Indian Journal of Agronomy **56**(2): 150–153 (June 2011)

Productivity and nutrient uptake of Bt-cotton (*Gossypium hirsutum*) as influenced by precision in application of irrigation and fertilizer

P.D. BHALERAO, G.S. GAIKWAD AND S.R. IMADE

Cotton Research Unit, Dr Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra 444 104

Received: August, 2010

ABSTRACT

Drip irrigation and fertigation has much scope in increasing the productivity of water and yield per unit area. Therefore, present field experiment was conducted from 2007-08 to 2009-10 at Akola (Maharashtra) to compare irrigation based on crop evapo-transpiration (Etc) and fertilizer through drip system against conventional irrigation and fertilizer application methods in Bt-cotton hybrid (*Gossypium hirsutum* L.). Results indicated that scheduling of irrigation at 1.0 Etc and application of 125% recommended dose of fertilizers (RDF) (125: 62.5: 62.5 kg NPK/ha) through drip, recorded highest seed cotton yield (2.17 t/ha), which was at par with 0.8 Etc with 125% RDF (2.02 t/ha). The yield enhancement due to drip system was 10.53, 11.49 and 12.39 % at 0.6, 0.8 and 1.0 Etc. respectively when compared with application of irrigation at 0.6 IW/CPE ratio. The water requirement at 0.6, 0.8 and 1.0 was 75.8, 96.4 and 177.7 mm/ha respectively, compared to 183.6 mm/ha under 0.6 IW/CPE ratio. Uptake of N, P and K was found maximum with irrigation applied at 1.0 Etc. along with 125% RDF (125:62.5:62.5 kg NPK/ha).

Key words: Bt-cotton, Drip irrigation, Fertigation, Nutrient uptake, Seed cotton yield, Water use efficiency

Release of Bt-cotton for commercial cultivation in India has been a historical event in increasing the productivity of cotton. It occupies around 80% of total area under cotton cultivation in the country. Water and fertilizers are most important production factors for cotton production. Day-to-day availability of both the inputs are scarce, hence its judicious use in scientific manner is essential for increasing the productivity. In India, cotton is mostly grown under rainfed conditions and hence the productivity is very low (502 kg lint/ha) when compared with world average (725 kg lint/ha). Application of irrigation based on crop evapotranspiration (Etc.) and fertigation are the new approaches for water and nutrient management. Drip irrigation and fertigation are the latest methods to supply water and nutrients in the root zone of plant and thereby increasing productivity. Adoption of micro-irrigation might help in increasing, productivity of crop, irrigated area and water use efficiency (Srivanappan, 2004).

At present, in India, furrow irrigation is mainly practiced for cotton crop. Cotton being a long duration and widely spaced crop, drip irrigation and fertigation offers much scope in enhancing the productivity of water and yield/unit area. Hence, an experiment was carried out to findout suitable irrigation schedule and fertilizer dose for Bt. cotton in Vidarbha region of Maharashtra.

Corresponding authorEmail: satishimade130884@rediffmail.com

MATERIALS AND METHODS

A field experiment was conducted from 2007-08 to 2009-10 at Cotton Research Unit, Dr Panjabrao Deshmukh Krishi Vidyapeeth, Akola. Bt. cotton hybrid bunny (BG I) was sown with spacing of 60 cm × 60 cm to 120 cm spacing in paired row planting technique on 4 July, 20 June and 1 July between 2007-08, 2008-09 and 2009-10, respectively. Adoption of paired row technique minimized the cost of laterals. The inline dripper distance was 60 cm. The plot size was 5.4 m × 7.2 m. The experimental soil was clayey in texture, low in available nitrogen (146.4 kg/ha), high in phosphorus (23.6 kg/ha) and potash (330 kg/ha) with pH of 7.6. The design used was split plot with three replications. The main plot comprises four irrigation treatments *viz.* irrigation at 0.6 Etc (I_1), 0.8 Etc (I_2), 1.0 Etc (I_3) and furrow irrigation at 0.6 IW/CPE ratio (I_4). Sub-plots received four fertilizer treatments *viz.* 75% RDF (F_1), 100% RDF (F_2), 125 % RDF (F_3) in 6 splits at 15 days interval though drip fertigation, except P which was given though basal application and 100% RDF in 3 splits to soil application (F_4). Application of 100:50:50 kg NPK/ha was considered as 100% RDF. The amount of water to be given in each irrigation was calculated by using following formula:

Table 1. Stage-wise rainfall distribution during the seasons

Stages of crop	Actual rainfall (mm)		
	2007-08	2008-09	2009-10
Before sowing	114.4	77.2	145.6
Sowing	181.1	20.8	77.1
Sowing to full emergence	39.5	1.6	48.0
Emergence to square initiation (Early growth stage)	205.0	205.9	91.4
Square to flower initiation (Peak square stage)	154.9	174.6	98.8
Flower to boll formation (Full bloom stage)	54.4	43.1	76.7
Boll formation to Ist boll opening	21.7	0.0	5.0
First picking to last picking	0.00	5.0	112.5
Actual rainfall (mm)	771.0	528.2	655.1
Effective rainfall (mm)	598.1	448.1	521.9

V = Eo X Kc X Kp

Whereas, V, Volume of water to be given/dripper (litres); Eo, Pan evaporation of two days (mm); Kc, Crop factor as per growth stages of cotton; Kp, Pan factor (0.7).

For cotton Kc values were 0.45, 0.75, 1.15 and 0.70 for seedling (0-25 DAS), crop development stage (26-70 DAS), boll development (71-120 DAS) and maturity stage (> 121 DAS) respectively as per *FAO* Irrigation Water Management Training Manual No 3 (1986). Based on the above formula quantity of water was calculated on alternate days and irrigation was scheduled. Time for irrigation was decided as per the discharge of water per dripper. The irrigation was given at alternate day through drip. For conventional irrigation 6 cm depth of irrigation was considered and irrigation given on the basis of cumulative pan evaporation. (100 mm CPE).The irrigation was cut off after starting the boll brusting. The field capacity of the soil was 35.5 and permanent wilting point was 18.0%.

The total rainfall 771.0, 528.2 and 655.1 mm were received during 2007-08, 2008-09 and 2009-10 respectively (Table 1). Out of that 598.07, 448.12 and 521.98 mm was effective rainfall during first, second and third year of study. The irrigation water requirement at 0.6, 0.8, 1.0 Etc and 0.6 IW/CPE were 75.79, 96.45, 177.77 and 183.65 mm/ha respectively. During all three years of experimentation, rainfall received before sowing and at the sowing was sufficient. However, during second year (2008-09) of study rainfall was very less after sowing which required application of irrigation to save the crop in I_4 treatment (0.6 IW/CPE ratio). Similarly rainfall was very less in second year when compared with first and third year of study. Dry spell at boll formation to 1st boll opening during second year drastically reduced the yield level when compared with first and third year of study. The consumptive use was increased with increasing Etc. levels from 0.6 to 1.0 Etc. and maximum with furrow irrigation (Table 2). There was maximum saving of irrigation water with drip irrigation when compared with furrow irrigation (Table 2).

RESULTS AND DISCUSSION

Growth and yield attributes

Pooled mean of three years (Table 3) revealed that plant height and dry matter per plant did not differ significantly with application of irrigation through drip at various levels and through furrow. However, maximum number of bolls, sympodial branches per plant and seed cotton yield per plant were recorded with scheduling of irrigation at 1.0 Etc (through drip) which was significantly more than other irrigation levels. This might be due to favourable micro-climate. These results are confirmatory with reported by Reddy and. Aruna (2009)

Plant height was maximum with 125% RDF being at par with 100% RDF applied through drip in six splits and through soil but significantly more than 75% RDF through drip. Dry matter accumulation per plant and boll weight were not influence significantly with various fertilizer levels. Sympodial branches, number of bolls and seed cotton yield per plant were significantly higher with 125% RDF than all other fertilizer levels. It indicated that Bt cotton required more nutrients for enhancing yield attributes. All the treatments were significantly superior to 75% RDF.

Seed cotton yield

During 2007-08 and 2009-10 irrigation applied at 1.0 Etc through drip, recorded the highest yield (1.98 t/ha) and found significantly superior to all other treatments.

Table 2. Treatment-wise irrigation water and consumptive use.

Irrigation level	Consumptive use (mm/ha)				Irrigation water applied (mm)			
	2007-08	2008-09	2009-10	Mean	2007-08	2008-09	2009-10	Mean
0.6 Etc	656.19	517.76	619.79	597.9	58.12	69.64	97.81	75.19
0. 8 Etc	675.08	530.05	652.40	619.2	77.01	81.93	130.42	96.45
1.0 Etc	694.15	542.32	685.01	640.5	96.08	94.20	163.03	117.77
0.6 IW/CPE ratio	749.02	648.12	721.98	706.4	150.95	200.0	200.0	183.65
Fertilizer levels	693.61	559.56	669.79	-	95.54	111.44	147.82	-

Table 3. Growth parameters and yield attributes as influenced by various treatments (Pooled Mean).

Treatment	Plant height (cm)	Sympodial branches/ plant	Dry matter weight/ plant (g)	Bolls/ plant	Boll weight (g)	Yield/ plant (g)	Seed cotton yield (t/ha)				Quantity of water applied (mm/ha)	WUE (kg/ha-mm)
							2007 -08	2008 -09	2009 -10	Mean		
Irrigation levels												
0.6 Etc (Drip)	87.3	16.8	133.3	27.1	4.17	93.7	2.02	1.87	1.40	1.76	597.3	2.95
0. 8 Etc (Drip)	86.6	16.9	141.7	27.9	4.29	104.1	2.03	1.95	1.52	1.83	619.2	2.96
1.0 Etc (Drip)	88.5	17.6	147.2	30.3	4.27	113.8	2.17	1.97	1.79	1.98	639.5	3.09
0.6 IW/CPE ratio (Furrow irrigation)	85.3	16.4	125.7	26.1	3.95	87.9	1.54	2.21	1.03	1.59	705.3	2.26
SEm ±	0.88	0.14	17.8	0.28	0.06	1.52	34.9	36.4	34.2	17.1	-	-
CD (P=0.05)	NS	0.48	NS	0.96	0.22	5.25	133.7	126.0	118.3	67.1	-	-
Fertilizer levels												
75% RDF (Fertigation)	84.4	16.5	133.7	26.1	4.06	90.0	1.78	1.72	1.37	1.62	641.5	2.53
100% RDF (Fertigation)	86.8	16.8	135.9	27.6	4.21	99.9	1.90	1.95	1.44	1.76	641.5	2.75
125% RDF (Fertigation)	89.2	17.5	139.6	29.4	4.23	109.7	2.10	2.30	1.51	1.97	641.5	3.08
100% RDF (Soil applied)	87.2	16.9	138.6	28.3	4.17	99.6	1.98	2.01	1.41	1.80	641.5	2.81
SEm ±	0.74	0.17	3.46	0.34	0.06	0.84	33.2	26.7	21.1	15.0	-	-
CD (P=0.05)	2.58	0.50	NS	0.99	NS	2.45	107.5	78.1	61.6	43.8	-	-

Etc: Evapotranspiration; RDF: Recommended dose of fertilizers; WUE: Water use efficiency

Difference between irrigation applied at 0.6 Etc and 0.8 Etc was not significant. These results are in confirmatory with Shinde *et.al* (2009). Significantly lowest yield (1.59 t/ha) was found with irrigation applied in furrows when compared with other treatments.

In the second year of study irrigation applied in furrows at 0.6 IW/CPE ratio recorded significantly higher seed cotton yield than irrigation applied at 0.6, 0.8 and 1.0 Etc through drip. Similar results were reported at Sirsa (Anonymous, 2002). This might be due to very less amount of rainfall after sowing (Table 1) which required one irrigation to protect the crop and maintain plant stand for obtaining yield. The irrigation applied in early stage of crop maintain soil moisture in the root zone of crop for longer time and rainfall received after that fully conserved in furrows which ultimately enhanced the seed cotton yield in furrow irrigation treatment compared to drip irrigation.

Pooled analysis of three years yield data revealed that irrigation applied at 1.0 Etc recorded significantly higher seed cotton yield than other irrigation levels (Table 3). Halemani *et al.* (2003) and Bhatoo *et.al.* (2009) also reported that drip irrigation at 1.0 Etc produced maximum yield than other levels of drip irrigation and furrow irrigation. Irrigation at 0.8 Etc significantly superior to 0.6 Etc. Similar results were reported at Sirsa (TMC, 2002). Application of irrigation through furrows gave significantly lowest seed cotton yield. Higher value of WUE (3.09) was found with application of irrigation at 1.0 Etc followed by 0.8 and 0.6 Etc. The enhanced water use efficiency (WUE) in drip system is due to decreased surface evaporation, runoff and percolation losses of water. These results are in agreement with Oweis and Hachum (2002). There was saving of 108.0, 86.1 and 65.8 mm/ha of water by adopting drip irrigation system at 0.6, 0.8 and 1.0 Etc, compared to furrow irrigation method. Asokaraja and Palanisamy (2003) reported water saving due to drip irrigation when compared with surface irrigation.

There was significant response to application of 125% RDF through drip in six splits than other treatments in all the three years of study. Similar types of results were reported by Tumbare *et al.* (1999). Application of 100% RDF either through drip or through soil did not differ significantly. However application of 75% RDF through drip recorded significantly lowest yield (1.78 t/ha) than all other fertilizer levels. Pooled mean indicated that application of 125% RDF recorded significantly higher seed cotton yield (1.97 t/ha) than 100% RDF through soil in three splits, 100% RDF through drip and 75% RDF. Higher

Table 4. Seed cotton yield (t/ha) as influenced by irrigation × fertilizer levels.

Irrigation/ fertilizer	75% RDF	100% RDF	125% RDF	100% RDF (Soil applied)	Mean
0.6 Etc (drip)	1.66	1.71	1.92	1.76	1.76
0. 8 Etc (drip)	1.70	1.76	2.02	1.86	1.83
1.0 Etc (drip)	1.81	1.91	2.17	2.02	1.98
0.6 IW/CPE ratio (furrow Irrigation)	1.33	1.68	1.78	1.59	1.59
Mean	1.62	1.76	1.97	1.80	
SEm±			60.3		
CD (P=0.05)			179.2		

RDF: Recommended dose of fertilizers, Etc: Evapotranspiration;

value of WUE (3.08) was noticed with application of 125% RDF.

Seed cotton yield was significantly influenced by interaction of irrigation and fertilizer levels (Table 4). Highest seed cotton yield (2.17 t/ha) was recorded with application of irrigation at 1.0 Etc through drip and 125% RDF and this combination being par with application of irrigation at 0.8 Etc with 125% RDF and 1.0 Etc with RDF combination but significantly superior to remaining all treatment combinations. Nalayini *et al.* (2006) at Coimbtore reported that scheduling of irrigation at 1.0 Etc was on par with 0.8 Etc through drip for cotton crop.

Table 5. Nutrient uptake as influenced by various treatments (pooled mean)

Treatment	Nutrient uptake (kg/ha)			Total uptake (kg/ha)
	N	P	K	
Irrigation				
0.6 Etc (drip)	50.20	23.74	42.44	116.38
0. 8 Etc (drip)	55.22	23.69	45.68	124.59
1.0 Etc (drip)	64.95	28.37	54.68	148.00
0.6 IW/CPE ratio (Furrow irrigation)	46.84	20.39	37.90	105.13
SEm±	0.94	0.62	0.52	-
CD (P=0.05)	3.26	2.16	1.79	-
Fertilizer levels				
75% RDF (fertigation)	49.56	22.18	40.54	112.28
100% RDF (fertigation)	58.29	22.89	44.10	125.28
125% RDF (fertigation)	59.80	25.78	50.70	136.28
100% RDF (soil applied)	54.57	25.33	45.37	125.27
SEm±	0.97	0.50	0.84	-
CD (P=0.05)	2.82	1.45	2.44	-

Etc, Evapotranspiration; RDF, Recommended dose of fertilizers,

Nutrient uptake

Significantly higher uptake of N, P and K was observed with application of irrigation at 1.0 Etc. There was significant response of NPK uptake with increasing Etc levels, however 0.6 and 0.8 Etc levels were on par with P uptake. Lowest uptake of NPK was found with application of irrigation at 0.6 IW/CPE ratio which was significantly lower than drip irrigation. This might be due to optimum levels of moisture in root zone of cotton with drip irrigation, when compared with surface irrigation.

Highest NPK uptake was observed with application of 125% RDF through drip in six splits which was significantly superior to 75 % and 100% RDF except nitrogen (N) uptake. Similar results were reported by Thind *et al.* (2008). Significantly lowest uptake of N was seen with 100% RDF in three splits, however, P and K were significantly less in 75% RDF.

The highest N uptake was noticed with application of irrigation at 1.0 Etc at 125% RDF (I_3F_3) combination being at par with irrigation level at 100% RDF (I_3F_2) but significantly superior over rest of combinations (Table 5). Similarly I_3F_2 combination was at par with I_3F_1 combination. These results indicated that availability of moisture in root zone in most important for nutrient uptake.

Quality parameters

Various fibre quality parameters and oil content did not differ significantly with application of irrigation either through drip or as surface at different levels.

It is concluded from the study that Bt cotton hybrid should be irrigated at 0.8 Etc for saving of water and fertilized with 125:62.5:62.5 kg NPK/ha for obtaining higher seed cotton yield in Vidarbha region of Maharashtra.

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