंचाई से उपज तथा जल उपयोग दक्षता हेतु एक प्रयोग वर्ष 2015 व 2016 में किया गया। उपचारों में 2 स्तर के टपक सिंचाई सहित 3 स्तर के उर्वरक प्रयोग एवं सतही मेड़–नाली सिंचाई को उपचार नियंत्रक के रूप में प्रयोग किया गया। परिणाम से स्पष्ट हुआ कि टपक उर्वरक उपचार आई–3 एफ–2 (वर्ष 2015) तथा आइ–2 एफ–3 (वर्ष 2016) में 27.0 व 24.3 प्रतिशत अधिक फल उपज पारम्परिक नाली–मेड़ सिंचाई फसल की तुलना में प्राप्त की गयी। औसत जल उपयोग दक्षता में वृद्धि 26.1 किग्रा. प्रति हेक्टेयर प्रति मिमी. नियंत्रक प्रखण्ड से 42.2 किग्रा. प्रति हेक्टेयर प्रति मिमी. एवं 52.8 किग्रा. प्रति हेक्टेयर प्रति मिमी. आई–2 सिंचाई उपचार में पाया गया। अधिकतम जल उपयोग दक्षता 60.4 किग्रा. प्रति हेक्टेयर प्रति मिमी. सिंचाई आई–1 ई.टी.सी.) के अन्तर्गत समान फल उपज पारम्परिक सिंचाई फसल तथा पानी (सिंचाई) की बचत 55.4 प्रतिशत नियंत्रक की तुलना में पाया गया। टपक सिंचाई के अन्तर्गत शुद्ध प्रतिफल अधिक गया जो नियंत्रक पारम्परिक नाली–मेड़ सिंचाई की तुलना में 25.6 प्रतिशत अधिक रहा।

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