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Research Paper

Effect of moisture conservation techniques on productivity, water-use efficiency and economics of Bt cotton (*Gossypium hirsutum*) in southern Rajasthan

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ABSTRACT

A field experiment was conducted during 2 consecutive *kharif* seasons of 2014 and 2015 at Banswara, Rajasthan to assess the effect of moisture conservation techniques like, polymulching and drip irrigation on productivity, water-use efficiency and economics of Bt. cotton (*Gossypium hirsutum* L.) in southern Rajasthan. The experiment was laid out in randomized block design with 3 replications comprising eight treatment combinations. The results revealed that polymulching improved the growth, yield, nutrient uptake and water-use efficiency compared to conventional irrigation. Polymulching increased seed-cotton yield and water-use efficiency by 42.5 and 99% respectively in comparison to conventional irrigation. Drip irrigation with polymulching was significantly superior to drip irrigation without polymulching at all irrigation regimes. Water-use efficiency was observed the highest (93.6 kg/ha-cm) under drip irrigation at 0.6 ETc + polymulching, while the lowest (28 kg/ha-cm) was recorded under conventional irrigation. The uptake of NPK was significantly influenced by polymulching and drip irrigation (with and without polymulching) compared to conventional irrigation. The maximum seed cotton yield (5,504 kg/ha), gross returns (₹220,145/ha) and net returns (₹169,105/ha) were recorded under drip irrigation at 0.8 ETc + polymulching, which was at par with drip irrigation at 0.6 ETc + polymulching and significantly superior to rest of the treatments. Maximum B: C ratio (3.31) was also recorded under drip irrigation 0.8 ETc + polymulching, which remained at par with drip irrigation at 0.6 ETc + polymulching, drip at 0.8 ETc without mulching and polymulching in conventional irrigation. Drip irrigation at 0.6 ETc with polymulching can be recommended as best moisture conservation technology for enhancing productivity of Bt. cotton under the agro-climatic condition of southern Rajasthan.

Key words: Bt. cotton, Drip irrigation, Economics, Polymulching, Water-use efficiency, Yield

India is the largest producer, consumer as well as exporter of cotton next to China with 34% of the total world area under cotton cultivation and contributing 21% of the total world production. In the year 2002–03, just prior to Bt introduction, the area and productivity of cotton was 7.67 million ha and 308 kg lint/ha respectively. After 13 years, cotton area and productivity were estimated to be 10.5 million ha and 568 lint/ha during 2016–17 (Cotton Advisory Board, 2016). The introgression of *Bacillus thuringiensis* gene in cotton has changed the crop morphology, phenology and physiology, and translocation efficiency of photosynthates into the bolls. These manipulations need high levels of inputs for better yield (Chen *et al.*, 2005). Water is the most important yield limiting factor for field crops. Ever increasing demand for irrigation water coupled with depleting ground water sources calls for efficient-use of water. Therefore, government agencies often recommend farmers to adopt water-saving irrigation methods such as drip irrigation to replace surface irrigation. Drip irrigation increases crop water productivity by increasing yields and decreasing the amount of water used (Cetin and Bilgen, 2002). At present, in India, micro-irrigation is mainly practiced in horticultural crops, whereas only 9.2% area is under field crops (Rane, 2011). Cotton being widely spaced row crop, drip irrigation offers much scope in terms of enhancing cotton yield and water productivity (Nalayini *et al.*, 2006). In this context, micro-irrigation could play a key role in increasing the productivity, water-use efficiency (WUE) and nutrient-use efficiency (NUE) for enhancing Bt. cotton yield. Hargilas and Saini (2017), reported increase in Bt. Cotton yield to the tune of 47.42% by scientific scheduling of irrigation

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through drip irrigation over conventional irrigation. The practice of mulching is used as a management tool in many parts of the world. Of late, Nalayini, *et al.*, (2011) reported use of polymulching for complete control of evaporation and saving precious water besides other advantages like weed control and enhanced yield to the tune of 1.57 fold in cotton crop. In view of the above facts, a field experiment was conducted to assess the effect of drip irrigation and polymulching on productivity, water-use efficiency and economics of Bt cotton under southern Rajasthan.

MATERIALS AND METHODS

A field experiment was conducted during 2 consecutive *kharif* seasons of 2014 and 2015 at Agricultural Research Station (MPUAT), Banswara, (23° 33' N, 74° 27' E, and 220 above mean sea-level), Rajasthan. It comes under southern plain agro-climatic zone of Rajasthan. The soil was clay loam slightly alkaline in reaction, low in organic carbon (0.48%) and available N (218 kg/ha), medium in available P_2O_5 (28 kg/ha) and high in available K_2O (362 kg/ha). The experiment consisted of 8 treatments, viz. T_1, conventional irrigation; T_2, polymulching; T_3, drip irrigation at 0.4 ET_C; T_4, drip irrigation at 0.4 ET_C + polymulching; T_5, drip irrigation at 0.6 ET_C; T_6, drip irrigation at 0.6 ET_C + polymulching; T_7, drip irrigation at 0.8 ET_C and T_8, drip irrigation at 0.8 ET_C + polymulching. The experiment was laid out in randomized block design with 3 replications. Bt cotton var 'Jai Bt' was sown on first fortnight of June by dibbling at 90 cm × 45 cm row and plant spacing on the raised bed for single row planting after the field preparation to a fine tilth and laying drip with spreading the polymulching as per treatment. In each bed, 30 cm from either edge of bed, sowing lines were marked at 90 cm apart at the centre of bed and lateral drip line was also placed in the centre of bed. The fertilizer dose of 120:60:40 kg of N : P : K was common to all the treatments. The basal fertilizers (25% N and full dose of P and K) were applied as band placement 5 cm away from the sowing lines for the conventional irrigation, and polymulching without drip and other treatments. The basal dose of fertilizers was applied at 20 days after sowing (DAS) through drip lines. A top-dressing of the remaining dose of N was given in 3 equal splits at 35 DAS, 65 DAS and 95 DAS as drip fertigation for drip treatments and drenching near the plant holes for conventional irrigation and polymulching without drip. The polymulching sheet was spread over the raised bed carefully and the edges were sealed with soil without much air trapped inside. The polymulch (30 micron thickness) used had silver colour on top layer to reflect more solar radiation on the crop and black colour on bottom layer to enhance the soil temperature. The sowing lines were marked on the polythene sheets using a rope with markings at required plant- to-plant spacing (45 cm). The holes were made using a 2 inch GI pipe (by pressing the pipe against the already spread sealed edges polymulch at required spacing) followed by the sowing of cotton seeds carefully in the sowing holes. An irrigation of 50 mm was given immediately after sowing. Subsequent irrigations were given as per the treatment schedule. During the growing season, the cotton crop received 629 and 675 rainfall in the first and second year of experimentation, respectively. Adequate plant protection measures were adopted as and when required.

The volume of water to be given on alternate days through drip irrigation (litre/day) was calculated by using following formula:

$V= E_p \times K_p\ (0.7) \times Kc \times A.$

whereas, V= volume of water to be given (liters/drip/day), E_p= pan evaporation of 2 days (mm), K_p= pan co-efficient (0.7), K_C = crop co-efficient (which vary for different growth stages of crop) (Brouwer and Heibloem, 1986). For cotton, the crop co-efficient (Kc) was 0.45 for seedling stage (0–25 DAS), 0.75 for crop development stage (26–70 DAS), 1.15 for boll development (71–120 DAS) and 0.70 for maturity stage (121 DAS-harvest). The evaporation reading recorded from class A open pan evaporimeter was considered as 100 per ET_C and after adjusting to pan factor (for Banswara, it is 0.7) and crop co-efficient, the amount of water to be given for 0.4, 0.6, and 0.8 ETc was calculated using the above formula and a ready reckoner was prepared and irrigation was scheduled on alternative days. The amount of water to be given was measured at each irrigation through hydrometer fixed at the main pipeline for drip system and through 'V' notch for polymulching without drip and conventional irrigation. The outline having emitters of 4 lph discharge capacity was operated at pressure of 1 kg/cm^2. The average emission uniformity of drip irrigation system was estimated at 91% for all treatments. In conventional irrigation, 6 cm depth of irrigation was considered and irrigation was given on the basis of cumulative pan evaporation (100 mm CPE). The irrigation was cut-off after inception of boll bursting. The field capacity of the soil was 35.5% and permanent wilting point was 18.0%. The observations on growth and yield components were recorded and analyzed statistically by using randomized block design. The water-use efficiency was calculated from yield data and quantity of irrigation water applied in each treatment.

RESULTS AND DISCUSSION

Growth and yield attributes

Polymulching promoted the growth of Bt cotton as evident from plant height enhancement to the tune of 7 cm to

21 cm under drip irrigation and 11 cm to 25 cm under polymulching and drip irrigation with polymulching than conventional irrigation (Table 1). This could be attributed to favourable micro-climate under polymulching with higher available soil moisture and nutrients, favourable soil temperature, lesser weeds competition etc. The healthy plants under polymulching and drip irrigation with polymulching had more (45.39–89.17%) sympod branches sprouting over conventional irrigation. The sympods per plant were significantly higher (13.85, 22.88, 32.33 and 45.39%) with polymulching under drip irrigation at its respective ET_c levels than without mulching. The number of bolls/plant also significantly increased by 17.14, 28.92, 17.85 and 27.54% with polymulching compared to drip irrigation at 0.8 ETc, 0.6 ETc, 0.4 ETc and conventional irrigation, respectively. The boll weight was not significantly influenced by moisture conservation techniques (Table 1). This might be attributed to the fact that polymulching checked the evaporation loss and also reduced the water and nutrient losses from weed flora, thus creating favourable conditions for the plants with availability of sufficient moisture retention in root zone for long periods which led to higher uptake of water and nutrients resulting in increased rate of photosynthesis, consequently leading to higher translocation of photosynthates from stem and leaves to sink.

Yield and yield components

Seed cotton yield was significantly affected by moisture conservation techniques. Polymulching increased the seed cotton yield by 42.45% over conventional irrigation (Table 2). Increase in seed cotton yield was 25.16, 49.87 and 61.70% with drip irrigation at 0.4, 0.6 and 0.8 ETc respectively compared to conventional irrigation. Seed-cotton yield under drip at 0.4 ETc was 13.4% lower than polymuching alone. Drip irrigation at 0.4, 0.6 and 0.8 ETc with mulching significantly increased the seed contton yield by 25.01, 32.52 and 40.76% over drip irrigation at respective ETc regimes without mulching. This might be due to the fact that reducing evapo-transpiration and percolation losses always maintained soil moisture nearer to the field capacity which ultimately enhanced assimilates partitioning towards economic yield. Similar research finding, was reported by Hargilas and Saini (2018). Drip irrigation at 0.8 ETc + polymulching produced maximum seed cotton yield (5,504 kg/ha) which was at par with drip irrigation at 0.6 ETc + polymulching and significantly superior to rest of the treatments. Similar trend was observed in dry-matter production which might be due to production of more vegetative biomass, more flowers and conversion into better bolls and more retention at the plants under drip irrigation (Choudhary *et al.*, 2016). The increase in yield could be attributed to the beneficial effect of mulching on conservation of soil moisture, which in turn resulted in increased number of growth and yield contributing characters (Yang *et al.*, 2017). Lint yield, ginning outturn and lint index were significantly enhacnced under polymulching and drip irrigation + polymulching. Maximum lint yield (1,999 kg/ha) recorded under drip at 0.8 ETc + polymulching which was at par with drip at 0.6 ETc + polymulching and significantly superior to rest of the treatments. Maximum ginning outturn (36.33%) was also recorded under drip at 0.8 ETc + polymulching, which was significantly superior to drip at 0.4 ETc, 0.6 ETc without polymuching and conventional irrigation and was at par with rest of the treatments. A similar trend was observed in lint index also, whereas, seed index was not significantly influenced by the treatments.

Water saving and nutrients uptake

Water requirement was 55.3, 57.8 and 60.4 ha-cm under drip irrigation at 0.4, 0.6 and 0.8 ETc against 95.6 ha-cm in conventional irrigation (Table 3). Water-use efficiency (WUE) is an important factor to the farmer from

Table 1. Effect of moisture conservation techniques on growth and yield attributes of Bt cotton (pooled data of 2 years)

Treatment	Plant height (cm)	Monopods/ plant	Sympods/ plant	Bolls/ plant	Boll weight (g)
Control	140	2.67	18	39	4.21
Polymulching	151	3.67	26	50	4.44
Drip irrigation at 0.4 ETc	147	4.00	23	46	4.40
Drip irrigation at 0.4 ETc + polymulching	157	4.97	30	54	4.53
Drip irrigation at 0.6 ETc	155	4.40	27	50	4.51
Drip irrigation at 0.6 ETc + polymulching	163	5.32	33	64	4.57
Drip irrigation at 0.8 ETc	161	5.00	30	59	4.55
Drip irrigation at 0.8 ETc + polymulching	165	5.33	35	69	4.59
SEm±	3.78	0.81	0.96	2.21	0.08
CD (P=0.05)	11.46	2.45	2.92	6.71	NS

NS, non-significant

the point of view of gaining maximum return (economic produce) from limited water resource. Since, polymulching completely controlled evaporative loss of water, polymulched cotton with or without drip recorded higher water-use efficiency than drip irrigation alone. Among the treatments, drip irrigation at 0.6 ETc + polymuching recorded the highest water-use efficiency (93.6 kg seed cotton yield/ha-cm) which was at par with drip irrigation at 0.8 ETc + polymulching and drip at 0.4 ETc + polymulching and significantly superior to rest of the treatments. The lowest (28.5 kg seed cotton yield/ha-cm) water-use efficiency was recorded under conventional irrigation. The maximum water saving (42.2%) was recorded under drip at 0.4 ETc with or without mulching over conventional irrigation and it reduced with higher ETc levels and minimum water saving (28.56%) was recorded in conventional irrigation. Nalayini *et al.* (2013) reported that drip irrigation at 0.4 ETc + polymulching enhanced the water-use efficiency by 2.38 fold over conventional irrigation. Different technologies of moisture conservation significantly influenced the N, P and K uptake (Table 3). Polymulching without drip observed 1.50, 1.53 and 1.56 fold higher NPK uptake over conventional irrigation. The uptake of NPK under drip irrigation at different ETc levels with polymulching was significantly higher than drip without polymulching. The maximum uptake (117.52, 36.29 and 181.72 kg NPK/ha) was recorded under drip at 0.8 ETc with polymuching which was at par with drip at 0.6 ETc with polymuching and significantly superior to rest of the treatments. This was due to availability of favourable soil moisture through out the crop growth period, which stimulated the plant growth and development. Since, the nutrient uptake is a product of nutrient content and dry-matter production, the trend of NPK uptake was recorded similar to dry-matter accumulation. Polymulching also enhanced the uptake of NPK

Table 2. Response of moisture conservation techniques on seed cotton yield, dry-matter production, lint yield, ginning outturn, lint and seed index (pooled data of 2 years)

Treatment	Seed cotton yield (kg/ha)	Dry matter production (kg/ha)	Lint yield (kg/ha)	Ginning outturn (%)	Lint index	Seed index
Control	2,723	5,213	916	33.67	3.37	10.00
Poly mulching	3,879	6,679	1,359	35.00	3.73	10.67
Drip irrigation at 0.4 ETc	3,408	6,048	1,089	32.00	3.31	10.33
Drip irrigation at 0.4 ETc + polymulching	4,797	7,937	1,662	34.67	3.82	11.00
Drip irrigation at 0.6 ETc	4,081	7,081	1,388	34.00	3.52	10.33
Drip irrigation at 0.6 ETc + polymulching	5,408	8,558	1,965	36.33	4.12	11.33
Drip irrigation at 0.8 ETc	4,403	7,403	1,527	34.67	3.93	11.33
Drip irrigation at 0.8 ETc + polymulching	5,504	8,604	1,999	36.33	4.12	11.33
SEm±	147	179	52	0.60	0.15	0.36
CD (P=0.05)	447	542	159	1.82	0.45	NS

NS, non-significant

Table 3. Effect of moisture conservation techniques on water-use efficiency and nutrient uptake of Bt cotton

Treatment	Quantity of water applied (ha-cm)	WUE (kg seed cotton/ha-cm of water)	% water saving over FP*	N uptake (kg/ha)	P uptake (kg/ha)	K uptake (kg/ha)
Control	95.6	28.5	0.00	54.58	15.52	80.80
Polymulching	68.3	56.8	28.6	81.83	23.79	126.03
Drip irrigation at 0.4 ETc	55.3	61.6	42.2	68.58	20.08	94.55
Drip irrigation at 0.4 ETc + polymulching	55.3	86.7	42.2	101.12	30.51	159.71
Drip irrigation at 0.6 ETc	57.8	70.6	39.5	89.98	26.39	134.65
Drip irrigation at 0.6 ETc + polymulching	57.8	93.6	39.5	112.84	34.93	176.53
Drip irrigation at 0.8 ETc	60.4	72.9	36.8	94.06	28.87	142.83
Drip irrigation at 0.8 ETc + polymulching	60.4	91.1	36.8	117.52	36.29	181.72
SEm±		2.44		2.42	0.62	4.60
CD (P=0.05)		7.40		7.33	1.89	13.94

FP*, Farmer's practice

Table 4. Effect of moisture conservation techniques on economics of Bt cotton (pooled data of 2 years)

Treatment	Cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	Benefit: cost ratio
Control	32,000	108,918	76,918	2.40
Polymulching	38,600	155,161	116,561	3.02
Drip irrigation at 0.4 ETc	43,000	136,307	93,307	2.17
Drip irrigation at 0.4 ETc + polymulching	50,600	191,890	141,290	2.79
Drip irrigation at 0.6 ETc	43,220	163,253	120,033	2.78
Drip irrigation at 0.6 ETc + polymulching	50,820	216,320	165,500	3.26
Drip irrigation at 0.8 ETc	43,440	176,107	132,667	3.05
Drip irrigation at 0.8 ETc + polymulching	51,040	220,145	169,105	3.31
SEm±		5,895	5,895	0.14
CD (P=0.05)		178,83	17,883	0.42

compared to without mulching. It might be due to conservation of more soil moisture and nutrients in the root zone of the crop to avoid nutrient losses from volatilization and leaching which helped in better utilization of nutrients that reflected on better growth and dry-matter production. Similar finding was reported by Ramamurthy *et al*. (2009).

Economics

The highest cost of cultivation (₹51,040/ha), gross returns (₹220,145/ha), net returns (₹169,105/ha) and B:C ratio (3.31) was recorded with drip irrigation at 0.8 ETc + polymulching. The gross returns and net returns of drip irrigation at 0.8 ETc + polymulching were at par with those with drip irrigation at 0.6 ETc + polymulching (₹216,320/ha) and (₹165,500/ha) and significantly superior to those obtained with of the treatments. Whereas, the B:C ratio (3.31) under drip irrigation at 0.8ETc + polymulching was at par with drip irrigation at 0.6 ETc + polymulching, drip irrigation at 0.8 ETc without polymulching and polymulching without drip and significantly superior to that obtained under rest of the treatments. The cost of drip irrigation and polymulching was higher than conventional irrigation, but return was more under drip irrigation + mulching compared to conventional irrigation and saved more water for crop fruiting in favourable micro-climatic condition. Polymulching reduced evaporation loss of soil moisture and prevented weed germination providing more water and nutrient to crop plant. Prajapati and Subhaiah (2015) also reported the highest B:C ratio (2.64) under drip irrigation at 0.8 ETc with silver plastic mulching.

On the basis of 2 years study, it can be concluded that polymulching is more effective to enhance the crop productivity, water-use efficiency and economical returns by controlling the weed flora, evaporative loss of water and consistently retaining higher available moisture in the soil. Drip irrigation at 0.6 ETc with polymulching recorded the highest water-use efficiency and benefit:cost ratio which was at par with drip irrigation at 0.8 ETc + polymulching. The study clearly suggest that polymulching technology has potential to be explored fully for enhancing the productivity of Bt. cotton and combined with drip irrigation, it could further save precious water which will help in bringing more area under irrigation with lesser pressure on ground water resources.

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