



Effect of Irrigation Levels and Plastic Mulch on Summer Okra (*Abelmoschus esculentus* L. Moench.)

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Abstract

An experiment was conducted to study the effect of irrigation levels and plastic mulch on okra (*Abelmoschus esculentus* L. Moench.) during summer season in 2017 at Instructional Farm, CAET, JAU, Junagadh. The effect of four drip irrigation levels viz.; 1.0 ETc (I₁), 0.8 ETc (I₂), 0.6 ETc (I₃) and 0.4 ETc (I₄) in conjunction with three mulch conditions; silver black plastic mulch (M₁), black plastic mulch (M₂) and no mulch (M₃) were studied on growth and yield response of okra. The experiment was laid out in split plot design taking twelve treatments replicated thrice with mulching as the main plot factor and irrigation levels as the subplot factor. Results of the study indicated that irrigation levels and mulching significantly influenced weed intensity, dry weight of weed, plant height, no. of fruits per plant, weight of fruits per plant and yield per hectare as compared to drip alone. Weed parameters were recorded lowest in combination of 0.4 ETc with silver black plastic mulch. The treatment combination of 0.8 ETc with silver black plastic mulch recorded maximum values of plant height (69.13 cm), fruits per plant (26.60 nos), weight of fruits per plant (441.67 g), crop yield (22424.24 kg/ha) (174.92 % higher than no mulch treatment) and water use efficiency (57.59 kg/ha-mm). The treatment combination of 0.8 ETc drip irrigation level with silver black plastic mulch was found most economical and resulted in highest crop yield with best water use efficiency.

Keywords: Drip irrigation; plastic mulch; water use efficiency; okra; crop parameters.

1. Introduction

Among the leading sectors, agriculture meets the major prerequisites of developing India. For a sustainable agricultural system water plays a vital role and considered as an essential input for the crop production. Even though India is blessed with ample water resources, the utilizable water for irrigation is actually restricted. It is prudent to make efficient use of water and bring more area under irrigation through available water resources (Zaman *et al.*, 2001). Therefore improvements in irrigation practices are required to increase the crop production and to endure the productivity levels (Tiwari *et al.*, 1998). Low productivity in many arid and semi-arid agricultural systems is often due to inadequate water and nutrient inputs. Productivity of the crop can be increased by adopting improved package of practices, particularly in-situ moisture conservation by mulching as well as high-tech irrigation especially drip irrigation with appropriate irrigation scheduling (Paul *et al.*, 2013).

Okra or Lady's finger (*Abelmoschus esculentus* (L.) Moench.) is one of the important vegetable crops grown throughout the tropics and subtropics of the world and is commonly grown with irrigation in dry season. India is the topmost country, which contributes to 70 % of global okra production. The total okra production in India in the year



2016-17 was 6146 thousand tonnes from an area of 528000 ha (NHB, 2017). In India, okra is commonly cultivated in the states of Gujarat, Maharashtra, Andhra Pradesh, Uttar Pradesh, Tamil Nadu, Karnataka, Haryana and Punjab. Among them, Gujarat is the fifth largest producer of okra in India and it constitutes about 10 % of the total production of okra in the country. According to the year 2016-17 data, the total area under okra cultivation in Gujarat was 73790 ha, with a production of 859.47 thousand tonnes (NHB, 2017). The nutritional value of 100 g of edible portion of okra contains 1.9 g protein, 0.2 g fat, 6.4 g carbohydrate, 0.7 g minerals and 1.2 g fibre (Gopalan *et al.*, 1989).

The Saurashtra region of Gujarat comes under semi-arid climatic zone and characterized by very scanty and erratic rainfall and fairly hot summer season. Water scarcity is a major factor limiting crop growth and yield in agricultural areas of this region. Since okra is a warm weather crop, it is considered as one of the most profitable vegetable crops during summer season. But okra requires sufficient moisture in the soil for faster growth and fruit production. Conserving the soil moisture and thus increasing the production of crop requires judicious use of existing water and its efficient management. This can be accomplished by adopting advanced methods of irrigation and improved water management practices. Drip irrigation in conjunction with soil mulching technology is therefore one of the best water management practice, which can improve the water use efficiency considerably.

Irrigation schedules which maintain soil water near field capacity, found to significantly increase the yield of okra and other crops (Home *et al.*, 2002). Scheduling the irrigation is very critical for the most efficient use of drip irrigation system, as excessive water application reduces yield, whereas insufficient irrigation causes water stress and diminishes production from crop (Abd El-Kader *et al.*, 2010). Irrigation scheduling is necessary which leads to the optimal use of irrigation water which is characterized as the supply of sufficient water to meet the plant needs in the root zone and for avoiding the leaching of nutrients into deeper soil. Direct evaporation from the soil is often a major loss of water which is available in the soil. Reduction of direct evaporation from soil helps to conserve soil moisture, save irrigation water, improve WUE and reduce salt accumulation in surface layer of the soil. Mulching is one of the management practices that can be used for increasing WUE (Rashidi and Keshavarzpour, 2011). This can be done by covering the soil surface with organic or inorganic mulch materials. Plastic mulch not only increases crop yields, soil temperature, and the WUE, but it also stabilizes the daily range of soil temperature (Xing *et al.*, 2012), which can benefit crop growth. Therefore use of plastic mulch in combination with drip irrigation will be beneficial through their influence on conservation of soil moisture, improving the WUE and thus increase in crop yield. Keeping this in background, a research work was carried out to identify the efficient water management strategy for okra crop by adopting different combinations of drip irrigation levels and plastic mulches.

2. Materials and Methods

A field experiment was carried out during summer season (February to May, 2017) at Instructional Farm, College of Agricultural Engineering and Technology, JAU, Junagadh (21.5 °N and 70.1 °E) with an altitude of 61.20 m above MSL. The area is situated in South Saurashtra Agro Climatic Zone of Gujarat State and the climate of the area is typically subtropical and semi-arid type with an average rainfall of 900 mm. The dominant soil texture was clay type with organic carbon content of 0.90 % and field capacity of 23.77 %. The dry bulk density of the soil was 1.37 g/cm³.

The experiment was laid out in split plot design having twelve treatments replicated thrice with mulching as the main plot factor and irrigation levels as the subplot factor. The treatments consisted of four irrigation levels viz., 1.0 ET_c (I₁), 0.8 ET_c (I₂), 0.6 ET_c (I₃) and 0.4 ET_c (I₄) and three mulch conditions; silver black plastic mulch (M₁), black plastic mulch (M₂) and no mulch (M₃). Total size of experimental plot was 9.9 m × 16.4 m. Experiment consisted of total 36 treatment plots of 1.10 m width and 3.5 m length. Individual plots comprised of a 3.5 m long bed with two



rows of summer okra of row spacing 0.30 m. Bed spacing was 1.10 m (center to center) and the plant spacing within row was 0.35 m. Local variety (Gujarat Junagadh Okra - 3 (GJO-3)) of summer okra was used for the experiment. The irrigation network consisted of a main line of 75 mm and submain line of 63 mm diameter PVC pipes and drip laterals of 16 mm \times 0.40 m \times 2 lph LLDPE material. The mulch materials of 25 μ m thickness were laid over the raised bed with drip lateral.

Sowing of okra seeds were done manually on 3rd February 2017. As per RDF for okra (N:P:K 150:50:50 kg/ha), 108.6 kg/ha diammonium phosphate (DAP) and 83.33 kg/ha murate of potash (MOP) were broadcasted before laying the mulch film. The N fertilizer, urea (283.58 kg/ha) was applied through venturi along with irrigation water in 2 splits (30 and 60 Days After Sowing (DAS)). Three hand weeding were done to remove weeds at 30 DAS, 60 DAS and at harvest stage.

JAU meteorological observatory located near to the experimental site delivered the data of daily maximum and minimum temperature, maximum and minimum relative humidity, solar radiation and wind speed and they were used to compute daily reference evapotranspiration (ET_0) according to FAO-56 (Allen *et al.*, 1998). Daily crop evapotranspiration (ET_c) was calculated as the product of ET_0 and the crop coefficient (K_c) for different growth stages of summer okra. But the information about K_c values of okra is not stated either in FAO-24 (Doorenbos and Pruitt, 1977) or in FAO-56 (Allen *et al.*, 1998). Therefore crop coefficient (K_c) values for different growth stages of okra as determined by Panigrahi and Sahu (2013) were adopted for the experiment. The crop coefficient values of okra crop were reduced by 10 % to account for the effect of plastic mulching on ET_c .

The influence of different irrigation levels and mulch conditions on weed parameters; weed intensity and dry weight of weed per m^2 at 30 DAS, 60 DAS and harvest stage were analyzed. The effects of irrigation levels and mulch conditions on crop parameters were studied in terms of plant growth parameters and yield attributes. The mean values of heights of plants at harvest stage, number and weight of fruit sets per plant, yield attributes (length and diameter of fruit) and crop yield were worked out treatment wise. First picking of okra fruit was done at 48 DAS (23rd March 2017) and it was repeated at alternate days up to 99 DAS. The okra fruit yield obtained for each treatment was divided by seasonal irrigation water application for the respective treatment in order to determine the WUE. The statistical analysis of various observations obtained from the investigation was carried out by means of split plot design and significance of variance was tested using F test (Panse and Sukhatme, 1985).

3. Results and Discussion

3.1 Weed parameters

The weed intensity (weed count/ m^2) at 30 DAS, 60 DAS and harvest stage was significantly affected by the plastic mulch and drip irrigation levels at 1 % significance level. The treatment combination of M_1I_4 resulted in minimum weed intensity and maximum weed intensity was observed in treatment combination of M_3I_1 and it was found significantly higher than the rest of treatment combinations at 5 % significance level as presented in Table 1 and Figure 1(a). The dry weight of weed (g/m^2) at 30 DAS, 60 DAS and harvest stage was also significantly affected by the plastic mulch and irrigation levels at 1 % significance level. The lowest dry weight of weed was observed in treatment combination M_1I_4 and the treatment combination of M_3I_1 showed significantly highest dry weight of weed at 1 % significance level. The weed intensity and dry weight of weed were observed lowest in silver black plastic mulch as shown in Table 1 and Figure 1(a) and (b). The silver black plastic and black plastic mulch suppressed the weeds due to less exposure of weed seeds to sunlight and thus the weed growth was found minimum under these mulch materials. The results obtained were in close agreement with those of Aminu-Taiwo *et al.* (2014), Naik *et al.*



(2015) and Singh and Ghosal (2015). The enhanced weed growth under I₁ irrigation level was due to more application of water.

Table 1 Effect of irrigation levels and plastic mulch on weed parameters

Treatments	Weed intensity, nos/m ²			Dry weight of weed, g/m ²		
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
M ₁ I ₁	16.33	21.00	25.67	7.88	6.70	10.76
M ₁ I ₂	13.67	20.00	24.00	7.71	6.37	9.31
M ₁ I ₃	10.67	14.00	23.67	4.26	5.74	7.28
M ₁ I ₄	8.33	12.67	22.67	4.00	4.07	6.07
M ₂ I ₁	25.33	30.00	38.67	9.57	9.02	13.11
M ₂ I ₂	21.00	23.67	35.00	9.42	7.97	11.30
M ₂ I ₃	17.00	23.67	28.33	5.50	6.90	9.89
M ₂ I ₄	11.00	16.67	27.33	4.59	6.26	8.05
M ₃ I ₁	71.67	87.33	103.33	38.70	48.09	50.19
M ₃ I ₂	68.67	74.67	100.67	33.47	39.75	48.38
M ₃ I ₃	50.67	65.00	89.33	31.17	35.85	41.94
M ₃ I ₄	48.67	56.33	77.67	28.46	31.30	33.28
C.D. at 5 %	2.57	2.89	3.24	0.92	1.40	1.95
S.Em.±	7.64	8.60	9.63	2.74	4.15	5.80

C.D. = Critical difference, S.Em. = Standard error of mean

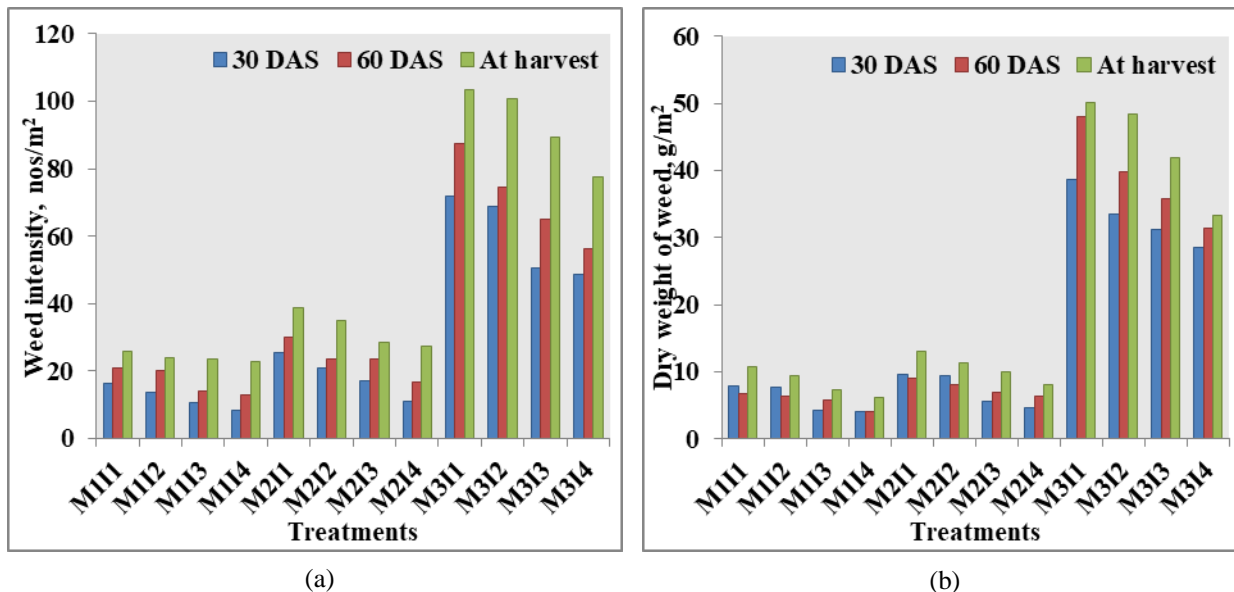


Figure 1 Effect of irrigation levels and plastic mulch on weed parameters; weed intensity (a) and dry weight of weed (b).



3.2 Crop parameters

A significant difference in height of plant at harvest stage was observed under different mulch conditions and drip irrigation levels alone at 1 % significance level. The higher plant height of 69.13 cm was observed with treatment M_1I_2 at 5 % significance level, which was at par with M_1I_1 , M_1I_3 and M_2I_2 while lower plant height was recorded with M_3I_4 treatment (18.96 cm) as shown in Table 2 and Figure 2(a). Drip irrigation along with plastic mulching resulted in higher plant height of okra due to soil moisture and temperature maintenance at an optimum level by mulch material. Therefore the use of plastic mulch might have enhanced nutrient uptake and helped the crop for improving plant height by virtue of less weed intensity and dry weight of weed. The results were in accord with those reported by Singh *et al.* (2009), Birbal *et al.* (2013) and Alenazi *et al.* (2015).

The treatment combination of different mulch conditions and drip irrigation levels caused a significant difference in number of fruits per plant at 5 % significance level. The highest number of fruits per plant was observed in treatment combination of M_1I_2 (26.60 nos) and it was at par with treatment combination M_1I_1 and M_2I_2 . The lowest number of fruits per plant was obtained from treatment combination M_3I_4 (6.74 nos) which was at par with treatment combination M_3I_3 (Table 2 and Figure 2(b)). Similar results were observed by Birbal *et al.* (2013) in okra, Tyagi and Sharma (2013) and Alenazi *et al.* (2015).

Maximum weight of fruits per plant of 441.67 g was observed in treatment combination of M_1I_2 and it was found to be at par with treatment combinations of M_1I_1 while minimum weight of fruits per plant was observed in M_3I_4 (83.37 g) which was at par with treatment combination of M_3I_3 (Figure 2(c)). The treatment combination of different mulch conditions and drip irrigation levels indicated a significant difference in weight of fruits per plant at 5 % significance level as given in Table 2.

The yield attributes; length and diameter of individual fruits selected randomly from each treatment was measured using digital vernier caliper. The mean value of length and diameter of each fruit was worked out and analyzed statistically as per treatments and presented in Figure 2(d) and (e). The interaction effect of different mulch conditions and drip irrigation levels on length and diameter of fruit was found statistically non-significant (Table 2). Maximum length (124.27 mm) and diameter (18.72 mm) of fruit were observed in M_1I_2 whereas minimum length (89.33 mm) and diameter (13.81 mm) of fruit were recorded with treatment combination of M_3I_3 .

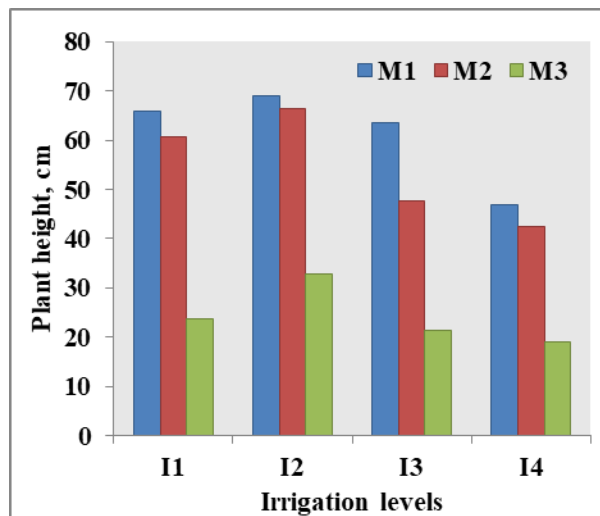
The highest crop yield was observed in treatment combination of M_1I_2 (22424.24 kg/ha) and it was found significantly higher than the rest of treatment at 5 % significance level. The findings obtained were akin with those of Singh *et al.* (2009) and Zhang *et al.* (2017). The lowest crop yield of 3419.91 kg/ha was recorded in with M_3I_4 and it was observed to be at par with M_3I_3 (Table 2 and Figure 2(f)). With the increase in applied water, sometimes yield increases and at a certain point the yield obtain a peak value. Beyond this value more water application will result in decreased yield. The increased yield in I_2 than I_1 might be due to this reason. Crop yield under silver black plastic mulch and black plastic mulch treatments were observed to be higher than no mulch treatment by 174.92 % and 136.19 % respectively. The higher soil moisture content maintained under plastic mulched treatments and better control of weed than in the bare soil plots had positively reflected on the vegetative and yield parameters. Consequently, use of silver black and black plastic mulch as soil cover increased the yield of okra.



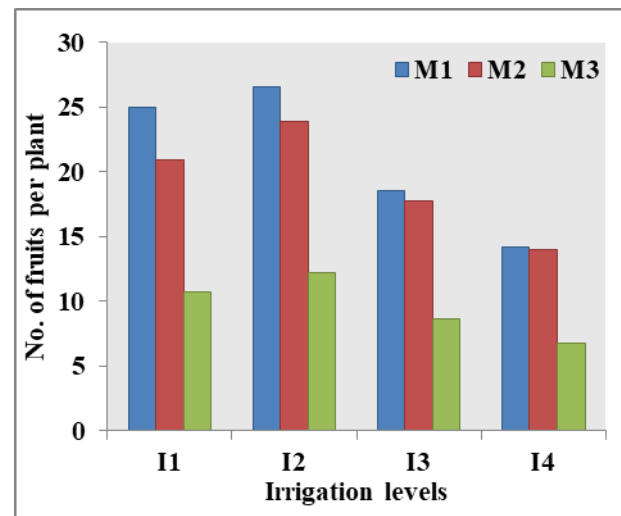
Table 2 Effect of irrigation levels and plastic mulch on crop parameters

Treatments	Plant height, cm	Fruits per plant, nos	Weight of fruits per plant, g	Length of fruit, mm	Diameter of fruit, mm	Mean crop yield, kg/ha
M ₁ I ₁	65.80	25.00	415.78	122.80	18.12	19653.68
M ₁ I ₂	69.13	26.60	441.67	124.27	18.72	22424.24
M ₁ I ₃	63.59	18.51	283.49	110.30	16.67	15948.05
M ₁ I ₄	46.80	14.19	194.08	108.87	15.87	10692.64
M ₂ I ₁	60.68	20.92	322.39	110.43	17.27	17099.57
M ₂ I ₂	66.39	23.85	378.72	120.03	17.61	19506.49
M ₂ I ₃	47.79	17.75	244.67	112.83	16.70	13341.99
M ₂ I ₄	42.41	13.99	210.67	104.17	15.60	9090.91
M ₃ I ₁	23.72	10.75	151.00	97.93	14.54	6987.01
M ₃ I ₂	32.88	12.17	159.36	104.53	15.53	8917.75
M ₃ I ₃	21.42	8.62	106.38	89.33	14.11	5671.00
M ₃ I ₄	18.96	6.74	83.37	92.70	13.81	3419.91
C.D. at 5 %	2.74	1.07	18.94	8.01	1.11	910.13
S.Em.±	8.14	3.19	56.28	NS	NS	2704.16

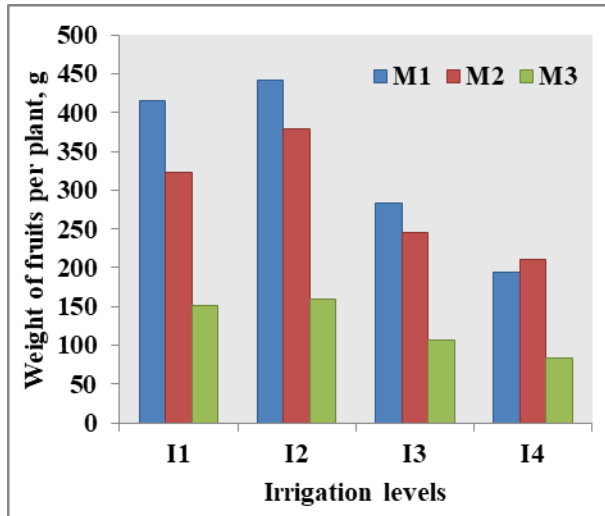
C.D. = Critical difference, S.Em. = Standard error of mean, NS = Not Significant



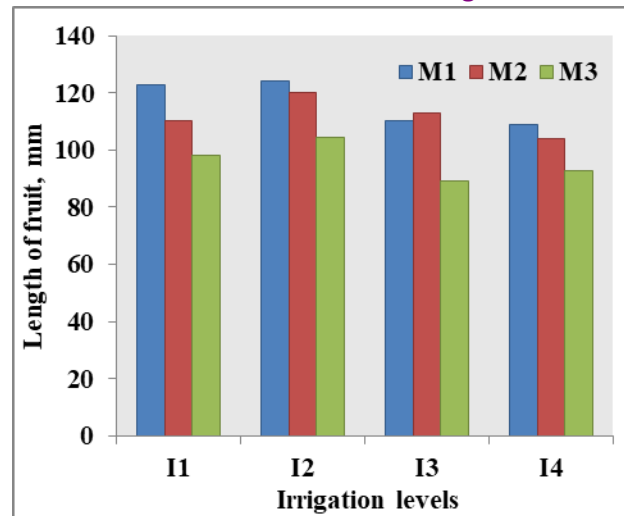
(a)



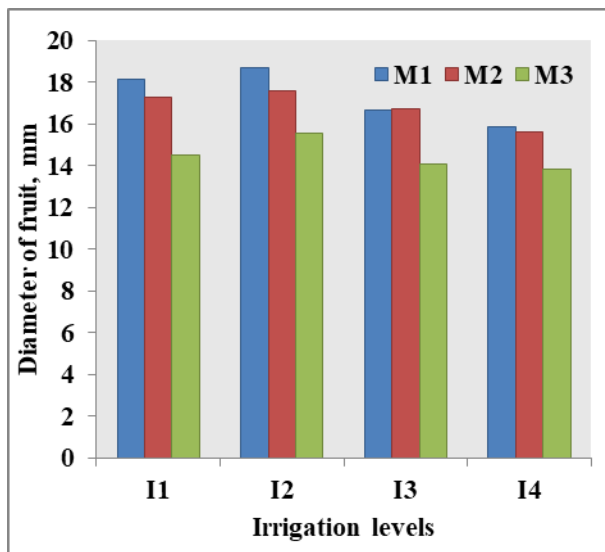
(b)



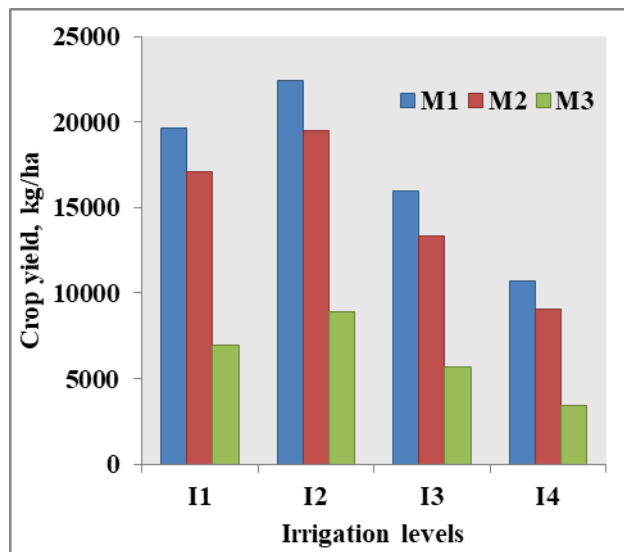
(c)



(d)



(e)



(f)

Figure 2 Effect of irrigation levels and plastic mulch on crop parameters; plant height (a), number of fruits per plant (b), weight of fruits per plant (c), length of fruit (d), diameter of fruit (e) and crop yield (f).



3.3 Water use efficiency

Maximum water use efficiency was obtained in treatment combination M₁I₂ (57.59 kg/ha-mm) whereas minimum WUE of 12.15 kg/ha-mm was recorded in M₃I₁ as shown in Table 3 and Figure 3. Similar finding was given by Zhang *et al.* (2017) which gave higher WUE under 0.8 ET_c and this result was sustained by Alenazi *et al.* (2015). The main reason for the higher WUE could be due to the uniform distribution of irrigation water, lower evaporation from the soil surface and easy availability of water and nutrients within the root zone. Also since evaporation from mulched treatment is minimal, transpiration is increased and increasing transpiration improves stomata opening, and photosynthesis (Ayars *et al.*, 1999). This could improve the okra crop yield.

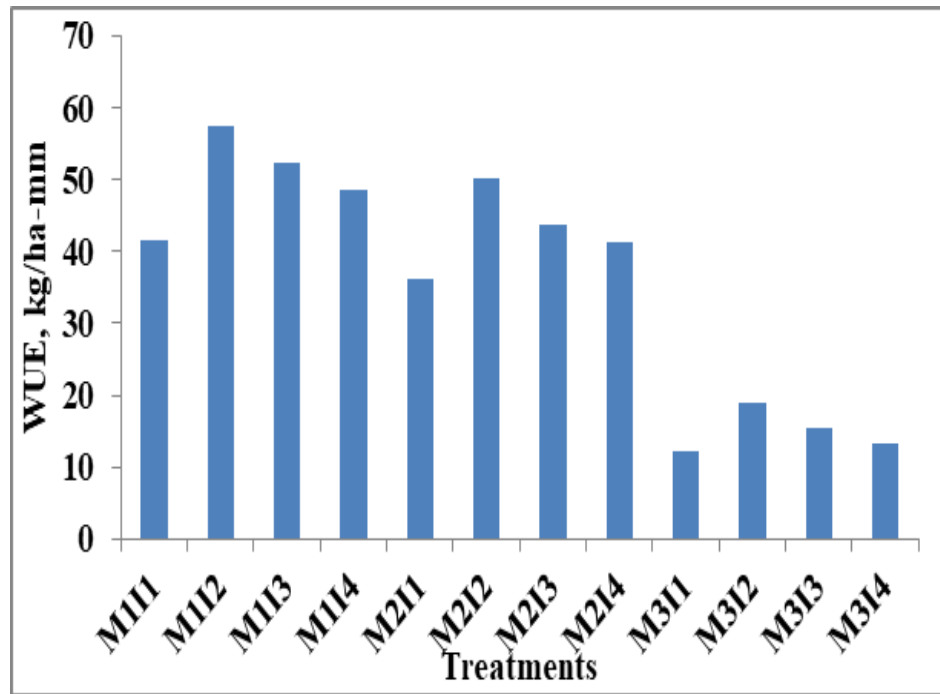


Figure 3 Effect of irrigation levels and plastic mulch on water use efficiency



Table 3 Effect of irrigation levels and plastic mulch on water use efficiency

Treatments	Mean crop yield, kg/ha	Irrigation water depth, mm	WUE, kg/ha.mm
M ₁ I ₁	19653.67	474.21	41.44
M ₁ I ₂	22424.24	389.37	57.59
M ₁ I ₃	15948.05	304.52	52.37
M ₁ I ₄	10692.64	219.68	48.67
M ₂ I ₁	17099.56	474.21	36.05
M ₂ I ₂	19506.49	389.37	50.09
M ₂ I ₃	13341.99	304.52	43.81
M ₂ I ₄	9090.90	219.68	41.38
M ₃ I ₁	6987.01	574.84	12.15
M ₃ I ₂	8917.75	469.87	18.97
M ₃ I ₃	5671.00	364.91	15.54
M ₃ I ₄	3419.91	259.94	13.15

4. Conclusion

The use of drip irrigation in combination with plastic mulch was found significantly superior for increasing the crop yield of okra and reducing the total amount of water applied under plastic mulch. Crop yield obtained in silver black plastic mulch treatment was observed to be 174.92 % higher than no mulch treatment whereas yield under 0.8 ET_c drip irrigation level was found 119.14 % higher than that with 0.4 ET_c level. The results of the investigation revealed that the drip irrigation level 0.8 ET_c along with silver black plastic mulch was most economical and resulted in highest crop yield with best water use efficiency. The increase in WUE increases the additional area under cultivation by using saved water and increased the gross income (Murali Krishna *et al.*, 2014). Therefore drip irrigation scheduled at 0.8 ET_c in conjunction with silver black plastic mulch can be adopted in water scarce situation of agricultural areas in the state as better water management option.

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