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Yield and Economics of Summer Okra (*Abelmoschus esculentus* L. Moench.) under Plastic Mulching and Drip Irrigation

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Abstract: An experiment was conducted to evaluate the combined effects of different mulch conditions and drip irrigation levels on yield and gross return of summer okra (Abelmoschus esculentus L. Moench.). Assessment of crop yield and economic returns was carried out for different treatment combinations viz.; silver black plastic mulch (M_1), black plastic mulch (M_2) and no mulch (M_3) in conjunction with 1.0 ETc (I_1), 0.8 ETc (I_2), 0.6 ETc (I_3) and 0.4 ETc (I_4) drip irrigation levels at Instructional Farm, CAET, JAU, Junagadh in 2017. The study results indicated that the highest crop yield (22424.24 kg/ha) was achieved under silver black plastic mulch with 0.8 ETc treatment combination. Economic analysis revealed that the maximum seasonal net return of ₹ 266719.52 per ha could be obtained by adopting silver black plastic mulch in combination with drip irrigation level at 0.8 ETc with a BCR of 4.83.
Keywords: Summer okra, crop yield, drip irrigation, plastic mulch, economic analysis, Benefit-Cost Ratio.

1. Introduction

Agriculture is by far the largest user of water accounting more than 70 % of water utilization worldwide and 90 % of water utilization in the developing countries (Sharma *et al*., 2007). Demand for water is increasing day by day due to the increase in population of the country, and therefore judicious use and management of water is a must for the future growth of Indian agriculture.

In commercial vegetable production, water is a most important input, especially in areas where vegetable production lack due to scarcity of water and or irregular distribution of rainfall particularly during summer season and okra (*Abelmoschus esculentus* L. Moench.) is one of the most profitable vegetables during the season. Though okra is mostly cultivated under irrigated condition, the inadequate supply of water at the critical stages of the plant growth often affects the productivity of okra in India. The moisture stress will affect the germination of seed, growth of plant, peg formation and seed fillings, all of which ultimately result in poor-quality yield (Rekha and Mahavishnan, 2008). So the soil moisture is crucial to achieve high economic returns, in terms of both yield and product quality.

The study area is typically sub-tropical with semi-arid climate and the region is facing water scarcity during summer. Scientific management of irrigation water assumes significance in view of the fact that water, as a resource in agriculture, has become a limiting factor especially in arid and semi-arid regions, as rainfall distribution in these regions is uncertain and erratic in time and space (Dunage *et al*., 2009). The return from crops is also found to be substantially higher under drip irrigation method mainly due to increased productivity and reduced cost of cultivation (Devika *et al.*, 2017). Mulching can also be used as one of the most effective conservation practices for reducing water loss through surface evaporation during summer. Therefore properly scheduled drip irrigation in combination with mulching can be used as one of the best irrigation method, which can improve the water management practice significantly in vegetable crops like okra.

Keeping in view the above facts, this experiment was undertaken to determine the crop yield and economics of summer okra under various treatment combinations of mulch conditions and drip irrigation levels for evaluating the economic feasibility of the crop.

2. Materials and Methods

2.1 Location of experimental site

The field experiment was carried out at Instructional Farm, College of Agricultural Engineering and Technology, JAU, Junagadh. The Instructional farm is geographically located at 21.5 °N latitude and 70.1 °E longitude with an altitude of 61.20 m above mean sea level. The current research was carried out during the summer season (February to May, 2017). The area is subtropical and of semi-arid type with an average annual rainfall of 900 mm and average pan evaporation of 5.6 mm/d (Sreeja and Satasiya, 2020).

2.2 Layout and Experimental details

The experiment was laid out in split plot design having twelve treatments replicated thrice with mulching as the main factor and irrigation levels as the sub factor. The experimental field was of 9.9 m × 16.4 m size with 36 treatment plots of 3.5 m length and 1.10 m width. The experiment was undertaken to evaluate the conjunctive impact of four drip irrigation levels; 1.0 ETc, 0.8 ETc, 0.6 ETc, 0.4 ETc and plastic mulches mainly; silver black plastic mulch (25 μm), black plastic mulch (25 μm) along with no mulch treatment on summer okra (Table 1).

The drip irrigation system was installed in the field before sowing of okra. The delivery line was of 75 mm in diameter with bypass assembly of 75 mm fitted on main line. A screen filter with filtering capacity 25 m^3/hr was adopted in present system. Venturi injector (63 mm) was used for application of water soluble fertilizer through drip irrigation. Pressure gauge of 0 - 4 kg/cm^2 was used for measuring the operating pressure in the main line. PVC pipe of 75 mm × 4 kg/cm^2 and 63 mm × 3.2 kg/cm^2 was used as main line and sub main line respectively. Heavy duty black coloured LLDPE lateral line of 16 mm × 2.5 kg/cm^2 was used as the drip system lateral with inline emitters of 2 lph discharge.

Silver black plastic mulch (25 μm) and black plastic mulch (25 μm) were adopted in the present study. A hole of 6 cm diameter was made at zig-zag geometry (two rows at 30 cm apart) in the mulch films and was laid manually on the beds before sowing.

Table 1 Details of treatments

Treatments	Mulch Condition	Irrigation level
M_1I_1	Silver black plastic mulch: 25 μm	1.0 ET_c by drip
M_1I_2	Silver black plastic mulch: 25 μm	0.8 ET_c by drip
M_1I_3	Silver black plastic mulch: 25 μm	0.6 ET_c by drip
M_1I_4	Silver black plastic mulch: 25 μm	0.4 ET_c by drip
M_2I_1	Black plastic mulch: 25 μm	1.0 ET_c by drip
M_2I_2	Black plastic mulch: 25 μm	0.8 ET_c by drip

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M_2I_3	Black plastic mulch: 25 µm	0.6 ET_c by drip
M_2I_4	Black plastic mulch: 25 µm	0.4 ET_c by drip
M_3I_1	No mulch (Raised bed with drip irrigation)	1.0 ET_c by drip
M_3I_2	No mulch (Raised bed with drip irrigation)	0.8 ET_c by drip
M_3I_3	No mulch (Raised bed with drip irrigation)	0.6 ET_c by drip
M_3I_4	No mulch (Raised bed with drip irrigation)	0.4 ET_c by drip

2.3 Crop details

Local variety (Gujarat Junagadh Okra - 3 (GJO-3)) of summer okra was used for the present study. The sowing was done manually on 3rd February 2017. The crop period of okra was 110 days and first picking was done at 48 days after sowing (DAS). The fertilizers were applied as per JAU RDF for okra (N:P:K 150:50:50 kg/ha) through broadcasting and drip fertigation.

2.4 Economic Analysis

The effects of different irrigation levels and mulch conditions were studied on crop yield and were calculated treatment wise. Economics of summer okra cultivation was also worked out. The economic analysis of okra cultivation consisted of total cost and total return per unit area. The cost was analysed commonly for both plastic mulching and irrigation levels while income analysis and other economical parameters were calculated separately on the basis of yield obtained from each treatment.

The total cost incurred from the field preparation to the final harvest stage was computed per hectare area basis. The total cost of cultivation (TCC) includes common and variable cost of okra cultivation and cost of irrigation (fixed and variable). The common cost of cultivation (CCC) comprises cost for the common agronomic practices involved during the experimental study. Variable cost of cultivation (VCC) includes cost of mulching and weeding. The cost of mulch material was calculated by considering the area covered by plastic mulch per kg of material. The fixed cost of irrigation (FCI) for all drip irrigation treatments included the cost of pumping unit, drip irrigation system and its installation. The rate of components and tax were considered for one hectare as per price fixed by Gujarat Green Revolution Company, Vadodara, Gujarat and (GGRC, 2017). The fixed cost of drip irrigation system was calculated considering the 10 years life of system serving for 2 seasons and 9 % rate of interest. Fixed cost was calculated by using the following equation;

$$FCI = P\left(\frac{i}{1-(1+i)^{-n}}\right) \quad (1)$$

Where,
P = Capital cost of irrigation system, ₹/ha
i = Interest rate
n = Life of drip system

The variable cost of irrigation (VCI) includes operational cost towards the labour and electricity for pumping, conveyance and irrigation applications and maintenance charges.

The gross return (GR) in terms of rupees per hectare was calculated based on the income received from okra yield and at the prevailing market price (₹ 15 per kg). The net return was worked out by deducting the total cost of the cultivation (TCC) from the gross return (GR) per hectare for each treatment. The benefit cost ratio

(BCR) of okra cultivation was worked out for each treatment by dividing the gross return with total cost of cultivation.

3. Results and Discussion

3.1 Crop yield

The yield of okra fruit was taken from each treatment plot and the crop yield was analysed statistically according to the split-plot design (SPD) to study the effect of different mulch conditions with different irrigation levels. The result revealed that the highest crop yield was observed in treatment combination of M_1I_2 (22424.24 kg/ha) and it was found significantly higher than the rest of treatment at 5 % significance level. The findings achieved are shown in Table 2 (Sreeja and Satasiya, 2020). The results obtained were in close agreement with those of Singh *et al.* (2009) and Zhang *et al*. (2017). The increase in application of water increases the yield up to a certain value and adoption of different mulch films had a positive effect on increasing the yield by moisture conservation and weed control.

Table 2 Effect of irrigation levels and plastic mulch on crop yield (kg/ha)

Treatments	Mean crop yield, kg/ha
M_1I_1	19653.68
M_1I_2	22424.24
M_1I_3	15948.05
M_1I_4	10692.64
M_2I_1	17099.57
M_2I_2	19506.49
M_2I_3	13341.99
M_2I_4	9090.91
M_3I_1	6987.01
M_3I_2	8917.75
M_3I_3	5671.00
M_3I_4	3419.91
C.D. at 5 %	910.13
S.Em.±	2704.16
C.D. = Critical difference, S.Em. = Standard error of mean	

3.2 Economic Analysis

The economics of okra cultivation was done and analysed for treatment combinations of different mulch conditions and drip irrigation levels. The common cost of cultivation (Table 3), variable cost of cultivation (Table 5), fixed and variable costs of irrigation (Table 6 and Table 7) were worked out for each treatment for calculating TCC.

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Table 3 Common cost of cultivation for okra (CCC)

Sr. No.	Particulars	Unit	Rate ₹ /unit	Quantity	Amount ₹ /ha
1	Land preparation by tractor	ha	4900.00	1	4900.00
2	Seed rate (5kg/ha)	kg	267.00	5	1335.00
3	Seed treatment with Thirum (5g/kg)	g	0.30	25	7.50
4	Total human labour requirement	man days	170.00	160	27200.00
5	Plant protection	Application	200.00	3	600.00
6	Cost of pesticides	ha	1167.32	1	1167.32
7	Cost of fertilizers (150:50:50; N:P:K kg/ha)				
	Urea (46:0:0)	kg	5.84	283.58	1656.11
	Diammonium phosphate (DAP) (18:46:0)	kg	19.00	108.60	2063.40
	Murate of potash (MOP) (0:0:60)	kg	6.20	83.33	516.65
Common cost of cultivation, ₹ /ha					**39445.97**

The total cost of cultivation (TCC) was found highest (₹ 70166.60 per hectare) in treatment combinations of M_1I_1 (silver black plastic mulch with 1.0 ET_c) and M_2I_1 (black plastic mulch with 1.0 ET_c). It was observed lowest (₹ 65439.04 per hectare) in treatment combination M_3I_4 (no mulch with 0.4 ET_c) and is depicted in Table 8.

Table 4 Calculation of Capital Recovery Factor (CRF)

Material	Life of material, year (n)	Interest rate, (i)	$CRF = \frac{i}{1-(1+i)^{-n}}$
Drip irrigation system	10	0.09	0.156
Silver black plastic mulch	2	0.09	0.568
Black plastic mulch	2	0.09	0.568
Pumping system	20	0.09	0.109

Table 5 Variable cost of cultivation for okra (VCC)

Sl. No.	Particulars			Silver black plastic mulch	Black plastic mulch	No mulch
1	Variable cost of cultivation	Weeding cost, ₹ /ha	man days	5	5	45
			Cost @ 170 ₹ /man days	850.00	850.00	7650.00
		Mulching cost ₹ /ha	Labour cost for mulch laying	350.00	350.00	0

			Mulch required, kg/ha	267	267	0
			Price of mulch, ₹ /kg	130.00	130.00	0
			Initial cost of mulch, ₹ /ha	34710.00	34710.00	0
			CRF	0.568	0.568	0
			Cost of mulch material per season	9857.64	9857.64	0
Variable cost of cultivation, ₹ /ha				**10207.64**	**10207.64**	**0**

Table 6 Fixed cost of irrigation (FCI)

Fixed cost of irrigation	Initial cost of irrigation, ₹ /ha	209273.85
	Cost of irrigation per season @ 0.156 CRF, ₹ /ha	16323.36
	Initial cost of pumping, ₹ /3ha	40000.00
	Cost of pumping per season @ 0.109 CRF, ₹ /ha	726.67
Total FCI, ₹ /ha		**17050.03**

Table 7 Variable cost of irrigation (VCI) and gross return of okra (GR)

Treatments	**Irrigation hours, hr**	**Cost of irrigation ₹ /ha**	**Mean crop yield, kg/ha**	**Gross return ₹ /ha**
M_1I_1	93.32	2612.96	19653.68	294805.19
M_1I_2	74.66	2090.48	22424.24	336363.63
M_1I_3	55.99	1567.72	15948.05	239220.78
M_1I_4	37.33	1045.24	10692.64	160389.61
M_2I_1	93.32	2612.96	17099.57	256493.51
M_2I_2	74.66	2090.48	19506.49	292597.40
M_2I_3	55.99	1567.72	13341.99	200129.87
M_2I_4	37.33	1045.24	9090.91	136363.64
M_3I_1	115.46	3232.88	6987.01	104805.19
M_3I_2	92.37	2586.36	8917.75	133766.23
M_3I_3	69.28	1939.84	5671.00	85064.93
M_3I_4	46.18	1293.04	3419.91	51298.70
Water cost @ ₹ 5/kWh, Sale price of okra @ 15 ₹ /kg				

Table 8 Economics of okra cultivation, ₹/ha

Treat ment	CCC	VCC	FCI	VCI	TCC	Gross return (GR)	Net return (TCC-GR)	BCR = GR/TCC
M_1I_1	39445.97	11057.64	17050.03	2612.96	70166.60	294805.19	224638.59	4.20
M_1I_2	39445.97	11057.64	17050.03	2090.48	69644.12	336363.63	266719.52	4.83
M_1I_3	39445.97	11057.64	17050.03	1567.72	69121.36	239220.78	170099.42	3.46
M_1I_4	39445.97	11057.64	17050.03	1045.24	68598.88	160389.61	91790.73	2.34
M_2I_1	39445.97	11057.64	17050.03	2612.96	70166.60	256493.51	186326.91	3.66
M_2I_2	39445.97	11057.64	17050.03	2090.48	69644.12	292597.40	222953.28	4.20
M_2I_3	39445.97	11057.64	17050.03	1567.72	69121.36	200129.87	131008.51	2.90
M_2I_4	39445.97	11057.64	17050.03	1045.24	68598.88	136363.64	67764.75	1.99
M_3I_1	39445.97	7650	17050.03	3232.88	67378.88	104805.19	37426.31	1.56
M_3I_2	39445.97	7650	17050.03	2586.36	66732.36	133766.23	67033.87	2.00
M_3I_3	39445.97	7650	17050.03	1939.84	66085.84	85064.93	18979.09	1.29
M_3I_4	39445.97	7650	17050.03	1293.04	65439.04	51298.70	-14140.34	0.78

CCC = Common cost of cultivation, VCC = Variable cost of cultivation, FCI = Fixed cost of irrigation, VCI = Variable cost of irrigation, TCC = Total cost of cultivation, BCR = Benefit cost ratio

The seasonal gross return, net return, total cost, and BCR for okra cultivation under various drip irrigation levels and mulch treatments are shown in Table 8. Highest gross return (₹ 336363.63) and net return (₹ 266719.52) per hectare were observed in M_1I_2 treatment combination while the lowest gross return of ₹ 51298.70 per hectare was observed in M_3I_4. The highest and lowest benefit cost ratios were observed as 4.83 and 0.78 under treatment combinations of M_1I_2 and M_3I_4 respectively as indicated in Table 8. M_1I_2 treatment combination was efficient in water saving, providing better yield and maximum seasonal gross return. These findings were akin with Singh *et al.* (2009) and Pradhan *et al*. (2010). Based on the economic analysis of the okra cultivation, silver black plastic mulch in combination with 0.8 ET_c drip irrigation levels was found to be more economical and cost effective as compared to other treatments.

4. Conclusion

The reduced cost of weeding and irrigation along with greater economic returns helps in sustainable crop production. Better results can be achieved by adopting silver black plastic mulch in combination with 0.8 ETc drip irrigation levels in terms maximum crop yield and gross return from summer okra cultivation by reducing

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the water utilization since water resources in the study area are limited during summer season. The economic analysis of different mulch conditions and drip irrigation level treatment combinations will be helpful in guiding the farming community of the region to adopt these water saving techniques for improving their crop production economically.

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