Indian Journal of Agricultural Sciences **80** (4): 271–4, April 2010

Response of *Bt* cotton (*Gossypium hirsutum*) hybrids to irrigation

I P S AHLAWAT[1] and B GANGAIAH[2]

Indian Agricultural Research Institute, New Delhi 110 012

Received: 5 October 2008; Accepted: 12 January 2010

ABSTRACT

A field experiment was conducted during 2006–07 at New Delhi to study the performance of 2 *Bt* cotton (*Gossypium hirsutum* L.) hybrids in relation to irrigation schedules based on irrigation water (IW)/cumulative pan evaporation (CPE) with an IW of 60 mm. Over the years, 'MRC 6304' and 'RCH 317' gave similar seed cotton yield (2.31 tonnes/ha) and net returns (Rs 30 165/ha). Irrigation of cotton at 0.6 IW/CPE ratio being on par with 0.4 IW/CPE ratio throughout crop duration recorded taller plants with more boll number (45.4) and higher boll weight (4.34 g), finally resulting in higher seed cotton yield (2.55 tonnes/ha) over 0.2 IW/CPE ratio throughout crop duration (2.20 tonnes/ha) and the crop irrigated at 0.4 IW/CPE ratio till onset of monsoon (2.05 tonnes/ha). The highest stalk yield was recorded with crop irrigated throughout at 0.6 IW/CPE ratio being significantly higher over all other irrigation treatments; the lowest being with crop irrigated at 0.4 IW/CPE ratio till onset of monsoon. Further irrigation 0.6 IW/CPE ratio fetched an additional net income of Rs 1 500/ha over 0.4 IW/CPE ratio throughout crop duration. Irrigation at 0.2 IW/CPE ratio also gave higher productivity and income over post-monsoon rainfed crop (0.4 IW/CPE irrigation from sowing to onset of monsoon). The data on mean consumptive use moisture extraction pattern and water productivity indicate that both the *Bt* hybrids behaved similarly to these parameters. Increasing IW/CPE ratio from post-monsoon rainfed (0.4 IW/CPE irrigation from sowing to onset of monsoon) to the highest of 0.6 IW/CPE ratio throughout the crop duration increased consumptive use, while water productivity based on consumptive use and quantity of irrigation water applied and marginal productivity were the highest with post-monsoon rainfed crop. Cotton irrigated at 0.4 and 0.6 IW/CPE ratio recorded more water extraction from top 60 cm, while crop irrigated throughout at 0.2 IW/CPE and post-monsoon rainfed crop extracted more water from deeper layers of soil (60–180 cm).

Key words: *Bt* Cotton, Consumptive use, Irrigation, Seed cotton yield

The importance of cotton (*Gossypium* sp.) in Indian economy can be judged from the fact that about 17 million farmers are dependent on its cultivation for their livelihood (Sue Branford 2008). The *Bt* (*Bacillus thuringiensis*) cotton with inherent ability to resist bollworm attack permitted for cultivation in India since 2002 has tremendously increased the cotton productivity and reduced the pesticide consumption drastically for bollworm control. In 2007–08, Bt cotton accounted for over 66% of total cotton acreage (9.53 million ha). In north-western India, cotton is sown immediately after wheat harvest and the summer season demands frequent irrigations. In this region, the water requirement of cotton ranges from 700 to 1 200 mm (Kairon *et al.* 2002). The entire area of cotton in northern zone is grown as irrigated [Punjab (96.5%), Haryana (99.4%), Uttar Pradesh (92.3%) and Rajasthan (95.0%) FAI 2005)]. Cotton is very sensitive to irrigation as excess irrigation in its starting period and uncontrolled water stress at later stages may adversely affect the cotton yield (Kashefipour *et al.* 2006). Further, *Bt* cotton performing better under irrigation than non-*Bt* (Jana 2005) calls for standardization of irrigation schedules based on scientific approaches. The optimum range of soil-moisture for cotton crop is from the field capacity to 20% of available water with the root zone extending up to about 0.75 m, having a total water requirement of about 0.4 m to 0.5 m (IIT 2008). The information on irrigation response of *Bt* cottons is lacking. Hence, the present study was made to evolve the optimum schedule of irrigation for *Bt* cotton.

MATERIALS AND METHODS

A field experiment was conducted during 2006 and 2007 at the Indian Agricultural Research Institute, New Delhi located at 28°35'N latitude and 77°12'E longitude at an altitude of about 228.61 m above mean sea level. The soil was sandy loam in texture (67% sand, 14% silt and 19% clay) with *p*H 7.8 (1:2.5 soil to water ratio) containing 3 800 kg/ha organic carbon (Walkey and Black method), 167 kg/ha Kjeldahl N (modified Kjeldahl's method,) 14.6 kg/ha 0.5 M $NaHCO_3$ extractable P (Olsen's method), 175 kg/ha

[1]Head (e mail: ahlawat47@hotmail.com), [2]Senior Scientist (e mail: bandla_gan@hotmail.com), Division of Agronomy

NH_4OAC extractable K (Flame photometer method), and 0.32 dS/m (at 25°C) ECe. The moisture content of soil (0–90 cm) at field capacity and permanent wilting point were 17.3 and 7.6%, respectively with a bulk density of 1.56 Mg/m^3. A pulse–wheat cropping system was practised in the field for the past 5 years.

The experiment with 16 treatments comprising combination of 2 *Bt* cotton hybrids ('MRC 6304' and 'RCH 317') in main plots and 4 irrigation schedules based on IW/CPE ratio with an IW of 60 mm (rainfed, ie irrigation till onset of monsoon at 0.4 IW/CPE ratio, irrigation at 0.2, 0.4 and 0.6 IW/CPE ratio throughout the crop cycle) as sub-plots was conducted in split-plot design with 3 replications. The sub-plots were separated by 3 m passage for acting as buffer area to check any movement of water from one treatment to the other one. Cotton was sown on 30 May during both the years at 120 cm × 90 cm by dibbling 1 seed/hill on a well prepared land after a pre-sowing irrigation. The gaps were filled with seedlings raised in plastic bags on 10th day after sowing. The crop received a basal dose of 26.4 kg P/ha (single superphosphate) and 42 kg K/ha (muriate of potash). Nitrogen as urea was applied in 3 splits of 40 kg/ha each at sowing, square formation and boll development stages. The crop completed its life-cycle on 4 December in 2006 and 30 November in 2007. The crop was protected from sucking pests through spray of monocrotophos 36% SL @ 2 litres (85 day after sowing) as per need.

A rainfall of 499.3 and 457.0 mm was received in 2006 and 2007 during crop growing season. The total and mean pan evaporation during crop life-cycle (1 June–30 November) was 1 287.2 and 7.0 mm/day in 2006 and 1 365.1 mm and 7.5 mm/day in 2007. In 0.4 IW/CPE ratio irrigation till onset of monsoon, crop was grown as rainfed from June 28 in 2006 as 73.6 mm rain was received in 2 days (18.3 and 55.3 mm on 28 and 29 June, respectively), while in 2007 the crop was grown entirely as rainfed as there was 55.4 mm rain in 4 days (26.5, 5.2, 22, 2.2 mm rain during 16–19 June). The cotton crop received 2 common irrigations on 31 May and 10 June during both the years. In addition to the above, rainfed cotton received 1 irrigation on 25 June 2006, however, it did not receive any irrigation in 2007. Two (18 September and 29 October in 2006 and 25 September and 21 November in 2007), 5 (25 June, 23 August, 29 September, 18 October and 23 November in 2006; 3 July, 27 August, 18 September, 11 October, 7 November in 2007) and 8 (19 June, 9 July, 16 and 27 August 26 September, 10 and 24 October, 21 November in 2006; 27 June, 9 July, 21 August 7 and 24 September, 11 and 27 October and 21 November in 2007) irrigations were given to cotton. One irrigation due on 30 July in 0.2, 0.4 and 0.6 IW/CPE ratio was not given due to failure of water supply system. Soil moisture content before and after irrigation was estimated (0–180 cm) gravimetrically and from which consumptive use of water was arrived. The water productivity was worked out by dividing seed cotton yield by consumptive use or water applied and both expressed as WP_{CU}/WP_A in kg/ha-mm. Marginal water use efficiency (WP_M in kg/ha-mm) was estimated by $(Y–Y_0)/I$, where Y_0, is yield of non-irrigated treatment and, I, is amount of water applied (Vories *et al.* 1991).

RESULTS AND DISCUSSION

Growth and yield attributes

Bt cotton hybrids did not differ significantly for plant height, boll number and weight. Among irrigation schedules, irrigation at 0.4 IW/CPE ratio being on par with 0.6 IW/CPE gave significantly taller plants with more number of bolls/plant and boll weight than irrigation at 0.2 IW/CPE ratio and rainfed crop (Table 1). Optimum soil moisture status with 0.4 and 0.6 IW/CPE ratio might have resulted in greater nutrient uptake, promoting the crop growth and development of yield attributes. Positive influence of adequate irrigations on bolls/plant and boll weight of cotton were also reported by Bhunia (2007). In general, number of bolls/plant and boll weight was more in 2006 than 2007. The lower yield attributes in 2007 could be due to water stress as a result of skipping irrigation at boll formation stage (30–31 July) in 0.2, 0.4 and 0.6 IW/CPE ratio.

Seed cotton yield

Seed cotton yield of the *Bt* hybrids differed markedly only in 2006 (Table 1). 'MRC 6304' gave significantly higher seed cotton yield than 'RCH 317' in 2006. A similar difference in seed cotton yield among *Bt* hybrids were also reported by Singh *et al.* (2006). Increasing frequency of irrigation from 0.2 to 0.4 IW/CPE ratio significantly increased seed cotton yield (Table 1). However, further increase in frequency of irrigation failed to improve the crop productivity. The productivity of cotton irrigated at 0.2 IW/CPE ratio and rainfed cotton (irrigation at 0.4 IW/CPE during summer only) was similar. During 2006, crop received 1 irrigation at 25 DAS in 0.4 IW/CPE ratio (summer only), while irrigation at 0.2 IW/CPE ratio received 2 irrigations, 1 each in September and October, which in fact did not coincide with critical stages (square and boll formation) of crop. During 2007, rainfed cotton (irrigation at 0.4 IW/CPE ratio summer only) did not receive any irrigation over common irrigations owing to early showers (55.4 mm rain during 3rd week of June) and subsequent rains in July (56.2 mm) and September (61.2 mm). Because of these rains coinciding with square and boll formation stages, this treatment yielded similar to irrigation at 0.2 IW/CPE ratio. Irrigation at 0.4 IW/CPE ratio resulted in marked increase in seed cotton yield over the rainfed cotton and cotton receiving irrigation at 0.2 IW/CPE ratio. A significant increase in irrigated *Bt* cotton yield over its rainfed crop was also reported by Pawar and Pawar (2008). The favourable moisture conditions obtained by irrigation of cotton at 0.4 IW/CPE ratio coinciding with square and boll formation stages resulted in better development of yield

Table 1 Growth, yield attributes, yield and economics as affected by Bt cotton hybrids and irrigation

Treatment	Plant height (cm)		Cotton stalks yield (tonnes/ha)		Bolls/plant yield (tonnes/ha)		Boll weight (g)		Seed cotton yield (tonnes/ha)			Economics (Rs × 103)*	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	Pooled	Cost of cultivation	Net income
Cotton hybrid													
'MRC 6304'	126.7	122.3	5.30	5.10	45.6	39.5	4.38	4.13	2.83	1.80	2.32	23.10	30.33
'RCH 317'	124.2	119.7	5.07	4.90	44.8	40.0	4.35	4.15	2.74	1.88	2.31	23.10	30.00
SEm	1.8	2.0	0.04	0.03	0.2	0.17	0.02	0.01	0.018	0.034	0.023		
CD (*P*=0.05)	NS	NS	0.14	0.10	NS	NS	NS	NS	0.062	NS	NS		
Irrigation (IW/CPE ratio)													
Rainfed**	116.0	111.2	4.60	4.30	41.2	37.9	4.08	4.03	2.60	1.51	2.05	21.00	24.68
0.2	119.0	114.4	4.90	4.70	42.3	38.1	4.16	4.05	2.70	1.70	2.20	21.80	27.22
0.4	131.2	127.4	5.48	5.39	48.3	41.3	4.34	4.22	2.89	2.01	2.45	24.40	30.27
0.6	135.8	131.0	5.77	5.61	49.0	41.7	4.42	4.26	2.95	2.15	2.55	25.20	31.77
SEm	2.6	2.9	0.06	0.04	0.3	0.25	0.03	0.02	0.026	0.049	0.033		
CD (*P*=0.05)	8.8	9.8	0.20	0.15	1.0	0.83	0.10	0.08	0.088	0.166	0.112		

*Seed cotton price: Rs/tonne 20 100; cotton stalks: 1 000 Rs/tonne; **Irrigations given at 0.4 IW/CPE ratio in summer only

attributes leading to higher seed cotton yields in the current investigation. A further increase in IW/CPE ratio to 0.6 did not provide more favourable moisture regime to crop than 0.4 IW/CPE ratio. Better performance of cotton at 0.4 IW/CPE ratios was ascribed to greater partitioning of photosynthates to reproductive parts as compared to 0.6 IW/CPE ratio that favoured production of more stalks with insignificant contribution to increase in SCY. These finding are in close agreement with those of Rajendran *et al.* (2005) and Bandopadhyay *et al.* (2009).

The interaction effect between hybrids and irrigation in 2006 revealed that 'MRC 6304' performed markedly superior to 'RCH 317' with frequent irrigations (irrigation at 0.4 and 0.6 IW/CPE ratio throughout the crop growth). It could be attributed to the differential rooting pattern of these 2 hybrids which was probably responsible to extract moisture from different layers of soil.

Stalk yield

'MRC 6304', on an average gave 4.52% higher stalk yield than 'RCH 317'. The higher stalk yield of 'MRC 6304' was ascribed to relatively taller plants. Each successive increase in irrigation schedule from control (irrigation at 0.4 IW/CPE ratio in summer only) to the highest IW/CPE ratio of 0.6 throughout the crop cycle increased the stalk yield owing to favourable soil moisture supply finally leading to increased vegetative growth. An increase in biomass yield with increasing moisture supply was also reported by Vories *et al.* (1991).

Economics

Among 2 *Bt* hybrids, 'MRC 6304' fetched Rs 330/ha more net income than 'RCH 317'. Among the irrigation schedules, the net income increased with increasing frequency of irrigation up to 0.6 IW/CPE ratio, being Rs 5 500 and 1 500/ha higher over the 0.2 and 0.4 IW/CPE ratio, respectively. Though 0.4 IW/CPE ratio had statistically similar seed cotton yield to that of 0.6 IW/CPE ratio, but an additional seed cotton (0.102 tonnes/ha) and stalk yields (0.25 tonnes/ha) gave Rs 1 500/ha more net returns (Table 1). Similar higher income in cotton irrigated at 0.8 IW/CPE ratio was reported in studies made at Parbhani, Maharashtra (Shinde *et al.* 2009).

Water-use functions

The mean moisture extraction pattern was similar in both the cotton hybrids. Among the irrigation schedules, frequent irrigations (0.6 IW/CPE ratio) led to depletion of more moisture from top layers, while post-monsoon rainfed crop (0.4 IW/CPE ratio in summer only) and less frequently irrigated (0.2 IW/CPE ratio) crop extracted more moisture from deeper soil layers.

The consumptive use of water was higher in 'MRC 6304' in first year, while 'RCH 317'recorded more consumptive use in second year. Over the years, 'RCH 317' had 7.0 mm higher consumptive use than 'MRC 6304' (537.3 mm). The mean consumptive use increased with the increase in IW/CPE ratio from 416.6 mm in 0.4 IW/CPE irrigation in summer only to 649.0 mm in 0.6 IW/CPE ratio throughout the crop cycle. Both *Bt* hybrids had similar water productivity in 2007, while in 2006; 'MRC 6304' had higher water productivity (WP_{CU} and WP_A) than 'RCH 317'. The higher water productivity of 'MRC 6304' in 2006 could be ascribed to more seed cotton yield, with similar water use in both the hybrids. The WP_{CU} and WP_A declined with increase in IW/CPE ratio, being the highest in irrigation at 0.4 IW/CPE in summer only in 2006 and irrigation at 0.2 IW/CPE ratio

Table 2 Water-use parameters of Bt cotton hybrids as influenced by irrigation

Treatment	Irrigation applied (mm)		Total water input (mm)		Consumptive use (mm)		Water productivity (WP) (kg seed cotton/ha-mm CU)		Marginal WP * (kg seed cotton/ ha-mm applied)		WP (kg seed cotton/ ha-mm irrigation applied)	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Cotton hybrid												
'MRC 6304'	240.0	225.0	739.3	677.0	544.3	530.3	5.56	3.40	1.25	1.51	20.60	8.00
'RCH 317'	240.0	225.0	739.3	677.0	538.3	550.3	5.34	3.41	1.23	1.55	20.17	8.36
Irrigation (IW/CPE ratio)												
Rainfed**	60.0	00.0	559.3	457.0	421.8	413.4	6.15	3.49			43.25	
0.2	120.0	120.0	619.3	577.0	509.0	485.2	5.31	3.50	1.67	1.58	22.50	14.17
0.4	300.0	300.0	799.3	757.0	589.5	630.1	4.90	3.19	1.21	1.67	9.63	6.70
0.6	480.0	480.0	979.3	937.0	644.8	653.1	4.58	3.29	0.83	1.33	6.16	4.48

*In 2006, 60 mm IW applied in rainfed is deducted from 0.2, 0.4 and 0.6 IW/CPE ratio for estimating WP_M; ** Irrigations given at 0.4 IW/CPE ratio in summer only; CU, consumptive use

throughout crop cycle in 2007. The decline in WP_{CU} and WP_A with frequent irrigations (0.6 IW/CPE ratio) may be ascribed to the fact that increase in yield was not commensurate with the increase in CU and applied water. The WP_M, however, was the highest with irrigation at 0.2 IW/CPE ratio in 2006 and 0.4 IW/CPE ratio in 2007 and the lowest with irrigation at 0.6 IW/CPE ratio in both the seasons (Table 2). The trend of WP_A in 2007 was similar to that of WP_M. A similar pattern in CU and WU_{CU} was also reported by Bandopadhyay *et al*. (2009). The trends of WP_A and WP_M in the present investigation are similar to those reported by Vories *et al*. (1991).

REFERENCES

Bandyopadhyay K K, Prakash A H, Sankaranarayanan K, Dharajothi B and Gopalakrishnan N. 2009. Effect of irrigation and nitrogen on soil water dynamics, productivity and input-use efficiency of *Bt* cotton (*Gossypium hirsutum*) in a Vertic Ustropept. *Indian Journal of Agricultural Sciences* **79** (6): 448–53.

Bhunia S R. 2007. Effect of methods of irrigation and levels of phosphorus on *desi* cotton (*Gossypium arboreum*) in shallow water-table condition. *Journal of Cotton Research and Development* **21**(2): 184–6.

FAI. 2005. *Fertilizer Statistics*. Fertilizer Association of India, New Delhi.

IIT. 2008. Soil Water Plant Relationships, Lesson 2, module 3 *(in) Irrigation Engineering Principles*, pp 1–18. Version 2 CE, Indian Institute of Technology, Kharagpur, http://nptel.iitm.ac.in/courses/Webcourse-contents/IIT Kharagpur/Water Resource Engg/pdf/m3l02.pdf.

Jana Orphal. 2005. Comparative analysis of the economics of *Bt* and non-*Bt* cotton production. *Pesticide Policy Project Publication Series Special Issue* No. 8, pp 1–72. January 2005. Hannover, Germany.

Kairon M S, Venugopalan M V and Blaise D. 2002. Cotton (*in*) Field Crop Production: Principles and Practices, pp 646–74. Prasad R (Ed), ICAR, New Delhi.

Kashefipour S M, Broomand Nasab S and Sohrabi B. 2006. Optimization of water productivity using production and cost functions for cotton. *Journal of Agronomy* **5**(1): 28–31.

Pawar D B and Pawar B R. 2008. Profitability of *Bt* cotton production. *International Journal of Agricultural Sciences* **4**(1): 270–3.

Rajendran T P, Venugopalan M V and Praharaj C S. 2005. Cotton research towards sufficiency to Indian textile industry. *Indian Journal of Agricultural Sciences* **75**(11): 699–705.

Shinde V S, Deshmukh L S and Raskar S K.2009. Response of cotton (*Gossypium hirsutum* L.) to protective irrigation at different critical growth stages. *Journal of Cotton Research and Development* **23**(1): 93–5.

Singh Jagvir, Rao M R K, Mohan Punit and Mayee C D.2006. Impact of soil depths on yield of *Bt* cotton hybrids under rainfed conditions. *Journal of Cotton Research and Development* **20**(1): 80–2.

Sue Branford. 2008. Indian farmers shun GM for organic solutions. *The Guardian*. **30** July 2008, pp 8.

Vories E D, Pitts D J and Fergusen J A. 1991. Response of cotton to different soil water deficits on clay soils. *Irrigation Science* **12**: 199–203.