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Research Article

RESPONSE OF OKRA TO DRIP IRRIGATION AND MULCHING IN TARAI CONDITION OF UTTARAKHAND

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Abstract: The study was conducted to evaluate the response of okra under different levels of drip irrigation and polythene mulching on crop growth, yield and water use of okra. The treatments included three irrigation levels of drip irrigation, (100% (T1), 80% (T2) and 60% (T3) of full irrigation requirement) and furrow irrigation (T4). The experiment also had same set of treatments under-mulched conditions (T5, T6, T7, T8). The study indicated that drip irrigation in combination with mulching, significantly increased plant height, stem diameter, number of leaves per plant and fruit yield of okra crop. The percentage increase in the yield due to mulches were 66.8 %, 65.8 %, 111.8 % and 131.1 % higher for mulched treatments T5, T6 T7and T8, respectively, over the corresponding non-mulched treatments. The drip irrigation in combination with mulching increased the okra yield significantly over furrow irrigation to the tune of 60-167 %. The study recommends drip irrigation with mulch for higher land and water productivity of okra grown during *zaid* season.

Keywords: *Drip irrigation, Mulching, Okra*

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Introduction

Okra (*Abelmoschu sesculentus* L. Moench.) is one of the important vegetables grown throughout the tropics and warmer parts of the world, where water availability is the major constraint to crop production [1]. The crop is commonly grown with irrigation in *zaid* season. India produces 6.35million tonnes of okra annually which is around 73 % of global okra production [2] the nutritional value of 100 g of edible portion of okra contains 1.9 g of protein, 0.2 g fat, 6.4 g carbohydrate, 0.7 g minerals and 1.2 g fibre [3]. Okra has a vast potential as one of the foreign exchange earner crops and accounts for about 60% of the export of fresh vegetables excluding potato, onion and garlic. Water withdrawal for agricultural purposes accounts for about 75% of all usages in developing countries and the FAO has predicted a 10 % net increase in use of water to meet the food demands by the year 2030 as compared to year [4]. Under different water availability situations, judicious management is essential to enhance water productivity. Hence, search for sustainable methods to increase crop water productivity is gaining importance. Traditionally, agricultural research has focused on maximizing total production. But, in recent years the focus has shifted to the limiting factors in production systems, notably the availability of either land or water. Within this context, water saving technique such as micro irrigation, plastic mulching and deficit irrigation (DI) has been widely investigated as a valuable strategy where water is the limiting factor in crop cultivation [5, 6]. Micro irrigation is a technique for the precise application of water to the plants with high water use efficiency. Drip irrigation along with plastic mulching is effective in increasing the yield when compared with surface irrigation [7,8]. Under adverse climatic conditions like high and low temperature regimes, mulching has favourable effect on growth and productivity of vegetables. Shallow tillage practices like racking of soil, simple scraping, hoeing, light digging etc. provide mulching effect, termed as mechanical mulching. It conserves soil moisture and increases soil aeration, microbial activities, nitrification process and also regulate soil temperature [9, 10]. Mulching is usually done with organic materials like straw, green leaves, dry leaves or by using plastic sheets.

Different colour and thickness of poly mulches are used for specific purposes. Mulching with black polyethylene sheet is very effective in suppressing weed growth in cultivation of vegetables. Yellow plastic mulch attracts white-flies and acts as a control measure of Leaf Curl Virus [11]. Paul, 2013 [12] indicated that by using drip irrigation system along with mulching, the yield of okra may increase up to 61 % over the surface method with the same quantity of water applied. Chandra and Singh, 2015 [13] have reported the beneficial effect of drip irrigation with mulch for broccoli crop in Tarai condition of Uttarakhand. The responses of okra to the combined effect of drip with different levels of irrigation in conjunction with mulch are not well known for Tarai condition of Uttarakhand. In present study, an attempt has been made to study the response of drip irrigation system with plastic mulch on growth and yield of okra compared to conventional furrow irrigation method with the aim of devising better irrigation management strategies under mulched and non-mulched drip and furrow irrigation systems.

Materials and Methods

Study Area and Layout of the Field Plot

The study area comes under climatic zone of western Himalayan region and is located in the Shivalik foothills of the Himalayas and represents the Tarai region of Uttarakhand state. The field experiment was conducted from March to June in the year 2014 at the experimental farm of department of Irrigation and Drainage Engineering, College of Technology, GBPUA&T, Pantnagar, Uttarakhand, located at 29˚N latitude, 79˚30´E longitude and at an altitude of 243.83 m above mean sea level. The meteorological data such as temperature, relative humidity, wind speed, sunshine hours, rainfall and pan evaporation during the crop period was obtained from the meteorological observatory located at Crop Research Centre, Pantnagar about 0.5 km away from the experimental site. The soil texture was sandy clay loam with field capacity of 26%. The gravimetric method was used to asses' field capacity of soil samples collected after 2 days of irrigation. The wilting point as derived using Pedo transfer function was 10 %. A field plot of 40 x 20 m was divided into twenty-four equal plots of 6 x 4 m.

The experiment was laid out in randomized block design having eight treatments replicated thrice. One meter gap was provided between each plot to avoid the effect of irrigation treatments. The layout of the experiment is presented in [Fig-1]. The plant to plant and row to row spacing was maintained at 50 x 50 cm. The okra hybrid (US 7109 F1) was sown in the 3rd week of March 2014. Standard agronomic practices such as fertilisation and plant protection measures were applied during the crop period. Fertilizer dose of 200 kg N, 100 kg each of P and K along with 4 t ha-1 were applied as nutritional requirement of crop. Half of NPK dose was applied as basal dose while the other half was applied through fertigation at an interval of 7 days. The experimental treatments included, T1- 100 % of full irrigation requirement met through drip, T2- 80 % of full irrigation requirement met through drip,T3- 60 % of full irrigation requirement met through drip,T4- Irrigation application when soil water content is lower by 60 % of field capacity using conventional flood furrow irrigation system,T5- 100 % of irrigation requirement met through drip with mulch,T6- 80 % of irrigation requirement met through drip with mulch, T7- 60 % of irrigation requirement met through drip with mulch, T8- Irrigation water application when soil water content is lower by 60 % of field capacity using conventional furrow irrigation system under plastic mulch.

The volume of water required was estimated using the equation,

$$V = \sum(E_{px}K_{cx}K_{px}S_{px}S_r \times WP - ER \times S_{px}S_r)$$

where, v is the volume of water in L/day/plant, Ep- Pan evaporation, mm/day, Kc– Crop coefficient, Kp- Pan factor (0.65), Sp- Plant to plant spacing, WP- wetting area (taken as 0.9), ER- effective rainfall, cm. The crop coefficients, Kc for different growth stages of okra were considered based on the unpublished report and local studies carried out in India. The crop coefficient Kc values are varying with the type of crop, its growing stage, growing season and prevailing weather conditions. The crop coefficient, Kc values were taken from Tiwari et al. 1998 [8]. The crop coefficient value for initial stage Kcinit was taken as 0.75, for mid stage Kc mid was taken as 1.15 and for end stage it was taken as Kcendas 0.87. The effective rainfall is the part of the rainfall that forms the part of the consumptive use. Effective rainfall was calculated on the basis of standard table provided in Irrigation Water Management Training Manual no. 3, FAO. All the recommended package and practices were followed including application of N:P:K @ 150:90:60 kg/ha. Black coloured polyethylene film of 25 micron thickness was used as per the requirement of the treatments. Drip irrigation system was laid out by 12 mm diameter lateral line. Lateral are provided with drippers of 1.5 liter per hour discharge capacity. The duration of delivery of water to each treatment was controlled with the help of gate valves provided at inlet of each laterals. In case of surface irrigation scheduling was done on basis of soil reaching 60 percent of field capacity. Tensiometers were used to determine soil moisture in case of surface irrigation. The plants under furrow method were irrigated by impounding water in furrows.

Biometric Observations

Five plants were randomly selected from each replication and selected plants were tagged by aluminium tag for identification. For taking biometric observations different parameters of vegetative growth such as plant height, stem diameter, number of leaves per plant, number of fruits per plant, fruit size and yield were recorded. The biometric parameters were recorded at 30 DAS, 60 DAS, 90 DAS and 105 DAS.

Crop yield

The harvesting of the crop was started on 5th May 2014. The harvesting was finished on 4th of July 2014. From each of the 6 m x 4 m observation plot, the total fruit yield was recorded and then converted to per hectare basis. All together there were 20-21 pickings. The picking of fruits was done at an interval of 2-3 days. The fruit size and fruit weight were also recorded.

Water Productivity

The water productivity for different treatments was calculated by dividing the total yield of fruit obtained from each treatment to the total volume of water applied during its growing period. The amount of water used to produce unit quantity of fruit was also determined.

Fig-1 Okra under furrow irrigation with plastic mulching (30 DAS)

Fig-2 Okra under drip irrigation and plastic mulching (30 DAS)

Fig-3 Okra under drip irrigation and plastic mulching (45 DAS)

Results and Discussion

Biometric Parameters and Yield

The effect of different levels of irrigation on biometric parameter such as plant height, stem diameter, number of leaves per plant, fruit length, fruit weight and fruit yield were analysed statistically and compared with that of furrow irrigation treatments. The experimental results of these biometric parameters are presented in [Table-1]. The height of plant under different level of drip irrigation is significantly superior to conventional furrow irrigation treatment T4 except for treatment T3 (Drip irrigation based on 60% irrigation requirement with LLDPE mulch) which is at par with treatment T4. The stem diameter under different level of drip irrigation was found significantly higher to conventional furrow irrigation. When similar comparison was made for number of leaves per plant it was found that only 100 % level of drip irrigation (T1) was found superior than conventional furrow irrigation (T4), whereas 80 % level of drip irrigation (T2) and 60 % level of drip irrigation (T3) were statistically at par with treatment T4. There was a significant increase in the fruit size, fruit weight and fruit yield in response to drip irrigation treatments at different levels of irrigation in comparison to furrow irrigation except for treatment T3 which is at par with treatment T4. The crop yield in treatment T1 was higher by 61 percent and treatment T2 (drip irrigation with 80 % irrigation requirement) was higher by 60.1 % compared to conventional furrow irrigation. The results corroborated the findings of Sivanappan [14], Tiwari [8] and Mishra [15]. The drip irrigation treatments T1, T2 and T3might have provided appropriate moisture at field capacity and better root development compared to furrow which facilitated luxuriant growth. Fertigation in drip irrigation system might have also provided better nutrient use efficiency compared to furrow irrigation method [16]. The result revealed that the plant height, stem diameter, number of leaves per plant fruit length, fruit weight and fruit yield were significantly superior in treatment T5 (Drip irrigation based on 100% irrigation requirement with LLDPE mulch) and T6 (Drip irrigation based on 80% irrigation requirement with LLDPE mulch) compared to rest of the treatments. There was significant influence of drip with plastic mulch over drip alone and furrow without mulch on plant height. The height of plant under treatment T5 was 74.70 percent higher than the height of plant under furrow irrigation without mulch (T4).

Table-1 *Growth and yield of okra as influenced by different treatments*

SN	Parameters	DAS	Treatments								CD at 5 %
			T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	
1	Plant height, cm	30 DAS	15.65_{c}	14.45_{cd}	11.93_{de}	10.93_{e}	24.28_{a}	21.43_{b}	19.82_{b}	20.17_{b}	2.65
		60 DAS	62.17_{c}	61.83_{c}	49.67_{d}	44.25_{d}	105.17_{a}	90.48_{b}	85.50_{b}	85.50_{b}	12.04
		90 DAS	113.00_{de}	105.30_{e}	91.05_{f}	80.30_{f}	160.67_{a}	152.48_{ab}	128.33_{cd}	134.25_{bc}	20.16
		105 DAS	120.00_{c}	117.50_{cd}	105.17_{de}	95.50_{e}	166.83_{a}	160.17_{a}	131.67_{bc}	141.00_{b}	17.86
2	Stem Diam., cm	30 DAS	7.30_{d}	5.90_{e}	5.25_{f}	4.80_{g}	9.18_{a}	9.13_{b}	7.86_{c}	7.96_{c}	0.12
		60 DAS	19.70_{e}	18.90_{f}	15.20_{g}	14.00_{h}	28.90_{a}	25.30_{b}	21.30_{d}	21.70_{c}	0.24
		90 DAS	26.10_{d}	24.60_{e}	23.90_{f}	21.60_{g}	33.30_{a}	30.40_{b}	26.00_{d}	27.50_{c}	0.33
		105 DAS	28.90_{c}	26.70_{e}	24.20_{f}	22.60_{g}	36.70_{a}	34.00_{b}	26.90_{de}	28.70_{c}	0.38
3	No. of Leaf/Plant	30 DAS	7.50_{cd}	7.00_{de}	6.33_{ef}	5.83_{f}	9.83_{a}	9.00_{ab}	8.17_{bc}	8.67_{b}	0.94
		60 DAS	35.00_{bc}	31.50_{cd}	26.67_{de}	22.67_{e}	44.17_{a}	40.67_{ab}	32.50_{cd}	35.00_{bcd}	6.34
		90 DAS	53.00_{bc}	40.17_{de}	34.00_{e}	30.50_{e}	65.67_{a}	54.17_{ab}	41.83_{cde}	46.50_{bcd}	12.43
		105 DAS	53.67_{bc}	41.17_{cde}	35.50_{de}	31.50_{e}	66.83_{a}	54.83_{ab}	42.50_{bcde}	47.33_{bcd}	12.54
4	Fruit length (cm)		19.30_{b}	18.70_{b}	17.50_{c}	16.70_{c}	20.90_{a}	20.10_{ab}	19.40_{b}	18.10_{bc}	1.25
6	Fruit Weight (g)		19.70_{b}	19.30_{b}	17.30_{c}	16.30_{c}	22.70_{a}	22.30_{a}	19.30_{b}	18.70_{bc}	1.92
7	Fruit Yield (t/ha)		10.45_{b}	10.39_{b}	7.94_{bc}	6.49_{c}	17.44_{a}	17.23_{a}	16.82_{a}	15.00_{a}	2.63

Table-2 *Water productivity of okra under different level of irrigation under mulch and non mulch condition*

Treatment	Water used (mm)	Water Productivity (kg/m^3)	Amount of water used to produce unit yield (Litre/kg)
T_1	452.90	2.31_{d}	433.39
T_2	383.60	2.70_{d}	369.20
T_3	314.40	2.53_{d}	395.97
T_4	652.36	0.99_{e}	1005.0
T_5	452.90	3.85_{c}	259.69
T_6	383.60	4.49_{b}	222.64
T_7	314.40	5.35_{a}	186.92
T_8	652.36	2.30_{d}	434.90
CD (P<0.5)		0.63	

There was significant influence of drip with plastic mulch over drip alone and furrow without mulch on plant height. Based on analysis of data the percentage increase in the plant height due to mulches were 39.0 percent, 36.3 percent, 25.2 percent and 47.6 percent for treatment T5, T6, T7 and T8 over corresponding level of irrigation under drip (T1, T2, T3) and furrow irrigation (T4) alone. The stem diameter under treatment T5 is 62.4 % higher than the stem diameter of plant under furrow irrigation without mulch (T4). The analysis of variance of observed data showed that plastic mulching has significant effect on stem diameter of okra plant. The percentage increase in stem diameter due to mulches were 26.9 %, 27.3 %, 11 % and 27 % for treatment T5, T6, T7 and T8 over corresponding level of irrigation under drip (T1, T2, T3) and furrow irrigation (T4) alone. The percentage increase for number of leaves per plant in treatment T5 over control (treatment T4) was 112 %. The percentage increase in number of leaves per plant due to mulches were 24.5 %, 33.2 %, 19.7 % and 50.2 % for treatment T5, T6,T7 and T8 over corresponding level of irrigation under drip (T1, T2, T3) and furrow irrigation (T4) alone. The analysis of the data revealed that the highest yield (17.44 t/ha) of okra was recorded under drip with 100%irrigation with LLDPE mulch (T5), followed by drip irrigation based on 80% irrigation with LLDPE mulch (T6) (17.23 t/ha). Based on analysis of data the percentage increase in the yield due to mulches were 66.8 %, 65.8 %, 111.8 % and 131.12 % for treatment T5, T6, T7 and T8 over corresponding level of irrigation under drip (T1, T2, T3) and furrow irrigation (T4) alone. Deficit Irrigation treatment T3 (60 % of irrigation requirement met through drip system) was suffering in want of moisture. But when mulch was applied in corresponding treatment T5 it has almost doubled the yield. Goyal et al.2009 [17] and Tiwari et al. 2003 [8] reported on similar lines. The fruit yield was statistically at par for treatment T5, T6, T7 and T8 and significantly superior to conventional furrow irrigation T4. Increase in soil temperature and efficient utilization of water and nutrients, resulting from the use of black polyethylene mulch might be important reason for the higher yield [18]. The highest fruit weight (22.7 g) was recorded under treatment of drip irrigation based on 100% irrigation with LLDPE mulch (T5), followed by drip irrigation based on 80% irrigation with LLDPE mulch (T6) (22.30 g). There was a significant increase in fruit size in response to drip irrigation treatment at two levels of irrigation in comparison to furrow irrigation. Irrigation methods and mulch significantly affected fruit length. However, fruit size response at 100 % irrigation and 80 % irrigation through drip was statistically at par. Fruit length was recorded highest under treatment of drip irrigation based on 100% of full irrigation with LLDPE mulch (T5) with a value of 20.90 cm, followed by drip irrigation based on 80% of full irrigation with LLDPE mulch (T6) with a value of 20.10 cm and lowest for conventional furrow irrigation (T4) with a value of 16.70 cm. The highest increase in vegetative growth and yield in treatment T5 and T6 might be due to availability of soil moisture as well as temperature at optimum level [8, 12, 19]. The lowest value of vegetative growth in T3 might be because of moisture stress. The lower value of vegetative growth in control i.e. furrow irrigation without mulch, T4might be because of unfavourable moisture regimes (moisture stress or excess moisture) in soil through surface irrigation and competition of weeds for nutrients [20]. The irrigation was applied in the furrow irrigation as the moisture level reached up to 60 % of field capacity. The beneficial effect of different mulches (both organic and synthetic) on growth and yield of different vegetables was also reported by earlier investigators [21-23].

Water Productivity

Water productivity (yield per unit volume of water used) of okra decreased with increase in irrigation levels i.e.T3, T2 and T1 for all the treatments of drip irrigation system [Table-2]. There was significant effect of LLDPE mulch over drip irrigation system alone. The increase in water productivity for drip irrigation system alone (T1) and drip irrigation system with LLDPE mulch (T5) over conventional furrow irrigation system (T4) was 133.3 % and 288.9 % respectively. Similar trend has been reported for water use efficiency for tomato crop by Tiwari et al. (1998b) [8] Sarkar and Singh (2007) [24]. The water productivity was highest (5.35 kg/m3) for treatment T7 (60% irrigation with mulch), followed by 4.49 kg/m3 underT6 (80% irrigation with mulch). Water used to produce 1 kg of okra was lowest under treatment T7 and was highest under T4. [Table-2] revealed that 186.9 litres of water were used to produce 1 kg of okra under treatment T7, followed by 222.64 litres of water under treatment T6 and highest 1005 litres of water under treatment T4. The okra crop was grown during the month of March-June when evaporative demand is very high. During these hot months moisture shortage can result in yield losses. The drip system along with mulch seems to be doing well for okra crop. The increased water productivity under drip irrigation is because of drip system that provides precise and measured quantity of water to individual plant. The saving of water combined with higher yield under drip irrigation are the reasons for increased water productivity. On the other hand, furrow irrigation has lowest water productivity.

It is because of furrow irrigation is associated with many losses like evaporation losses, seepage losses, deep percolation losses etc. Higher water productivity in treatments having drip with mulch was due to higher fruit yield compared to other treatments. Supply of more energy to the evaporation site (bare soil) increased evaporation and caused the lowest level of WUE. Mulch acts as a barrier in between microclimate and soil surface (evaporating site) and thus there was a decrease in vapour pressure gradient in between them. This reduces both loss of water from the soil surface through evaporation as well as the upward flux of soil water from the lower layers to the top layer [24]. During the winter season mulching escalate the root zone thermal status and reduced its diurnal variation, which also creates favourable environment for greater root proliferation and steady movement of water in the soil [24]. The beneficial effect of drip irrigation and mulching on water use efficiency of different vegetables was also reported by earlier investigators [23, 8, 9, and 12].

Conclusion

The present study shows that drip irrigation in combination with 25 µ black plastic mulching, significantly increases the biometric growth parameters such as plant height, stem diameter, number of leaves per plant and canopy spread for okra.

Application of research: The drip irrigation in combination with mulching can increase the okra crop yield over furrow irrigation to the tune of 60-167 %. The increase in water productivity of okra for drip irrigation system alone and drip irrigation system with mulch over conventional furrow irrigation was 133 % and 289 % respectively.

Research Category: Drip irrigation

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Study area / Sample Collection: Shivalik foothills of the Himalayas and represents the Tarai region of Uttarakhand state.

Cultivar / Variety / Breed name: Okra (*Abelmoschu sesculentus* L. Moench.)

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
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