

## Drip fertigation and crop management in Bt cotton (*Gossypium hirsutum*)

R.B. MANE<sup>1</sup>, A.D. TUMBARE<sup>2</sup> AND U.S. SURVE<sup>3</sup>

*Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra 413 722*

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### ABSTRACT

A field experiment was conducted during the rainy season of 2014 and 2015 at Rahuri, Maharashtra, to study the effect of deficit irrigation, fertigation and planting techniques on growth, yield and quality parameters of Bt cotton (*Gossypium hirsutum* L.). Scheduling of irrigation at 1.0 ETc recorded significantly maximum growth, yield attributes and seed-cotton yield of Bt cotton, being at par with 0.8 ETc irrigation regime. Maximum and significantly higher seed-cotton yield was recorded in 1.0 ETc irrigation regime (3.3 t/ha), being at par with 0.8 ETc irrigation regime (3.1 t/ha) on pooled mean basis. Planting of Bt cotton at 90 cm × 90 cm was found superior to 150 cm × 60 cm in respect of growth, yield attributes and seed-cotton yield of Bt cotton. Planting of Bt cotton at 90 cm × 90 cm resulted in significantly higher seed-cotton yield (3.3 t/ha) than 150 cm × 60 cm planting (2.3 t/ha) on pooled mean basis. Fertigation of 100% GRDF up to 100 days + 20 kg MgSO<sub>4</sub>/ha and 25 kg ZnSO<sub>4</sub>/ha up to flowering at weekly interval + foliar spray of Fe (1.0 %) and B (0.5 %) at flowering and boll-development stages was found suitable for achieving the maximum growth, yield attributes and seed-cotton yield (3.1 t/ha) of Bt cotton. The maximum water-use efficiency was obtained with 0.6 ETc irrigation regime (7.00 kg/ha-cm), followed by 0.8 ETc irrigation regime during both the years.

**Key words :** Bt cotton, Fertigation, Growth, Irrigation regimes, Planting techniques, Quality parameters, Seed-cotton yield

Cotton generates employment for about 60 million people either directly or indirectly involved in the agricultural and industrial sectors of cotton production, processing, textiles and related activities (Chaudhary and Gaur, 2010). With the introduction of Bt cotton hybrids, there has been a significant change in the cotton cultivation scenario of India. Now, around 95–97% area under cotton is occupied by Bt cotton hybrids. However, the average production is very low when compared to world's average. This is mainly because 70% of cotton area is under rainfed condition. Lack of knowledge about important agronomical practices could also be another reason. So, there is a need to identify suitable Bt cotton genotype which gives higher net returns with lower cost of cultivation. Hence, with these ideas in view, the present study was undertaken.

Water is very crucial input in agriculture; its efficient utilization is prime need today in agriculture. Though the drip irrigation saves almost 40 to 60% of irrigation water, there is scope for more precise use of irrigation water.

Hence the concept of deficit irrigation emerged for use of limited water resources more efficiently for increasing the productivity of crops. The system shows unique advantages as compared to other irrigation systems like water saving (40–60%), increased yield (15–20%) and labour saving (30–40%).

The productivity of cotton can be improved by adopting suitable agronomic practices like maintenance of ideal plant density, use of optimum dose of fertilizer as well as proper water-management practices. It is essential to find out suitable plant density for recently released Bt cotton hybrid to realize the maximum yield potential. There is a positive relationship between plant population and seed-cotton yield in cotton crop (Bhalerao *et al.*, 2008)

The reasons for decreasing productivity are due to decreasing soil fertility especially micronutrients, imbalanced use of fertilizer and occurrences of physiological disorders like square dropping, square drying, leaf reddening etc. Among these, imbalanced use of major and micro-nutrients is the major problem. These nutrients are more important, because in Bt cotton synchronized boll development altered the source-sink relationship due to rapid translocation of saccharides and nutrients from leaves to the developing bolls (Hebbar *et al.*, 2007). To

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<sup>1</sup>Corresponding author's Email: rajendrabmane24@gmail.com

<sup>1</sup>Ph.D. Scholar, <sup>2,3</sup>Associate Professor, Department of Agronomy

overcome these constraints, additional nutrition through foliar feeding is required over and above the normal fertilizer recommendation. This is one of the most efficient ways of supplying essential nutrients to a growing crop. Fertigation is the injection of fertilizers, soil amendments and other water-soluble products into an irrigation system. Through fertigation nutrients can be applied in correct doses and at appropriate stage of plant growth. In addition, it improves fertilizer-use efficiency, hastens the maturity of crop and improves the quality of produce. Among the various agronomic practices to increase cotton productivity, fertilizer management especially under irrigated situation is considered a key factor. Generally, split applications of major nutrients along with foliar application of minor nutrients are followed in cotton cultivation. Since cotton being a long-duration crop with indeterminate type of growth habit, will benefit the growth and yield.

In view of shrinking water resources and increasing cost of water-soluble fertilizers and to exploit the yield potentiality of Bt cotton genotype by following important agro technique such as varied planting techniques and nutrient managements the efforts were made to plan and conduct an experiment by considering deficit irrigation, planting techniques and nutrient management for enhancing the productivity and quality of Bt cotton during 2 consecutive seasons.

## MATERIALS AND METHODS

The present investigation was conducted at the Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra. The soil was silty clay, low in available nitrogen (175.6 kg/ha), medium in phosphorus (20.7 kg/ha) and high in potassium (448.1 kg/ha), with slightly alkaline in reaction (*pH* 8.10). The soil micronutrients were deficit in zinc (0.3 mg/kg) and ferrous (1.1 mg/kg) and high in manganese (15.9 mg/kg) and copper (2.1 mg/kg). The moisture content at field capacity and permanent wilting point were 36.49% and 17.50% respectively. The experiment was laid out in split plot design with 3 replications. The treatments comprised 4 irrigation regimes [ $I_1$ , 0.6 Etc;  $I_2$ , 0.8 Etc;  $I_3$ , 1.0 ETc and  $I_4$ , surface irrigation (control)] and 2 planting techniques ( $P_1$ , 90 cm × 90 cm and  $P_2$ , 150 cm × 60 cm) as main plot treatments and 3 levels of fertigation [ $F_1$ , 100% (GRDF)];  $F_2$ , 100% GRDF +  $MgSO_4$  (20 kg/ha); and  $F_3$ , 100% GRDF +  $MgSO_4$  (20 kg/ha) +  $ZnSO_4$  (25 kg/ha) and foliar spray of 1%  $FeSO_4$  (at flowering and boll development) + boron @ 0.5% (at flowering and boll development) as subplot treatment. The 100% GRDF (General recommended dose of fertilizers) was used as 10 t/ha FYM + 125 : 65 : 65 kg/ha N:  $P_2O_5$ :  $K_2O$ . The surface irrigation with recommended dose of fertilizer was taken as control treatment. Fertigation was started 10 days after sowing by

using Automatic Fertigation Unit and scheduled at weekly intervals in 12 equal splits up to boll-development stage. Fertigation was done through 19 : 19 : 19 grade water-soluble fertilizer and urea. In treatment  $F_2$  and  $F_3$ ,  $MgSO_4$  @ 20 kg/ha and  $ZnSO_4$  @ 25 kg/ha was applied at weekly intervals in 9 equal splits up to flowering, whereas in the control treatment, it was applied at sowing as a basal dose. In surface-irrigation method, irrigation was applied at 75 mm CPE with 7.5 cm of irrigation depth at each irrigation turn. In drip-irrigation method, scheduling of irrigation was done at every alternate day on the basis of pan evaporation (PE) and crop coefficient (Kc). The scheduling of irrigation was done by using following formula.

$$\text{Volume of water = } \frac{\text{Epan} \times \text{Kpan} \times \text{Kc} \times S_1 \times S_2 \times \text{Wa}}{\text{System efficiency (\%)}}$$

(litre/plant/alternate/day)

where Epan, pan evaporation (mm); Kpan, pan coefficient (0.7); Kc, crop coefficient (as per growth stages);  $S_1$ , inter row spacing (m);  $S_2$ , intra row spacing (m); and Wa, wetted area (%).

The operating time of system was calculated as:

$$\text{Time required (hours) = } \frac{\text{Total volume of water (litre)}}{\text{Number of emitters} \times \text{Emitter discharge (Lph)}}$$

Crop coefficient (kc) for application irrigation (Doorenbos and Pruitt, 1977)

Sr. No.	Crop-growth period (DAP)	Crop coefficient (kc)
1	0–15	0.40
2	15–30	0.50
3	30–60	0.70
4	60–75	0.80
5	75–105	1.05
6	105–135	1.25
7	135–150	0.80
8	150–165	0.90

The farmyard manure was applied common to all the treatments @ 10 t/ha well before the dibbling of the cotton seeds. Before application of farmyard manure in the field, it was analyzed for nutrient contents by using standard analytical method. The seed material of Bt cotton hybrid 'Ajeet 155BG II' was planted on 10 June 2014 and 18 June 2015. The average maximum temperature was 40.3 to 29.0°C and the minimum temperature 24.7 to 12.1°C. The mean relative humidity was between 81 and 52% at morning hours, and between 68 and 21% at evening hours. The pan evaporation was high in May and thereafter it decreased. The total precipitation received during the crop-growth period was 456.20 mm in 27 rainy days during the first season and in the second season, it was 285.2 mm in 25 rainy days which was almost 50% less than the first

season. The mean maximum temperature ranged between 40.4 and 28.4°C, and minimum temperature between 24.4 and 13.9°C. The mean relative humidity at morning hours ranged between 81 and 36%, whereas at evening hours it ranged between 64 and 16%. The evaporation and bright sunshine hours were almost similar as observed in the first season. Four pickings were done each year and picking was started on 8 September 2014 and 19 October 2015. For controlling the sucking pest infestation recommended package of practices were adopted. Various growth and yield observations as well as physiological observations were recorded by selecting 5 plants from each treatment. The growth observations were recorded periodically at an interval of 28 days and physiological observation were recorded at an interval of 14 days during the growth period. Data obtained on various variables were analyzed by analysis of variance method (Panse and Sukhatme, 1985).

## RESULTS AND DISCUSSION

### Growth-attributing characters

Among the irrigation regimes, irrigation at 1.0 ETc showed significantly higher growth attributes, viz. plant height, monopodial branches/plant, sympodial branches/

plant, leaves/plant, leaf area/plant and dry matter/plant than the other irrigation regimes on pooled mean basis (Table 1). This was because scheduling of irrigation at 1.0 ETc irrigation regime created favourable environment at root rhizosphere for increasing the soil moisture and nutrient absorption which led to increase the cell elongation and multiplications. Optimum supply of moisture and nutrients also resulted in maximum photosynthetic rate and stomatal conductance which ultimately reflected on healthy and vigorous plant growth. These results are in close conformity with those reported by Wiggins *et al.* (2014). In case of planting techniques, planting at 90 cm × 90 cm exhibited significantly higher plant height, sympodial branches/plant, monopodial branches/plant, leaves/plant, leaf area/plant and dry-matter/plant than other planting techniques. This might be owing to uniform and optimum plants/unit area in 90 cm × 90 cm planting utilized the added inputs (nutrients) and natural resources (space, water, sunlight) more efficiently for increasing the growth attributes of crop compared to 150 cm × 60 cm. In wider spacing, i.e. 150 cm × 60 cm, there was a competition for moisture and nutrients because of close spacing in inter-plant (60 cm) resulted in inadequate availability of growth

**Table 1.** Growth-contributing characters of Bt cotton as influenced by irrigation, planting and fertigation (pooled data over 2 years)

Treatment	Plant height (cm)	Monopodial branches/plant	Sympodial branches/plant	Leaves/plant	Leaf area/plant (dm <sup>2</sup> )	Dry matter/plant(g)
<i>Irrigation regimes</i>						
I <sub>1</sub> , 0.6 Etc	109.2	1.6	16.2	98.3	285.3	514.5
I <sub>2</sub> , 0.8 Etc	120.2	1.7	18.3	145.6	470.3	606.9
I <sub>3</sub> , 1.0 Etc	136.8	1.8	19.9	172.8	612.6	636.9
I <sub>4</sub> , Surface irrigation (control)	121.0	1.7	17.0	128.9	442.0	545.7
SEm±	1.9	0.04	0.3	0.8	14.3	14.1
CD (P=0.05)	5.9	NS	0.9	2.6	44.1	43.5
<i>Planting techniques</i>						
P <sub>1</sub> , 90 cm × 90 cm	127.9	1.8	18.8	140.3	447.1	612.0
P <sub>2</sub> , 150 cm × 60 cm	115.7	1.7	16.9	132.5	457.9	540.0
SEm±	1.4	0.03	0.3	1.2	12.8	8.4
CD (P=0.05)	4.1	N.S.	0.8	3.5	N.S.	25.2
<i>Fertigation (Nutrient management)</i>						
F <sub>1</sub> , 100% GRDF	113.9	1.7	15.2	127.0	399.4	507.4
F <sub>2</sub> , 100% GRDF + 20 kg MgSO <sub>4</sub> /ha	121.2	1.7	18.1	136.1	447.7	569.7
F <sub>3</sub> , 100% GRDF + 20 kg MgSO <sub>4</sub> + 25 kg ZnSO <sub>4</sub> + foliar spray of Fe (1%) and B (0.5%)	130.3	1.8	20.3	146.2	510.6	650.9
SEm±	1.6	0.04	0.2	1.2	10.7	9.5
CD (P=0.05)	4.7	N.S.	0.4	3.3	30.4	26.7
<i>Interactions (I × P × F)</i>						
I × P	NS	NS	NS	NS	NS	NS
I × F	NS	NS	NS	NS	NS	NS
P × F	NS	NS	NS	NS	NS	NS
I × P × F	NS	NS	NS	NS	NS	NS

GRDF, General recommended dose of fertilizers; Etc, evapotranspiration of crop; NS, non-significant

factors which adversely affected the growth attributes of crop. These results confirm the findings of Pendharkar *et al.* (2010). Among the nutrient-management treatments, fertigation of 100% GRDF up to 100 days + 20 kg MgSO<sub>4</sub>/ha and 25 kg ZnSO<sub>4</sub>/ha up to flowering at weekly interval + foliar spray of Fe (1.0%) and B (0.5%) at flowering and boll-development stages registered significantly higher growth attributes, viz. plant height, sympodial branches/plant, monopodial branches/plant, leaves/plant (167.3), leaf area/plant and dry-matter/plant (650.9 g). This might be owing to application of fertilizers in 12 equal splits at weekly interval up to boll-development stage increased the use efficiency of added nutrients which fulfilled the nutritional requirement of crop, moreover foliar nutrition of iron and boron at appropriate stages which provides balance nutrition. Zinc is necessary for the synthesis of tryptophan and thus involves in auxin synthesis which helps in elongation of cells and increases the plant height. Increase of micronutrient contents in leaves might have increased the production of metabolites synthesized and thus the plant had the chance to bear more fruiting branches. Similarly, continuous application of fertilizers

up to boll-development stage improve the physiological activities like photosynthetic rate, CO<sub>2</sub> concentration, stomatal conductance and transpiration rate which helps to accelerate the growth attributes in Bt cotton. These results are in conformity with Aruna (2011)

#### Yield-contributing characters

Scheduling of irrigation at 1.0 Etc was found superior in registering significantly higher yield-contributing characters, viz. picked bolls/plant, seed-cotton weight/boll, seed-cotton weight/plant, seed weight/plant and lint weight/plant than rest of the deficit irrigation regimes and surface irrigation on pooled mean basis (Table 2). This might be owing adequate availability of water and better conductive rhizosphere environment for higher uptake of nutrients and in turn boost the growth, leading to the development of higher growth and yield attributes through supply of more photosynthates towards the sink. These results are in close conformity with those reported by Wiggins *et al.* (2014). In case of planting techniques, planting at 90 cm × 90 cm exhibited significantly higher yield attributes, picked bolls/plant, seed-cotton weight/

**Table 2.** Yield-contributing characters and seed cotton yield of Bt cotton as influenced by irrigation, planting and fertigation (pooled data over 2 years)

Treatment	Picked bolls/plant	Seed-cotton weight/boll (g)	Seed-cotton weight/plant (g)	Seed weight/plant (g)	Lint-weight/plant (g)	Seed-cotton yield (t/ha)
<i>Irrigation regimes</i>						
I <sub>1</sub> , 0.6 Etc	43.8	3.7	176.8	143.0	62.7	2.3
I <sub>2</sub> , 0.8 Etc	56.2	3.9	250.5	210.7	91.2	3.1
I <sub>3</sub> , 1.0 Etc	64.7	4.1	302.8	251.1	108.4	3.3
I <sub>4</sub> , Surface irrigation (control)	50.1	3.8	213.4	173.8	75.9	2.5
SEm±	1.2	0.03	5.8	5.3	2.1	0.1
CD (P=0.05)	3.7	0.11	17.8	16.5	6.4	0.3
<i>Planting techniques</i>						
P <sub>1</sub> , 90 cm × 90 cm	61.5	3.8	264.8	219.4	95.1	3.3
P <sub>2</sub> , 150 cm × 60 cm	45.8	3.9	206.9	169.9	74.0	2.3
SEm±	0.7	0.03	3.9	2.9	1.4	0.1
CD (P=0.05)	1.9	0.10	11.6	8.5	4.1	0.2
<i>Fertigation (Nutrient management)</i>						
F <sub>1</sub> , 100% GRDF	48.8	3.8	209.1	174.8	74.8	2.5
F <sub>2</sub> , 100% GRDF + 20 kg MgSO <sub>4</sub> /ha	53.8	3.9	235.7	194.5	84.4	2.8
F <sub>3</sub> , 100% GRDF + 20 kg MgSO <sub>4</sub> + 25 kg ZnSO <sub>4</sub> + foliar spray of Fe (1%) and B (0.5%)	58.6	3.9	262.7	214.6	94.5	3.1
SEm±	0.8	0.02	3.6	3.2	1.3	0.05
CD (P=0.05)	2.1	0.06	10.2	8.9	3.7	0.13
<i>Interactions (I × P × F)</i>						
I × P	NS	NS	NS	NS	NS	NS
I × F	NS	NS	NS	NS	NS	NS
P × F	NS	NS	NS	NS	NS	NS
I × P × F	NS	NS	NS	NS	NS	NS

GRDF, General recommended dose of fertilizers; Etc, evapotranspiration of crop; NS, non-significant

plant, seed weight/plant and lint weight/plant than 150 cm × 60 cm planting technique (Table 2). This is because of more plants/unit area and more light interception in closed planting (90 cm × 90 cm) resulted in higher photosynthetic rate and translocation of photosynthates towards reproductive organs which helped increase the yield attributes in Bt cotton. These results confirm the findings of Jat *et al.* (2014). Among the nutrient-management treatments, fertigation of 100% GRDF up to 100 days + 20 kg MgSO<sub>4</sub>/ha and 25 kg ZnSO<sub>4</sub>/ha up to flowering at weekly interval + foliar spray of Fe (1.0%) and B (0.5%) at flowering and boll-development stages resulted in significantly higher yield-contributing characters, viz. picked bolls/plant, seed-cotton weight/boll, seed-cotton weight/plant, seed weight/plant and lint weight/plant on pooled mean basis. This might be because of frequent application of nutrients in 12 equal splits as per the requirement of crop increased the use efficiency of added nutrients thereby increased the physiological activities which translocated more photosynthates towards reproductive organs and resulted in increase in the yield attributes of Bt cotton. The reverse trend was noticed with fertigation of 100% GRDF alone because of limiting micro nutrients. (Table 2). The results confirm the findings of Yadav *et al.* (2014).

#### Seed-cotton yield

The seed-cotton yield was maximum and significantly higher in 1.0 ETc irrigation regime. It was at par with 0.8 ETc irrigation regime on pooled mean basis (Table 2). The increase in yield was 45.7% higher over 0.6 ETc irrigation regime and 30.7% over surface-irrigation method. Under deficit irrigation, 0.8 ETc irrigation regime was found most suitable one compared to 0.6 ETc irrigation regime,

as it recorded almost identical yield obtained from 1.0 ETc irrigation. This indicated a saving of 20% irrigation water over 1.0 ETc irrigation regime. The deficit irrigation regime (0.6 ETc) resulted in significantly minimum seed-cotton yield (2.3 t/ha) because the crop continuously faced the problem of moisture stress at root rhizosphere throughout the crop-growth period which affected the physiological activities responsible for growth and development of crop. Our results support those of Sampathkumar *et al.* (2012). Planting of Bt cotton at 90 cm × 90 cm resulted in significantly higher seed-cotton yield (3.3 t/ha) than that obtained from 150 cm × 60 cm planting (2.3 t/ha) on pooled mean basis. The results confirm the findings of Devraj *et al.* (2011).

The enhancement of seed-cotton yield (3.1 t/ha) was observed in fertigation of 100% GRDF up to 100 days + 20 kg MgSO<sub>4</sub>/ha and 25 kg ZnSO<sub>4</sub>/ha up to flowering at weekly interval + foliar spray of Fe (1.0%) and B (0.5%) at flowering and boll-development stages on pooled mean basis because the nutritional requirement of crop fulfilled by supplying N, P and K through fertigation in 12 equal splits up to 100 days and fertigation of MgSO<sub>4</sub> and ZnSO<sub>4</sub> in 9 equal splits up to 70 days after planting (DAP) along with foliar nutrition of iron and boron. This was reflected on luxurious growth of crop which increased the biomass accumulation and translocation of photosynthates towards reproductive organs. These activities finally increased the seed-cotton yield (Table 2). These results are in line of Waikar *et al.* (2015).

#### Water-use efficiency

Scheduling of irrigation at 0.6 ETc through drip resulted in the maximum water-use efficiency followed by

**Table 3.** Water applied, total water used and water use efficiency (WUE) in Bt cotton as influenced by irrigation, planting and fertigation (pooled data over 2 years)

Treatment	Water applied (mm)	Effective rainfall (mm)	Total water used (mm)	Seed-cotton yield (kg/ha)	WUE (kg/ha/mm)
<i>Irrigation regimes</i>					
I <sub>1</sub> , 0.6 Etc	295.1	31.2	326.3	2281.0	7.0
I <sub>2</sub> , 0.8 Etc	393.5	41.6	435.0	3078.1	7.0
I <sub>3</sub> , 1.0 Etc	491.9	52.0	543.7	3324.0	6.1
I <sub>4</sub> , Surface irrigation (control)	750.0	147.1	897.1	2543.2	2.8
<i>Planting techniques</i>					
P <sub>1</sub> , 90 cm × 90 cm	482.6	67.9	550.6	3296.3	6.0
P <sub>2</sub> , 150 cm × 60 cm	482.6	67.9	550.6	2327.2	4.3
<i>Fertigation (Nutrient management)</i>					
F <sub>1</sub> , 100% GRDF	482.6	67.9	550.6	2493.0	4.5
F <sub>2</sub> , 100% GRDF + 20 kg MgSO <sub>4</sub> /ha	482.6	67.9	550.6	2790.2	5.1
F <sub>3</sub> , 100% GRDF + 20 kg MgSO <sub>4</sub> + 25 kg ZnSO <sub>4</sub> + foliar spray of Fe (1%) and B (0.5%)	482.6	67.9	550.6	3134.1	5.7

GRDF, General recommended dose of fertilizers; Etc, evapotranspiration of crop; NS, non-significant

**Table 4.** Quality parameters of Bt cotton as influenced by irrigation, planting and fertigation (pooled data over 2 years)

Treatment	Ginning (%)	2.5% span length (mm)	Uniformity ratio (%)	Micronaire value	Bundle strength (g/tex)
<i>Irrigation regimes</i>					
I <sub>1</sub> , 0.6 Etc	35.37	28.56	50.67	3.58	22.66
I <sub>2</sub> , 0.8 Etc	35.41	28.70	50.50	3.58	23.11
I <sub>3</sub> , 1.0 Etc	35.43	28.87	50.08	3.58	23.25
I <sub>4</sub> , Surface irrigation (control)	35.42	28.15	50.42	3.47	22.74
SEm±	0.02	0.375	0.372	0.030	0.161
CD (P=0.05)	NS	NS	NS	NS	NS
<i>Planting techniques</i>					
P <sub>1</sub> , 90 cm × 90 cm	35.41	28.67	50.18	3.51	23.05
P <sub>2</sub> , 150 cm × 60 cm	35.40	28.47	50.65	3.59	22.83
SEm±	0.04	0.263	0.274	0.035	0.320
CD (P=0.05)	NS	NS	NS	NS	NS
<i>Fertigation (Nutrient management)</i>					
F <sub>1</sub> , 100% GRDF	35.39	28.29	50.50	3.60	23.02
F <sub>2</sub> , 100% GRDF + 20 kg MgSO <sub>4</sub> /ha	35.41	28.55	50.40	3.59	22.78
F <sub>3</sub> , 100% GRDF + 20 kg MgSO <sub>4</sub> + 25 kg ZnSO <sub>4</sub> + foliar spray of Fe (1%) and B (0.5%)	35.42	28.86	50.35	3.46	23.02
SEm±	0.04	0.479	0.524	0.061	0.551
CD (P=0.05)	NS	NS	NS	NS	NS
<i>Interactions (I×P×F)</i>					
I × P	NS	NS	NS	NS	NS
I × F	NS	NS	NS	NS	NS
P × F	NS	NS	NS	NS	NS
I × P × F	NS	NS	NS	NS	NS

GRDF, General recommended dose of fertilizers; Etc, evapotranspiration of crop; NS, non-significant

0.8 ETc and 1.0 ETc (Table 3). However, minimum water use efficiency (2.9 kg/ha-mm) was observed in surface irrigation method during both years. This might be because deep root-system of cotton extracted moisture from higher depth of soil and fulfilled crop-water requirement even under deficit irrigation. This indicates that Bt cotton responded to deficit irrigation and gave higher yield with minimum quantity of irrigation water. These results confirm the findings of Ilhe and Tumbare (2015). The maximum water-use efficiency was recorded under 90 cm × 90 cm planting compared to 150 cm × 60 cm planting. This might be because under close spacing (90 cm × 90 cm), each plant extracted uniform moisture from the root rhizosphere compared to wider spacing (Table 3). These results are in accordance with those reported by Shukla *et al.* (2013). Fertigation of 100% GRDF up to 100 days + 20 kg MgSO<sub>4</sub>/ha and 25 kg ZnSO<sub>4</sub>/ha up to flowering at weekly intervals + foliar spray of Fe (1.0%) and B (0.5%) at flowering and boll-development stages recorded the maximum water-use efficiency on pooled mean basis (Table 3). This might be because of higher biomass production and seed-cotton yield compared 100% GRDF alone (F<sub>1</sub>) and 100% GRDF + 20 kg MgSO<sub>4</sub>/ha (F<sub>2</sub>). These results confirm

those reported by Jaykumar *et al.* (2015).

#### Quality parameter

The cotton-quality parameters, viz. ginning percentage, 2.5% span length, uniformity ratio, micronaire value and bundle strength were not influenced significantly due to different irrigation regimes and planting techniques on pooled mean basis. (Table 4). Our findings support the results of Wiggins *et al.* (2014) for irrigation regimes and of Pendharkar *et al.* (2010) and Bharathi *et al.* (2014) for planting techniques. Different fertigation treatments, on pooled mean basis, did not significantly influence ginning percentage, 2.5% span length, uniformity ratio, micronaire value and bundle strength. Similar results were also reported by Wiggins *et al.* (2014).

Thus, it could be concluded that, scheduling of irrigation at 0.8 ETc irrigation regime coupled with 90 cm × 90 cm planting technique and fertigation of 100% GRDF up to 100 days +20 kg MgSO<sub>4</sub>/ha and 25 kg ZnSO<sub>4</sub>/ha up to flowering at weekly intervals + foliar spray of ferrous sulphate (1.0%) and borax (0.5%) at flowering and boll-development stages recorded maximum growth, yield-contributing characters and seed-cotton yield in Bt cotton.

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