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Interactive effects of irrigation and mulches on soil temperature and yield of okra (*Abelmoschus esculentus* L.)

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Abstract

This experiment was conducted to evaluate the comparative effect of different irrigation levels in combination with mulching materials on soil temperature, water use efficiency and yield of okra *(Abelmoschus esculentus* L.). Irrigation was scheduled at (I_1) 15% available soil moisture depletion (ASMD), (I_2) 30% ASMD (I_3), 45% ASMD, and (I_4) 60% ASMD with combination of black plastic mulch (M_1), wheat straw mulch (M_2) and bare soil (M_3) as a control. Comparatively, black plastic mulch increased soil temperature whiles wheat straw mulch decreased it over bare soil (control). The yield parameters; number of fruits, fruit yield per plant, per plot and per hectare were 4.03, 0.68 kg plant^{-1}, 17.2 kg plot^{-1}, and 17.2 tha^{-1} recorded in M_3I_2 (30% ASMD +black plastic mulch). The highest WUE was 292.97 kg/ha-cm obtained in treatment, M_3I_2. Using drip irrigation system, black plastic mulch resulted to 14.1% water saving whiles wheat straw mulch 5.27% over bare soil.

Keywords: Mulch, soil moisture, temperature, water use efficiency and yield

Introduction

Agriculture is the fundamental requirement for human survival and supports life and generates rural employment. Irrigation water is a crucial factor in meeting the food demand of ever increasing population of the world. Furthermore, the major resources inherent to modern agriculture are getting exhausted. These natural resources include arable land with fertile soil and fresh water. Several hectares of farm land remains deprived of cultivation due to the irregular precipitation, falling water table and lack of irrigation facilities. Water is a precious natural resource therefore, the development of water resources and their effective management is quite important for survival and economic growth of a nation. Current trends of balancing the demand and supply of water to ensure self-sufficiency in agriculture indicate that fresh water resources are inadequate and several regions are facing water shortage during post rainy season. Therefore, water saving irrigation methods should be followed in order to save water and maximize yield

Rajasthan is one of the driest states in India with large areas under arid and semi-arid conditions. The only source of water; rainfall, is subject to a high degree of variability, inadequacy and uncertainty due to climatic conditions in the state. The average annual rainfall is 531 mm as against the national average of 880 mm and ranges from 100 mm to 1000 mm in the State. Furthermore, the annual potential evapotranspiration is quite high, between 1400-1470 mm, across the state indicating that there is a net water deficit situation on an annual basis (Mudrakartha, 2010) [11] Except for a couple of months during a good monsoon season, the net water deficiency situation prevails throughout the year. In areas of recurrent water scarcity and long drought spells such as in Udaipur (Raj.), deficit irrigation (DI) which involves irrigating less than full evapotranspiration (ETc) with mulch practice becomes a common practice in mitigating yield reductions thus, necessitates development of water management methods that maximizes water use efficiency.

Drip irrigation is the system for slow and regular application of water, directly to the root zone of plants, through network of economically designed plastic pipes with low-discharge emitters. It limits the irrigation water closely to the consumptive use of plants. Thus, drip irrigation minimizes the conventional losses such as deep percolation, run-off and soil evaporation. It is understood that conventional surface irrigation methods supply water unevenly with respect to space and time. In addition, losses such as evaporation, percolation, conveyance and seepage are major constraints in obtaining higher water use efficiency. Thus, there is an urgent need for maximum and efficient utilization of available resources; of which pressurized irrigation system has assumed greater importance.

Nowadays application of black plastic mulch film is becoming popular and very good results have been achieved particularly in dry land agriculture. The use of polyethylene mulch has been reported to conserve soil moisture appreciably. Hence, under prevailing drought and water scarcity conditions, conservation of soil moisture and to ensure availability of soil moisture to crop is of much importance. The black polyethylene mulch also checks all types of weeds in addition to soil moisture conservation; therefore, black plastic mulch is more beneficial (Mohapatra *et al*, 1999) [10]. The beneficial effects of organic and synthetic mulches for crop production have been widely discussed by (Ravi and Lourduraj 1996) [13]. Organic mulches including sawdust, dry grass (lawn clippings), maize cobs, rice and wheat straw, water hyacinth etc., have been very effective for vegetable growth and yield by improving moisture content of soil, heat energy and add some of the organic nitrogen and other mineral to improve nutrient status of the soil (Saeed and Ahmad, 2009). Mulching has been used to obtain good vegetable growth and yield in crops like sweet potato, potato, tomato and pepper (Awodoyin and Ogunyemi, 2005; Rahman *et al*., 2006) [12]. Organic mulches have the advantage of being biodegradable, but decomposition may result in a temporary reduction in soil mineral nitrogen.

Okra (*Abelmoschus esculentus L*.) is a cheap and nutritious vegetable. Hundred grams of consumable unripe okra contains 10.4 g dry matter, 3100 calories of energy, 1.8 g protein, 90 mg calcium, 110 mg iron, 0.1mg carotene, 0.01 mg thiamine, 0.08mg riboflavin, 0.08 mg niacin and 18 mg vitamin C, (Thamburaj and Narendra, 2001). Okra is a high water use crop despite having considerable drought resistance. For high yields, an adequate water supply and relatively moist soils are required during the total growing period. Reduction in water supply during the growing period in general has an adverse effect on yield and the greatest reduction in yield occurs when there is a continuous water shortage until the time of first picking (Al-Harbi *et al*, 2008) [1]. Therefore the aim of this study was to determine the effect of drip irrigation levels and mulching on soil temperature and yield of okra in the field.

Materials and methods

This experiment was carried out at the Plasticulture Farm of the College of Technology and Engineering, Maharana Pratap University of Agriculture and Technology (MPUAT), Udaipur, Rajasthan in March-July 2017. Udaipur is situated on longitude of 75°42'E and latitude of 24°35' N and at an elevation of 582.17 meters above mean sea level. The experimental soil has sandy loam texture (69.37 % Coarse sand, 19.81 % fine sand, 18.26 % silt and 12.37 % clay), with bulk density 1.45 kg m-^{3}, basic infiltration rate 2.8 cmhr^{-1}, and hydraulic conductivity 125 cmday-^{1}. The volumetric soil water content at field capacity (-0.033 MPa) and permanent wilt point (-1.50 MPa) are 20.95% and 6.8%, respectively. The chemical properties of the soil were pH 7.78, EC 1.26 dS m^{-1}, organic carbon 0.5%, calcium carbonate 3%, available-nitrogen, phosphorous and potassium as 96.86, 28.63 and 103.04 kgha^{-1}, respectively as determined according to (Dewis and Freitas 1977, and Klute, 1986) [7].

The experiment was arranged in a 4x3 factorial randomized complete block design (RCBD) with three replications in 12 plots. Irrigation constituted (I_1), 15% Available Soil Moisture Depletion (ASMD), (I_2) 30% ASMD, (I_3) 45% ASMD and (I_4). 60% ASMD, in combination with black plastic mulch (M_3), wheat straw mulch (M_2) and bare soil (M_1) as control. The ASMD method was employed to determine the consumptive use of irrigated okra crop by gravimetric method. Soil moisture was measured by collecting soil samples at the depths of 0-25 cm for the first 25 days, at 0 - 35 cm for the next 30 days and at 0 - 45 cm for the remaining irrigation period. The targeted moisture was determined based on the formula.

$$M_{2i} = \theta_{fc} - \left(\theta_{fc} - \theta_{wp}\right)MAD \quad (1)$$

Where; $\theta_{fc=}$ Soil moisture at field capacity %, $\theta_{wp\ =}$ Soil moisture at permanent wilting point % and MAD= management allowable deficit (decimal). From the soil moisture content so obtained, the quantity of water consumed by the crop in evaporation and transpiration or to be applied to the field was estimated.

$$\mathrm{d} = \sum_{i=1}^{n}\left(\frac{M1i - M2i}{100} \times Ai \times Di\right) \quad (2)$$

Where; d= net depth of water applied during an irrigation (cm), n=number of soil layers sampled in the root zone depth D, M_{1i}= moisture content in the ith layer of soil at field capacity (%), M_{2i} = moisture content in the ith layer of soil before irrigation (%) A_i = apparent specific gravity of the ith layer of the soil, D_i = depth of ith layer of the soil (cm). The volume of irrigation water applied using a drip system was determined from the depth of irrigation.

$$V = \sum_{i=1}^{n}\left(0.1\frac{d}{EU}\right)XCA \quad (3)$$

Where; V=Volume of water required (liter/day/plant) d= net depth of water applied during an irrigation, (cm), CA= crop area (cm^2), E_U= Emission uniformity (%). Furthermore, for the known discharge rate of emitters, the water application period for irrigation was calculated by the following equation.

$$T = \frac{V}{q} \quad (4)$$

T=Duration of irrigation (hrs), quantity of water to be applied (litters), average emitter discharge (lph).

The row and plant spacing were 50 cm and 30 cm respectively with a Nath okra F_1 Hybrid variety Amrapali (NOH-1053), a short early maturing crop plant which were soaked in water for about 12 hours, before sowing to obtain better germination. farm yard manure at the rate of 25t/ha was incorporated before planting and the M_2 plots were covered with a mulch rate of 6 t/ha, while a sheet of 25 micron black plastic mulch was placed over the M_3 plots using the projections to fix it in the soil by heaps of soil on the four corners of the beds.

Soil thermometers were installed at 5 cm and 10 cm in each plot and soil temperature were recorded in the morning and afternoon respectively. Yield parameters measured included, number of fruits per plant, fruit weight per plant, fruit weight per plot and fruit yield per hectare. Analysis of variance (SAS, 1998) was performed on the data to determine effects of treatments and their interactions at 5% significant levels.

Result and Discussion

Irrigation applied: The available soil water on volume basis was determined as the difference between field capacity (20.95%) and permanent wilting point (6.8%). Irrigation was scheduled to commence when soil moisture was depleted to a required treatment level at 18.83, 16.71, 14.58 and 12.46 % for I_1, I_2, I_3 and I_4 respectively. The black plastic mulch (M_3) was effective in conserving soil moisture than the other treatments hence could take more days before the next irrigation. It was also revealed that irrigation interval increased with increase in water deficit and was conversed for number of irrigation. This is attributed to the effectiveness of mulch to conserve soil moisture and the decreased crop evapotranspiration associated with water stress. Consequently, more moisture saving percentage was recorded in soil covered with surface mulch i.e. M_3 (14.1 %) and M_2 (5.4 %) over M_1. These results are in agreement with report by (Mahadeen 2014) [8] that the mulched plots had higher soil moisture content than bare soil plots, which positively reflected on vegetative and yield parameters. Covering soils with surface mulch reduced the amount of water lost through evaporation.

Soil temperature

The influence of mulching on maximum (8:00AM), minimum (2:00PM) and mean soil temperature at 5 cm and 10 cm depths are presented in (Table 1). The weekly average temperature for morning and afternoon for both 5 cm and 10 cm depths are shown graphically (Figures 1-4). The average temperature revealed that M_3 recorded an increase in temperatures of (5.9 %) and (8.0%) while M_2 had a decrease of (8.1 %) and (5.4%) over M_1 (control) at 5 cm and 10 cm depths respectively and the afternoon records indicated that M_3 revealed an increase in temperatures of (4.9 %) and (4.1%) while M_2 had a decrease of (5.1 %) and (5.0%) over M_1 (control) at 5cm and 10 cm depths, respectively. The soil temperature in black plastic mulch plots were on average 1.6°C and 2.2°C (morning), 1.8°C and 1.5°C (afternoon) higher than bare soil plots and wheat straw mulch was on average 2.2°C and 1.5°C (morning), 1.9°C and 1.9°C (afternoon) lower than bare soil plots at 5cm and 10cm depths respectively. This trend showed that the presence of soil moisture was influential in moderating soil temperature regardless of the type of mulch and are in conformity with reports by (Gupta, 1989, and Awodoyin *et al.*, 2007) [6, 2], that plastic mulch increase soil temperature and (Sinkevičienė *et al*, 2009) revealed that organic mulches decreases soil temperature.

Table 1: Variation of soil temperature at 5 cm and 10 cm in different treatments

Treatments	Temperature Range @ 5 cm (⁰C)		Temperature Range @ 10 cm (⁰C)		Mean Temperature @ 5 cm (⁰C)		Mean Temperature @ 10 cm (⁰C)	
	Min	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
M_1I_1	22.1-28.7	30-38.7	22-28.8	34.3-38.2	26.0	35.8	26.5	36.8
M_2I_1	19.8-27.2	29.5-36.5	20.5-27.5	32.5-36.3	23.8	33.8	24.9	34.9
M_3I_1	23.8-30.2	35.6-39.4	24.8-30.6	36.4-39.8	27.6	37.5	28.4	38.2
$M1I_2$	22.7-29	30.1-39	22.5-29.4	35.2-38.3	26.4	36.0	26.7	37.1
M_2I_2	21-27.4	29.8-36.6	21.3-27.8	33.3-36.4	24.4	34.3	25.4	35.3
M_3I_2	25-30	36.2-39.5	25.8-30.8	37-40.2	28.2	37.9	29.0	38.5
M_1I_3	26-29.7	30.2-39.2	23.1-29.7	35.5-39	28.2	36.6	27.0	37.4
M_2I_3	19.4-28	30-36.9	20.2-28.5	33.7-37.3	25.6	34.7	25.5	35.6
M_3I_3	24.8 -31	36.8-39.8	25.2-31.1	37.3-40.3	28.4	38.3	29.1	38.9
M_1I_4	22.8-39.8	30.8-39.5	23.8-30	35.8-39.3	26.8	36.8	27.3	37.5
M_2I_4	20-27.8	30.3-37.1	21.7-28.8	33.8-37.5	24.9	35.0	25.8	35.7
M_3I_4	26.2-37.1	36.6-40.4	26.5-31.8	37.4- 41.2	29.4	38.7	29.7	39.3

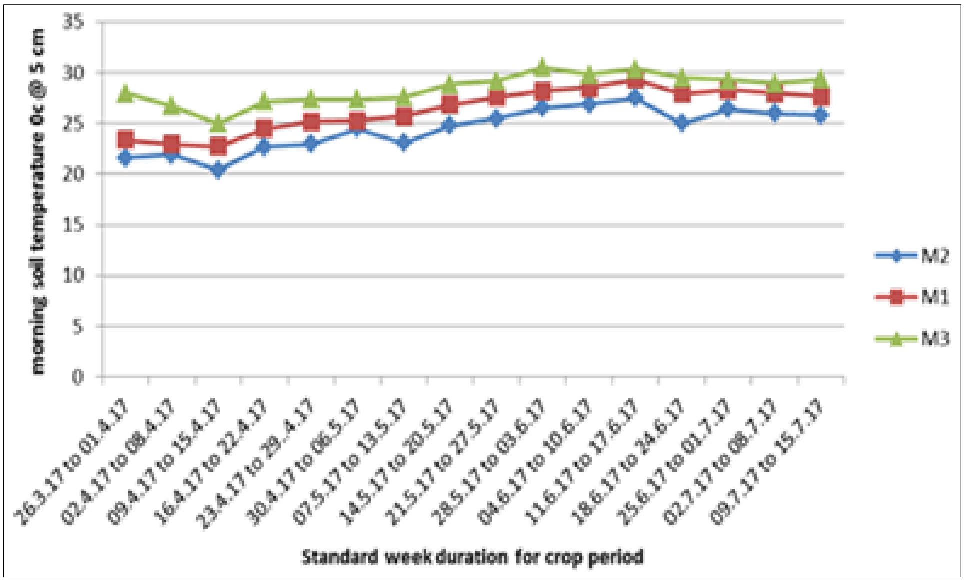

Fig 1: 5 cm depth (morning)

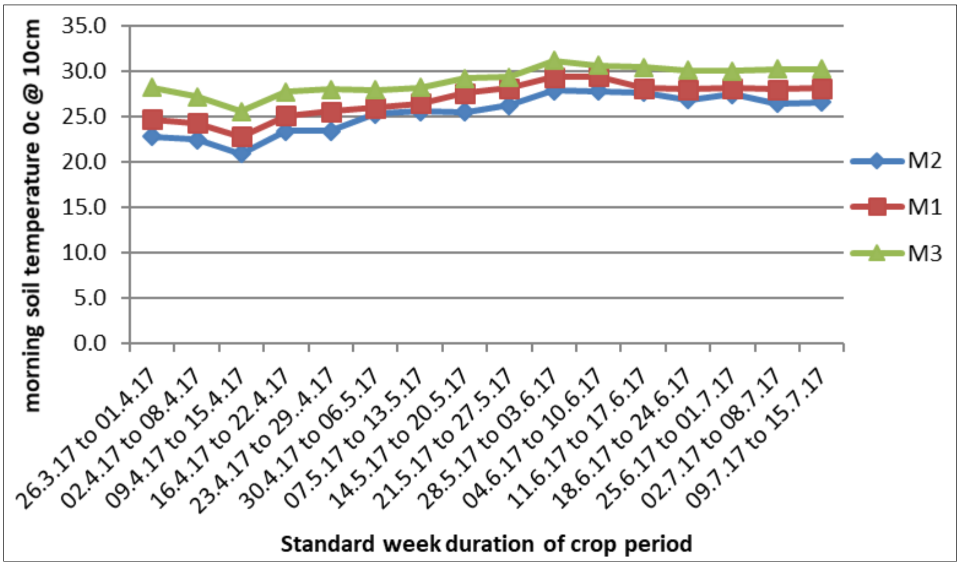

Fig 2: 10 cm depth (morning)

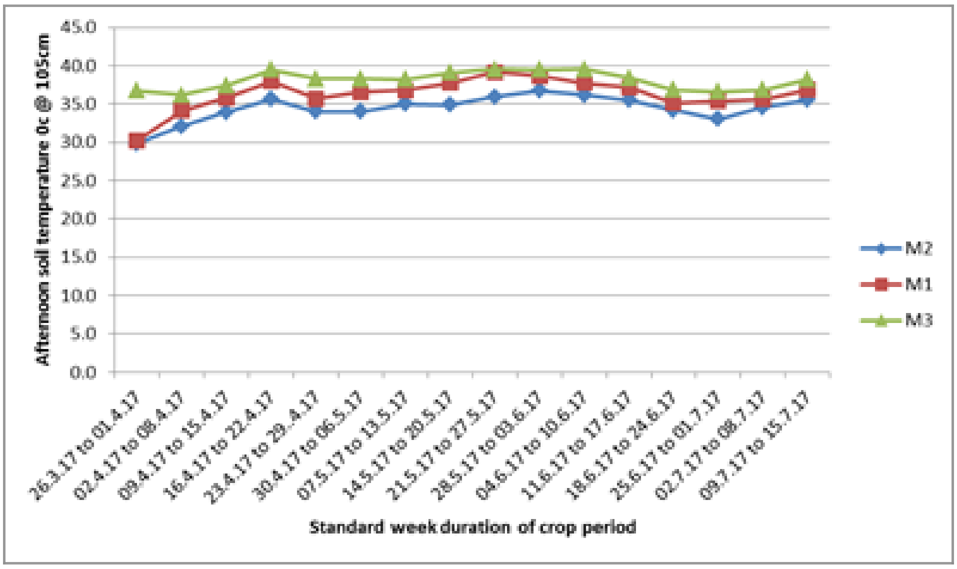

Fig 3: 5 cm depth (afternoon)

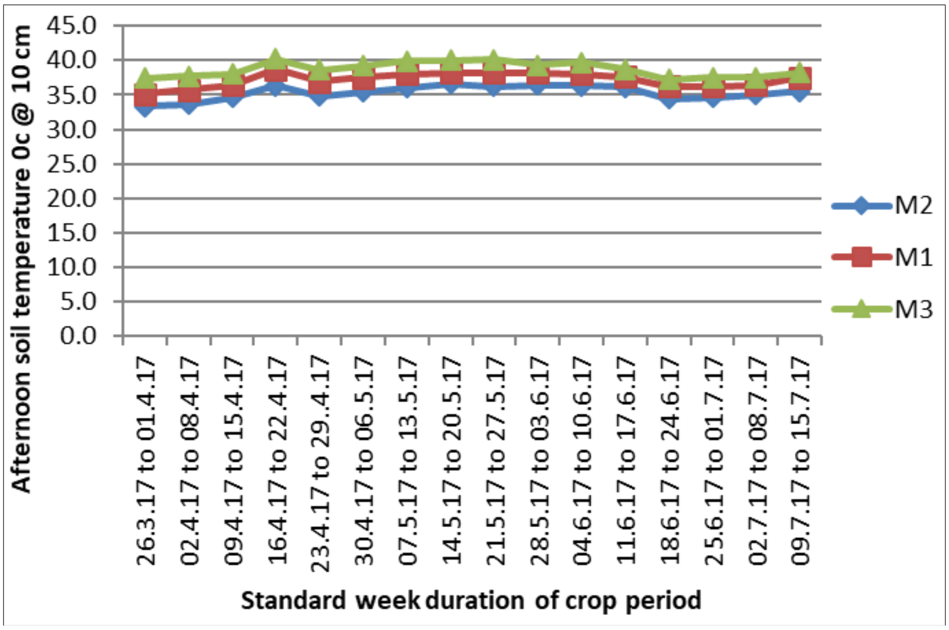

Fig 4: 10 cm depth (afternoon)

Table 2: Effect of mulching and irrigation on marketable yield attributes of okra crop

Treatments	No of fruits per plant	Fruits yield per plant (kg/plant)	Fruits yield per plot (kg/plot)	Marketable yield (t/ha)	Water used (cm)	Water used efficiency (kg/ha-cm)
Mulches						
M_1	2.19	0.42	10.70	10.70	65.64	162.91
M_2	2.76	0.50	13.10	13.10	60.55	216.34
M_3	3.49	0.64	15.98	15.98	57.52	277.92
S. Em.±	0.08	0.01	0.52	0.52	0.63	1.23
CD (p<0.05)	0.23*	0.04*	1.53*	1.53*	1.84*	3.60*
Irrigation levels						
I_1	2.82	0.50	13.56	13.56	68.83	156.67
I_2	3.13	0.58	14.49	14.49	62.71	175.17
I_3	2.96	0.54	13.64	13.64	60.35	171.07
I4	2.36	0.47	11.34	11.34	56.05	154.25
S. Em.±	0.09	0.01	0.60	0.60	0.73	1.42
CD (p<0.05)	0.26*	0.04*	1.76*	1.76*	2.15*	4.16*
I x MS. Em.±	0.15	0.02	1.04	1.04	1.20	2.45
CD (p<0.05)	0.45*	0.07*	3.06^{ns}	3.06^{ns}	3.71^{ns}	7.21*
CV (%)	9.47	8.23	13.62	13.62	3.59	1.94

*****significantly different at 5% level of significance are **^{ns}** not significantly different at 5% level of significance. CD (5%) = critical difference at 5% level; and CV (%) = coefficient of variation in percent.

Yield parameters and water use efficiency

The yield attributes of okra recorded were number of fruits per plant, yield of fruits per plant and yield of fruits per hectare and were significantly (p<0.05) influenced by irrigation and mulch treatments but the interaction shows no significant on the effect on the yield parameter (Table 2). The maximum average number of fruits per plant per harvest, yield of fruits per plant, yield of fruits per hectare were (4.03 plant^{-1}), (0.68 kg per plant), (17.2 tha^{-1}) respectively obtained in M_3I_2 (30% ASMD with Black Plastic mulch). The water use efficiency was highly significantly and the maximum value was 292.38 kg/ha-cm in treatment, M_3I_2 (30 % ASMD with black plastic mulch). This shows that black plastic mulch and proper irrigation scheduling should be done to increase yield and save water and improve okra yield. However, black plastic mulch was more effective in influencing the yield parameters than grass mulched plots and the control. This result agrees with the findings revealed by (Govindappa *et al.,* 2015) [5] that mulching was highly advantageous in crop production with minimized soil moisture transpiration and that mulching achieved the higher yield levels in both fruit and vegetable crops (Mamkagh 2009) [9]. Also (Brown and Channell-butcher 2000) [3] reported using black plastic mulch as soil covering significantly increased yield of okra and their components compared with bare soil. It is evident that black plastic mulches significantly increased the water use efficiency of okra crop over control.

Conclusion

Cultivating sandy loam soil is a promising solution to overcome the fight against hunger especially in the developing countries. The obtained data revealed the significant effect of irrigation levels on fruit yield parameters in combination with mulch treatments and interaction effect. On the basis of these results, it could be inferred that the use of drip in combination with mulching can increase the okra yield and water use efficiency significantly at irrigation level with 30% available soil moisture depletion with plastic mulch. It can be clearly noticed that the plant yield attributes were greater in drip with Black plastic mulch as compared to bare soil. Comparatively, Black plastic mulch surpassed wheat Straw mulch in okra yield, in maintaining water use efficiency, and in general plant growth and yield. The global climate change pervading the crop growing environment should be critically looked into and encourage people especially the smallholder farmers to ‘think outside the box’ of their current practices and capitalize upon certain technologies that exist within their present crops and within the soil systems in which these crops grow. The irrigation level with 30% available soil moisture depletion with plastic treatment is recommended for okra cultivation under similar agro-climatic conditions of Udaipur due to its higher water use efficiency (WUE) of 292.97 kg/ha- cm as compared with other treatments.

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