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Influence of Irrigation Regimes, Frequency and Mulching on Productivity of Bt. Cotton

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High evaporative conditions, scarcity of groundwater and deficient rainfall condition are detrimental to cotton yields in Saurashtra region of Gujarat. Climatic change adds another dimension to this complex nexus of soil-water-plant-atmosphere. Adverse environmental conditions coupled with water scarcity intrigued farmers of this region to adopt drip irrigation with mulch in Bt. cotton for mitigating the impact of climatic aberrations. So far, no study has reported the conjunctive impact of different mulches (silver black plastic mulch and biodegradable plastic mulch), irrigation regimes (0.6, 0.8, and 1.0 ETc) and frequency (2, 3 and 5 days) on economic productivity of Bt. cotton. An experiment was undertaken consecutively for two years (2013-14 and 2014-15) to address this issue. Irrigation scheduling was done based on actual evapotranspiration measured with help of soil moisture sensors. The control treatment was taken as drip with no mulch. Silver black plastic mulch recorded the highest plant height (1.92m), number of sympodial (30.9) and monopodial branches (6.1), number of bolls (61.5), mean boll weight (4.77g), seed cotton yield (4661 kg ha^{-1}), water use efficiency (20.48 kg ha^{-1}mm^{-1}) at 0.8 ETc and 3 days of irrigation frequency. These attributes increased with increase in irrigation regimes and decreased with increase in irrigation frequency in control treatment. The highest benefit cost ratio of 3.28 and internal rate of return of 141.52% was observed in silver black plastic mulch at 0.8 ETc and 3 days of irrigation frequency and the lowest was observed in no mulched treatment at 0.6 ETc and 5 days of irrigation frequency.

Key words: Plastic mulch, Drip irrigation, Moisture regimes, Irrigation frequency

Cotton is an important commercial crop in the world. Indian economy continues to receive great support from the most important commercial fibre crop. However, the cotton productivity is still below the potential mainly, because of high evaporative conditions, scarcity of groundwater, deficient rainfall and poor water management practices like poor irrigation scheduling during water scarce conditions, lack knowledge on the frequency of irrigation during low availability of water, low water application efficiencies, water use efficiencies in surface irrigation practices, the traditional management of farms and the climatic conditions characterized by poor and irregular rainfall. Therefore, there is a need for effective on-farm water management, to increase crop yield and save water resources (Farahani *et al.,* 2008). Adverse environmental conditions coupled with water scarcity intrigued farmers of this region to adopt drip irrigation with mulching in Bt. cotton for mitigating the impact of climatic aberrations. Drip irrigation can reduce input cost, increase yield, give more water productivity than surface irrigation and reduce the risk of yield reduction due to inter-irrigation dry spells (Rajendra *et al.,* 2012). Managing congenial soil moisture in the crop root zone and preventing losses from soil is very much essential for attaining more productivity per drop of water. Mulching reduced water loss, regulate soil temperature, control weeds and increase water use efficiency in cotton (Ramesh *et al.,* 2006; Naliyani *et al.,* 2009; Murugan and Gopinath 2001; Zhang *et al.,* 2005). For appropriate water management, it is necessary to irrigate the crop based on water demand under drip irrigation with plastic mulch (Peter *et al.,* 2003; Patel and Rajput 2007). Relatively few studies were conducted to analyze the conjunctive performance of drip irrigation with silver black plastic mulch and biodegradable plastic mulch on productivity of Bt. cotton under variable irrigation regimes and frequency. Hence, present investigation aimed to study the techno-economic feasibility of drip irrigation with various irrigation regimes, frequency and mulch material on productivity of Bt. cotton.

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Material and Methods

A field experiment was conducted at Junagadh Agricultural University (21°30' N, 70°27' E and 77.5 above mean sea level) to study conjunctive impact of different mulches (silver black plastic mulch and biodegradable plastic mulch) irrigation regimes (0.6 ET_c, 0.8 ET_c, 1.0 ET_c) and frequency (2, 3 and 5 days) on Bt. cotton (Hy-6, BG-II) along with no mulch as control for consecutive two years during Kharif 2013-14 and 2014-15. Split-split plot design with irrigation regimes (I_1=0.6 ET_c, I_2=0.8 ET_c and

I_3=1.0 ETc) as main factor, irrigation frequency (F_1=2 days, F_2= 3 days and F_3=5 days) as sub factor and mulch material (M_1= silver black plastic mulch, M_2= biodegradable plastic mulch and C = control) as sub-sub factor was adopted with twenty seven combinations. Each treatment was replicated thrice. The temporal variation of morphological parameters and yield attributes at the end of experiment were monitored. Experimental field soil is sandy loam (1-1.5 m depth) with volumetric water content at field capacity and wilting point determined at 39 and 15%, respectively. Two cotton seeds were sown at 2.5 cm depth directly through the holes made on the mulch film. Thinning as well as gap filling was done after germination of plants. Package of agronomical practices recommended by Cotton Research Station, Junagadh Agricultural University, Junagadh was adopted. Irrigation scheduling was done based on actual evapotranspiration measured with the help of soil moisture sensors installed at 10 and 50 cm from top of the soil near the root zone of cotton crop in different treatments.

Results and Discussion

Significant difference in the plant height, number of sympodia and number of bolls per plant among the treatments was observed during both the years. Drip irrigation with silver plastic mulch at 0.80 ETc with 3 days of irrigation frequency recorded taller plants, with more number of bolls and sympodia per plant than the other treatments, because water was released strictly in the root zone maintaining soil: air ratio at an optimum level for plant growth and development. This situation might have increased the availability of nutrients in the soil throughout the growing season, which ultimately resulted in higher growth and development of cotton (Tindall *et al.,* 1991; Farias *et al.,* 1998).

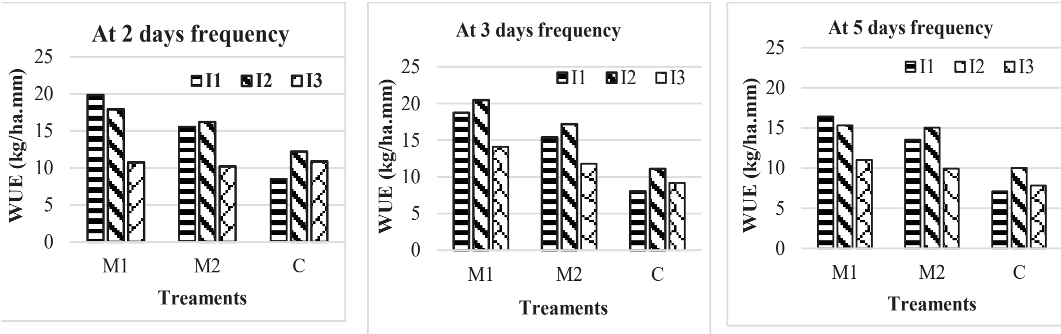

Fig.1 Water Use Efficiency at different treatments

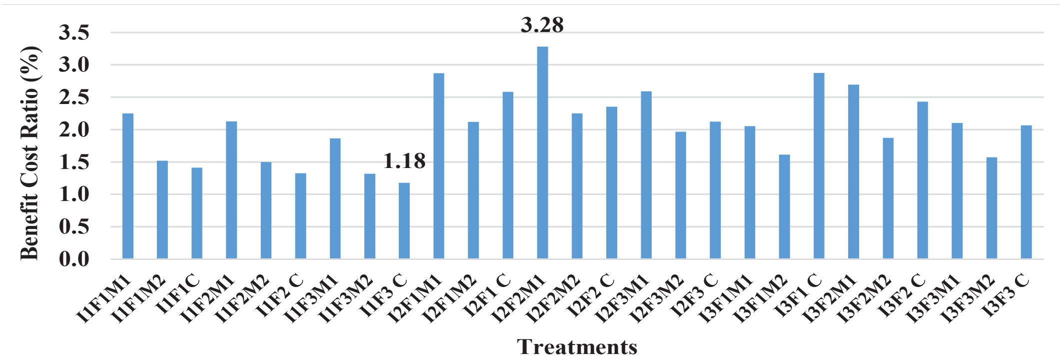

Fig.2 Benefit cost ratio of different treatments

Morphological attributes

The highest average plant height (1.92 m) of cotton was attained at $I_2F_2M_1$, followed by 1.76 m and 0.76 m at $I_2F_2M_2$ and $I_1F_3M_3$, respectively. $I_3F_1M_2$ at par with $I_1F_2M_2$, silver black plastic mulch performed well as compared to biodegradable plastic mulch and control. Significant difference was observed among all the treatments. More monopodial branches (6.1) and sympodial branches (30.9) were observed at $I_2F_2M_1$. Enhanced sympodial branches might be due to better partitioning of assimilates towards reproductive parts as the source was not limiting under mulching. Better root growth and assimilation of photosynthates under mulching might have caused higher partitioning of assimilates towards reproductive structure as could be seen from the production of more bolls (61.5 bolls plant-1) as against 22.3 bolls plant-1 at $I_1F_2M_3$. Treatment $I_1F_2M_2$ was found to be at par with $I_1F_3M_1$ and $I_3F_1M_2$. This shows that response of lower irrigation regimes at higher irrigation frequency was better as compared to higher irrigation regimes with lower irrigation frequency (Nalayini and Shanmugham 2002; Nalayini *et al.,* 2004).

Yield attributes

Silver black plastic mulch at 0.8 ETc and 3 days of irrigation frequency ($I_2F_2M_1$) recorded significantly higher seed cotton yield (4661 kg ha^{-1}) followed by 3988 kg ha^{-1} and 1431 kg ha^{-1} with $I_2F_2M_2$ and $I_1F_3M_3$, respectively (Table 1). Higher uptake of nutrients due to higher temperature coupled with higher available soil moisture might have caused significant increase in root cation exchange capacity, nutrient uptake (Tindall *et al.,* 1991), dry matter accumulation and partitioning of assimilates under silver black plastic mulch ultimately increasing the yield besides saving water (Lourduraj *et al.,* 1996; Nalayini *et al.,* 2009). Higher production under silver plastic mulch may also be due to lower leaf whitefly populations (Summers and Stapleton 2002) and lower thrips count as reported by Matteson *et al*., (1992). It can also reduce the incidence of aphid-borne viruses and exclude some species of pest (Schalk *et al.,* 1979). Significant difference was found among all the treatments at 5% significance level. Treatment $I_2F_3M_2$ was found to be at par with $I_3F_1M_3$. $I_2F_3M_3$ and $I_3F_3M_3$. This indicates that at same irrigation frequency, drip irrigation without mulch could perform better at 0.8 ETc.

Table 1. Morphological parameters of Bt. cotton

Treatments		Plant height (m)	Number of sympodia (plant^{-1})	Number of monopodia (plant^{-1})	Number of bolls (plant^{-1})	Mean boll weight (g)	Seed cotton yield (kgha^{-1})
I1F1M1		1.47	22.1	4.4	49.2	3.19	3197
I1F1M2		1.11	16.6	3.4	37.0	3.14	2687
I1F1C		0.79	11.9	2.6	26.3	2.20	1712
I1F2M1		1.37	20.5	4.0	45.3	3.16	3020
I1F2M2		1.20	18.0	3.6	39.8	3.13	2656
I1F2 C		0.78	11.7	2.4	22.8	2.74	1610
I1F3M1		1.25	18.7	3.8	39.7	3.02	2647
I1F3M2		1.05	15.7	3.2	35.0	2.92	2336
I1F3 C		0.76	11.4	2.3	23.3	2.26	1431
I2F1M1		1.65	24.7	5.0	55.0	4.30	4078
I2F1M2		1.68	25.2	5.0	56.2	4.44	3750
I2F1 C		1.41	21.2	4.2	47.0	3.67	3136
I2F2M1		1.92	30.9	6.1	61.5	4.77	4661
I2F2M2		1.76	27.0	5.3	59.8	4.63	3988
I2F2 C		1.49	22.3	4.5	44.0	3.53	2858
I2F3M1		1.60	24.0	4.8	50.7	3.98	3677
I2F3M2		1.60	24.0	4.8	53.6	4.22	3484
I2F3 C		1.25	18.7	3.8	38.6	3.15	2578
I3F1M1		1.31	19.6	3.8	43.7	3.65	2917
I3F1M2		1.18	17.7	3.4	39.4	3.28	2855
I3F1 C		1.71	25.6	5.0	56.8	4.42	3540
I3F2M1		1.70	25.5	5.1	56.3	4.48	3824
I3F2M2		1.49	22.3	4.4	49.4	4.12	3316
I3F2 C		1.54	23.2	4.6	45.4	3.79	2952
I3F3M1		1.42	21.3	4.3	44.7	3.73	2984
I3F3M2		1.25	18.7	3.7	41.8	3.48	2787
I3F3 C		1.33	19.9	4.0	40.8	3.06	2506
I	S.Em.±	0.022	0.343	0.057	0.674	0.161	44.69
	C.D.at 5%	0.070	1.118	0.186	2.197	0.977	145.76
F	S.Em.±	0.021	0.321	0.066	0.551	0.043	37.63
	C.D.at 5%	0.06	0.94	0.19	1.61	0.13	109.83
M	S.Em.±	0.02	0.34	0.06	0.75	0.05	51.38
	C.D.at 5%	0.06	0.96	0.18	2.11	0.14	145.04
I x F	S.Em.±	0.04	0.56	0.12	0.95	0.08	65.17
	C.D.at 5%	NS	1.62	0.34	NS	NS	NS
I x M	S.Em.±	0.04	0.59	0.11	1.29	0.09	89.00
	C.D.at 5%	0.11	1.66	0.31	3.65	0.25	251.22
F x M	S.Em.±	0.04	0.59	0.11	1.29	0.09	89.00
	C.D.at 5%	0.11	1.66	0.31	3.65	0.25	251.22
I x F x M	S.Em.±	0.07	0.59	0.19	2.24	0.15	154.15
	C.D.at 5%	0.19	1.66	0.55	6.32	0.43	435.13

Irrigation water

Irrigation scheduling was done based on actual evapotranspiration measured with the help of soil moisture sensors installed with data loggers in different treatments at irrigation regimes. The sensors were calibrated for local condition and moisture content calculated based on calibrated soil moisture characteristic curve. Actual crop evapotranspiration was calculated considering the root depth of cotton with model developed by Fereres *et al.,* (1981). Irrigation water applied as per the actual evapotranspiration at different irrigation regimes. The results revealed that silver black plastic mulch save 19.77% irrigation water at 0.6 ETc followed by 15.43% and 11.45% at 1.0 ETc and 0.8 ETc, respectively as compared to control (Ramesh *et al.,* 2006; Nalayini *et al.,* 2009).

Water use efficiency

The mean irrigation water use efficiency (WUE) for (defined as the ratio of total seed cotton yield to the net irrigation requirement) for different treatments are shown in Fig. 1. WUE values ranged from 20.48 kg $ha^{-1}mm^{-1}$ to 7.13 kg $ha^{-1}mm^{-1}$. The highest mean WUE (20.48 kg $ha^{-1}mm^{-1}$) was found in silver black plastic mulch scheduled at 0.8 ETc with 3 days of irrigation frequency and the lowest WUE (7.13 kg $ha^{-1}mm^{-1}$) was observed in control scheduled at 0.6 ETc with 5 days of irrigation frequency. Silver black plastic mulch might have altered microclimate by changing the soil energy balance, suppress soil water evaporation (Glab and Kulig 2008; Parmar 2013), reduced weed problems (Hamid *et al.,* 2012), increased moisture conservation and increased soil water contents (Zhang *et al.,* 2005), reduced insect pest (Csizinszky *et al.,* 1995) and prevented soil born disease, ultimately increasing crop growth and yield (Eissa 2002).

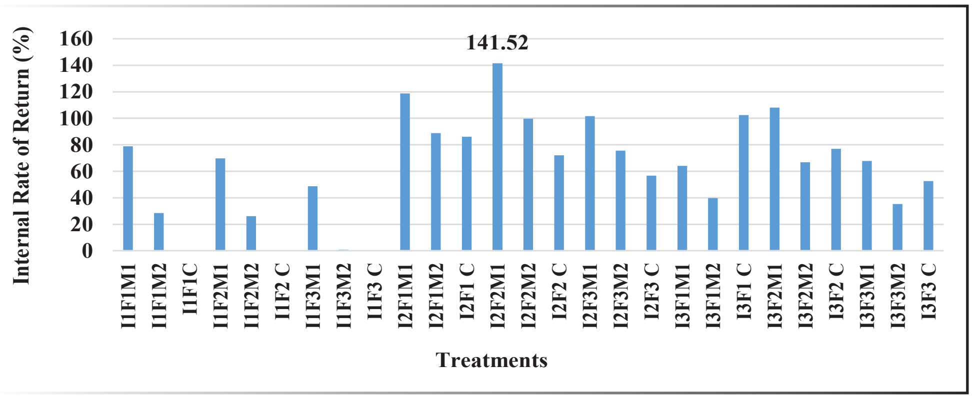

Fig.3 Response of irrigation regimes, frequency and mulching on Internal Rate of Return of Bt. Cotton

Economics

Economics of drip with silver black plastic mulch, biodegradable plastic mulch and drip without mulch for one ha. was estimated based on prevailing rate of year 2015. Biodegradable mulch added 31.49% and 19.82% higher total cost compared to control and silver black plastic mulch, respectively. The highest benefit cost ratio (3.28) was found with drip irrigation and silver black plastic mulch with 0.8 ETc at 3 days of irrigation frequency (Fig. 2). The highest internal rate of return (141.52%) was observed for silver black plastic mulch with 0.8 ETc at 3 days of irrigation frequency (Fig. 3). The lowest IRR was observed under drip irrigation with 0.6 ETc at 5 days of irrigation frequency.

Conclusion

Drip irrigation coupled with silver black plastic mulch scheduled at 0.8 ETc with 3 days of irrigation frequency resulted in better performance of morphological variables, yield attributes, and WUE than drip irrigation with biodegradable plastic mulch and control. Drip irrigation with silver plastic mulch scheduled at 0.6 ETc with 3 days of irrigation frequency was found to be at par with drip irrigation without mulch scheduled at 1.0 ETc with 3 days of irrigation frequency. Silver black plastic mulch enhanced the yield by 38.68 and 14.44% yield, respectively than biodegradable mulch and control scheduled at 0.8 ETc with 3 days of irrigation frequency. Silver black plastic mulch was found to increase benefit cost ratio (3.28), internal rate of return (141.52%) and water use efficiency (20.48 kg $ha^{-1}mm^{-1}$) compared to biodegradable plastic mulch and control scheduled at 0.8 ETc with 3 days of irrigation frequency.

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