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Effect of drip irrigation and fertigation on yield, economics and water use efficiency of *intra-hirsutum* Bt cotton

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Abstract: A field experiment was carried out *in vertisols* at Agricultural Research Station, Dharwad during *kharif* 2015-16 to assess the effect of different levels of drip irrigation and fertigation of N & K on seed cotton yield and water use efficiency (WUE). Three levels of drip irrigation *viz.,* irrigation at 1.0 Etc, 0.8 Etc and 0.6 Etc and three levels of N & K (100%, 75%, and 50% of recommended dose of N & K) applied through fertigation were compared with furrow method of irrigation with basal application of fertilizers. Significantly higher seed cotton yield (SCY) was recorded in drip irrigation at 1.0 Etc with fertigation of 100% N & K in six equal splits (4,024 kg ha^{-1}), however it was on par with drip irrigation at 0.8 Etc and 75% N & K in six equal splits (3943 kg ha^{-1}). Drip irrigation at 1.0 Etc with basal application of 100% RDF and furrow irrigation with basal application of 100% RDF in four equal splits recorded significantly lower SCY. Significantly higher WUE was obtained with drip irrigation at 0.8 Etc level (6.8 kg ha^{-1}-mm) which was on par with 1.0 Etc level (6.6 kg ha^{-1}-mm). Similarly higher water use efficiency was recorded at 100 per cent fertigation of RD N & K and it was on par with 75 per cent fertigation of RD N & K. Drip irrigation at 1.0 Etc recorded significantly higher consumptive use of water (503.2 mm) as compared to drip irrigation at 0.8 Etc and 0.6 Etc.

Keywords: Cotton, Consumptive use, Drip irrigation, Fertigation

Introduction

India is one of the major producers of cotton in the world with largest acreage of 11.7 m ha. During last ten years, Bt. cotton has substantially contributed in increasing national and state productivity. Drip irrigation could help to bring more area under cotton irrigation with increased crop yields. Next to water, nutrient limits the growth, quality and yield of cotton. Irrigation method and fertilizer application with appropriate schedule is one of the important factors that affect the seed cotton yield (SCY). Management of water and nutrients plays a key role in enhancing the productivity of Bt cotton which is occupying more than 90 per cent area. In this context, micro-irrigation could play a key role in increasing the productivity, water use efficiency (WUE) and nutrient use efficiency (NUE). The amount of fertilizer lost through leaching could be as low as 10 per cent in drip fertigation as compared to 50 per cent in the conventional method of fertilizer application (Sankaranarayanan *et al.*, 2010). In view of it a field experiment was undertaken in medium deep black soils with specific objectives of assessing the effect of drip fertigation on seed cotton yield and water use efficiency of *intra hirsutum* Bt cotton.

Material and methods

A field experiment was conducted during *kharif* 2015 at Agriculture Research Station, Dharwad farm to assess the effect of different levels of drip irrigation and fertigation of N & K on seed cotton yield and water use efficiency as against the furrow method of irrigation and tradition method of fertilizer application. The soil of the experimental site was medium deep black soil with medium organic carbon(0.56%) and neutral soil reaction (7.1). The soil available N, P_2O_5 and K_2O were in low (285 kg ha^{-1}), medium (35 kg ha^{-1}) and high (525 kg ha^{-1}) range respectively. The experiment was laid out in factorial randomized block design and was replicated thrice. First class BG-II hybrid was sown during first week of June at a spacing 120 cm (60 cm-120 cm) × 60 cm under paired row system of planting and 90 cm × 60 cm with single row planting was followed under control treatments. The experiment consisted of eleven treatments *viz.*, I_1F_1 : drip irrigation (DI) at 1.0 Etc with 100% RD N & K fertigation, I_1F_2 : DI at 1.0 Etc with 75% RD N & K fertigation, I_1F_3 : DI at 1.0 Etc with 50% RD N & K fertigation, I_2F_1: DI at 0.8 Etc with 100 % RD N & K fertigation, I_2F_2 : DI at 0.8 Etc with 75% RD N & K fertigation, I_2F_3 : DI at 0.8 Etc with 50% RD N & K fertigation, I_3F_1 : DI at 0.6 Etc with 100% RD N & K fertigation, I_3F_2 : DI at 0.6 Etc with 75% RD N & K fertigation, I_3F_3 : DI at 0.6 Etc with 50% RD N & K fertigation, C_1 : drip irrigation at 1.0 Etc with basal application of 100% RDF and C_2 : furrow irrigation at 0.8 IW/CPE ratio with basal application of 100% RDF.

Scheduling of irrigation was undertaken on the basis of crop coefficient factors during cotton growth period and pan coefficient at every three days interval by considering rainfall using the formula $V = E_0 \times Kc \times Kp$ where V: Volume of water to be given through drip (lit), E_0: Pan evaporation of two days (mm), Kc : Crop Coefficient factors during cotton growth period, Kp: Pan factor (0.70). For cotton crop the 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 to at harvest) respectively as per FAO Irrigation Water Management Training Manual No 3 (1986). Quantity of water to be applied to each treatment once in three days was calculated using the above equation and accordingly irrigation was scheduled. WUE (kg ha-cm^{-1}) was estimated by using equation *i.e.,* economic crop yield (kg ha^{-1})/water used (ha-cm) and consumptive use of water (mm) was estimated at 30 cm depth by using formula IR + ER + Σ Mbi - Mai / 100 x BDi x Di where IR= Irrigation water applied (mm), ER= Effective

rainfall (mm), Mbi = Moisture percentage at the time of planting in i^{th} layer, Mai = Moisture percentage after harvesting of crop in i^{th} layer, BDi = Bulk density of i^{th} layer (g cc^{-1}) and Di = Depth of i^{th} layer (mm). Fertigation was given in six equal splits at 15 days interval and during the crop growth period a total of 326 mm of effective rainfall was received.

Results and discussion

Effect drip fertigation on seed cotton yield and its parameters

The results (Table 1) revealed higher number of sympodia per plant, total number of bolls per plant, boll weight and seed cotton yield per plant with scheduling of irrigation at 1.0 Etc (18.5, 40.9, 6.8 and 235.8, respectively) which was significantly higher than 0.6 Etc. However, it was on par with 0.8 Etc (17.7, 38.1, 6.4 and 227.9, respectively). Significantly higher number of sympodia per plant, total number of bolls per plant, boll weight and seed cotton yield per plant were obtained with fertigation of 100 per cent RD N & K in six equal splits (19.4, 41.6, 7.2 and 240, respectively) as compared to 50 per cent RD N and K, however it was on par with 75 per cent RD N and K (18.5, 39.06, 6.5 and 229.3 respectively). These results are in agreement with findings of Bhalerao *et al.* (2011) who reported that the yield attributes of Bt cotton were improved with the application of more nutrients. Though the interaction effect was significant, irrigating at 1.0 Etc with fertigation of 100 per cent RD N and K (I_1F_1) in six equal splits was registered significantly higher number of sympodia per plant (21.3) and it was on par with 0.8 Etc irrigation level with fertigation of 100 per cent RD N and K (I_2F_1) (20.9). Irrigating at 1.0 Etc with fertigation of 100 per cent RD N and K (I_1F_1) in six equal splits recorded significantly higher number of total bolls per plant, boll weight and seed cotton yield per plant (47.9, 7.9 and 279.3, respectively) and it was on par with drip irrigation at 0.8 Etc with fertigation of 100 per cent RD N & K (I_2F_1), drip irrigation at 1.0 Etc with fertigation of 75 per cent RD N and K (I_1F_2), and drip irrigation at 0.8 Etc with fertigation of 75 per cent RD N and

Table 1. Effect of drip irrigation and fertigation levels on yield parameters of *intra- hirsutum* Bt cotton

Treatment	Number of sympodia plant^{-1}	Total bolls plant^{-1}	Boll weight (g)	Seed cotton yield per plant (g)	Seed cotton yield (kg ha^{-1})
Irrigation levels (I)					
I_1: 1.0 Etc	18.5	40.9	6.8	235.8	3606
I_2 : 0.8 Etc	17.7	38.1	6.4	227.9	3435
I_3 : 0.6 Etc	15.0	29.2	5.9	159.6	2583
S.Em±	0.31	1.12	0.23	5.71	101
C.D at 5%	0.91	3.34	0.70	17.10	302
Fertigation levels (F)					
F_1 : 100 % RDF	19.9	41.6	7.2	240.0	3654
F_2 : 75 % RDF	18.5	39.1	6.5	229.3	3472
F_3 : 50 % RDF	14.5	27.5	5.4	153.9	2499
S.Em±	0.31	1.12	0.23	5.71	101
C.D. at 5%	0.91	3.34	0.70	17.10	302
Interactions (I x F)					
I_1F_1	21.3	47.8	7.9	279.3	4024
I_1F_2	18.5	43.2	6.8	265.7	3978
I_1F_3	15.7	31.6	5.6	162.3	2814
I_2F_1	20.8	45.4	7.0	270.0	4014
I_2F_2	18.2	42.7	6.8	261.7	3943
I_2F_3	14.1	26.1	5.5	152.0	2348
I_3F_1	16.0	31.5	6.5	170.7	2923
I_3F_2	15.4	31.3	5.9	160.7	2493
I_3F_3	13.7	24.8	5.3	147.3	2334
S.Em±	0.53	1.93	0.40	9.88	175
C.D. at 5%	1.58	5.79	1.21	29.63	523
Controls					
C_1	16.20	36.4	6.7	186.7	2943
C_2	14.7	26.9	5.8	155.3	2352
S.Em±	0.48	2.02	0.39	9.58	167
C.D. at 5%	1.42	5.97	1.15	28.27	491

Irrigation Levels — Fertigation levels (F)

I_1: 1.0 Etc — F_1 : 100% RD N & K (150: 75: 75 kg ha^{-1})

I_2 : 0.8 Etc — F_2 : 75% RD N & K (112.5: 75: 56.25 kg ha^{-1})

I_3 : 0.6 Etc — F_3 : 50% RD N & K (75: 75: 37.5 kg ha^{-1})

Controls

C_1: Drip irrigation at 1.0 Etc + 100% RD N & K in 4 splits through soil (25% each as basal and at 30, 60 & 90 DAS).

C_2: Furrow Irrigation at 0.8 IW/CPE ratio +100% RD N & K in 4 splits through soil (25% each as basal and at 30, 60 & 90 DAS).

K (I_2F_2). Drip irrigation at 0.6 Etc with fertigation of 50 per cent RD N and K (I_3F_3) was recorded significantly lower number of sympodia per plant, total bolls per plant, boll weight and seed cotton yield per plant as compared to rest of the treatments (13.7, 24.8, 5.3 and 147.3, respectively). The results are in conformity with earlier reports of Basavanneppa (2012) and Jayakumar *et al. (*2015) who reported improvement in the yield attributes of cotton under drip fertigation. This may be due to enhanced availability and uptake of nutrients leading to enhanced photosynthesis, expansion of leaves and translocation of nutrients to reproductive parts compared to conventional method of soil application of nutrients.

Drip irrigation at 1.0 Etc with basal dose of 100 per cent RDF in furrow planting system (C_1) recorded significantly higher number of sympodia per plant, total bolls per plant, boll weight and seed cotton yield per plant (16.2, 36.4, 6.7 and 155.3, respectively) as compared to furrow irrigation with basal dose of 100 per cent RDF in single row planting system (C_2).

Seed cotton yield increased with each level of irrigation where in drip irrigation at 1.0 Etc registered significantly higher seed cotton yield (3606 kg ha^{-1}) as compared to 0.6 Etc., but it was on par with 0.8 Etc (3435 kg ha^{-1}). The findings are in conformity with results of Rajendran and Arunvenkatesh (2014) and Bhalerao *et al.* (2011) who reported higher number of bolls, sympodial branches per plant and seed cotton yield per plant with scheduling of drip irrigation at 1.0 Etc. Aladakatti *et al.* (2012) also reported that drip irrigation at 80% PE once in 3 days interval increased the seed cotton yield and WUE when compared to other drip irrigation treatments. This was mainly due to limited quantity of water applied, increased seed cotton yield and favourable micro-climate. Seed cotton yield increased with each level of fertigation levels. Paired row sowing with fertigation of 100 per cent RD N & K (150:75 NP_2O_5 kg ha^{-1}) in six equal splits recorded significantly higher seed cotton yield (3,654 kg ha^{-1}), as compared to 50 per cent RD N and K., but it was on par with 75 per cent RD N and K (3,472 kg ha^{-1}). The results are in conformity with the findings of Balasubramanian *et al.* (2000): Bhakare *et al*. (2015): Nalayini *et al.* (2012) who reported 25 per cent fertilizer saving through drip fertigation to cotton and opined that as nutrients are supplied along with the water in the root zone through drip system, root proliferation was greater resulting in enhanced uptake of nutrients and water.

The interaction effects had significant effect on seed cotton yield. Irrigating at 1.0 Etc with fertigation of 100 per cent RD N & K (I_1F_1) in six equal split application recorded significantly higher seed cotton yield (4,024 kg ha^{-1}), and it was on par with drip irrigation at 0.8 Etc with 100 per cent RD N and K (I_2F_1), 1.0 Etc with 75 per cent RD N and K (I_1F_2) and 0.8 Etc with 75 per cent RD N and K (I_2F_2). Drip irrigation at 0.6 Etc with fertigation of 50 per cent RD N and K (I_3F_3) recorded significantly lower SCY as compared to all other treatments. Drip irrigation at 1.0 Etc with fertigation of 100 per cent RD N & K (I_1F_1), drip irrigation at 0.8 Etc with fertigation of 100 per cent RD N & K (I_2F_1), drip irrigation at 1.0 Etc with fertigation of 75 per cent RD N and K (I_1F_2), and drip irrigation at 0.8 Etc with fertigation of 75 per cent RD N and K (I_2F_2)(4024, 4014, 3978 and 3943 kg ha^{-1}) were registered significantly superior SCY as compared to control plots C_1 and C_2. However drip irrigation at 1.0 Etc with basal dose of 100 per cent RDF in single row planting system (C_1) recorded significantly higher seed cotton yield (2,943 kg ha^{-1}) than C_2 (2,352 kg ha^{-1}).

Effect on water use efficiency and consumptive use

Amount of water applied varied based on Etc levels. Water applied in paired row sowing with irrigation level I_1 (1.0 Etc) was 544 mm, for I_2 (0.8 Etc) 508 mm and for I_3 (0.6 Etc) 462 mm (Table 2). For normal row planting with irrigation at 1.0 Etc and 0.8 IW/CPE totally 435 mm and 686 mm of water was applied respectively. Significantly, higher water use efficiency (WUE)

Table 2. Water use efficiency (WUE) and consumptive use of water (mm) of *intra-hirsutum* Bt cotton as influenced by drip irrigation and fertigation levels

Treatment	Water applied (mm)	WUE (kg ha^{-1}-mm)	CU (mm)
Irrigation levels (I)			
I_1: 1.0 Etc	544	6.6	503
I_2 : 0.8 Etc	508	6.8	483
I_3 : 0.6 Etc	462	5.6	450
S.Em±	-	0.20	2.95
C.D. at 5%	-	0.61	8.83
Fertigation levels (F)			
F_1 : 100 % RD N & K	-	7.2	487
F_2 : 75 % RD N & K	-	6.8	489
F_3 : 50 % RD N & K	-	5.00	459
S.Em±	-	0.20	2.95
C.D. at 5%	-	0.61	8.83
Interactions (I x F)			
I_1F_1	544	7.4	540
I_1F_2	508	7.3	507
I_1F_3	462	5.2	461
I_2F_1	544	7.9	493
I_2F_2	508	7.8	496
I_2F_3	462	4.6	460
I_3F_1	544	6.3	430
I_3F_2	508	5.4	463
I_3F_3	462	5.1	456
S.Em±	-	0.35	5.10
C.D. at 5%	-	1.05	15.30
Comparision with controls			
C_1	435	6.8	423
C_2	686	3.4	684
S.Em±	-	0.33	5.46
C.D. at 5%	-	0.98	16.09

Irrigation Levels	Fertigation levels (F)
I_1: 1.0 Etc	F_1 : 100 % RD N & K (150: 75: 75 kg ha^{-1})
I_2 : 0.8 Etc	F_2 : 75 % RD N & K (112.5: 75: 56.25 kg ha^{-1})
I_3 : 0.6 Etc	F_3 : 50 % RD N & K (75: 75: 37.5 kg ha^{-1})

Controls

C_1: Drip irrigation at 1.0 Etc + 100 % RD N & K in 4 splits through soil (25 % each as basal and at 30, 60 & 90 DAS).

C_2: Furrow Irrigation at 0.8 IW/CPE ratio +100 % RD N & K in 4 splits through soil (25 % each as basal and at 30, 60 & 90 DAS).

of 6.76 kg ha^{-1}- mm was registered with 0.8 Etc which was on par with 1.0 Etc and significantly superior over 0.6 Etc. Lowest WUE was recorded in surface furrow irrigation. Application of 100 per cent RD N & K through fertigation in 6 equal splits was recorded significantly highest WUE, however it was on par with 75 per cent RD N & K fertigation over 50 per cent RD N & K fertigation and with both the control plots (C_1 and C_2). Drip irrigation at 0.8 Etc with fertigation of 100 per cent RD N & K (I_2F_1) recorded significantly highest WUE (7.90 kg ha^{-1}-mm) which was on par with 0.8 Etc with fertigation of 75 per cent RD N and K (I_2F_2), 1.0 Etc with fertigation of 100 per cent RD N & K (I_1F_1) and drip irrigation at 1.0 Etc with fertigation of 75 per cent RD N and K (I_1F_2). Drip irrigation at 0.8 Etc with fertigation of 50 per cent RD N & K (I_2F_3) recorded the lowest WUE (4.62 kg ha^{-1}-mm). Drip irrigation at 0.8 Etc with fertigation of 100 per cent RD N & K (I_2F_1) recorded significantly highest WUE over drip irrigation at 1.0 Etc with basal application of 100% RDF and furrow irrigation at 0.8 IW/CPE ratio with basal application of 100 % RDF. These results are in close conformity with the findings of Ramesh *et al.* (2006): Balasubramanian *et al.* (2000): Patil *et al.* (2008) who reported higher water use efficiency in fertigation treatments in cotton owing to better crop growth and increased seed cotton yield due to continuous availability of plant nutrients in the root zone throughout the growth stages. Drip irrigation at 1.0 Etc recorded significantly higher consumptive use of water (503.2 mm) as compared to 0.8 Etc.and 0.6 Etc. Fertigation with 75 per cent RD N and K in six equal splits recorded significantly higher consumptive use of water (489.1 mm) which was on par with fertigation of 100 per cent RD N and K (487.8 mm). Drip irrigation at 1.0 Etc with 100% RDN & K recorded significantly highest consumptive use of water (540.1 mm) as compared to other treatment combinations (Table 2). Furrow irrigation at 0.8 IW/CPE ratio with basal application of 100% RDF recorded significantly highest consumptive use of water (684.4 mm) as compared to drip irrigation at 1.0 Etc with basal application of 100% RDF (423 mm). Aladakatti *et al.* (2012) also reported higher consumptive use of water under furrow irrigation and considerably lower consumptive use of water under drip fertigation in cotton crop.

Economics of drip fertigation in Bt cotton

Higher gross returns ((₹ 1,93,872 ha^{-1}), net returns (₹ 1,34,262 ha^{-1}) and BC ratio (3.25) were recorded at 1.0 Etc with fertigation of 100 per cent recommended N & K, however it was on par with 0.8 Etc with fertigation of 75 per cent recommended N & K. Lowest net returns ((₹ 58,317 ha^{-1}) BC ratio (2.18) was recorded in recommended N & K as soil application (Table 3).

Table 3. Economics of *intra- hirsutum* Bt cotton as influenced by irrigation and fertigation levels

Treatment	Gross returns (₹/ ha)	Net returns (₹/ ha)	B:C ratio
Interactions (I x F)			
I_1F_1	193872	134262	3.25
I_1F_2	184515	126896	3.20
I_1F_3	120187	70685	2.42
I_2F_1	190825	131517	3.21
I_2F_2	184387	126777	3.20
I_2F_3	106687	58669	2.22
I_3F_1	116947	65762	2.28
I_3F_2	114080	64222	2.29
I_3F_3	107314	59229	2.23
S.Em±	7871	7001	0.11
C.D. at 5%	23596	20988	0.32
C_1	134328	81210	2.52
C_2	107553	58317	2.18
S.Em±	7652	6808	0.10
C.D. at 5%	22576	20083	0.30

Irrigation Levels	Fertigation levels (F)
I_1: 1.0 Etc	F_1 : 100% RD N & K (150: 75: 75 kg ha^{-1})
I_2 : 0.8 Etc	F_2 : 75% RD N & K (112.5: 75: 56.25 kg ha^{-1})
I_3 : 0.6 Etc	F_3 : 50% RD N & K (75: 75: 37.5 kg ha^{-1})

Controls

C_1: Drip irrigation at 1.0 Etc + 100% RD N & K in 4 splits through soil (25% each as basal and at 30, 60 & 90 DAS). C_2: Furrow Irrigation at 0.8 IW/CPE ratio +100% RD N & K in 4 splits through soil (25% each as basal and at 30, 60 & 90 DAS).

Conclusion

From the results it was concluded that planting of *intra-hirsutum* Bt cotton hybrid in paired row planting and drip irrigation at 0.8 Etc along with fertigation of 75 per cent recommended dose of nitrogen and potassium (112.5: 75: 56.3 N, P_2O_5 & K_2O kg ha^{-1}) in six equal splits at 15 days interval and basal soil application of entire phosphorous in medium deep black soils was found optimum for realising higher seed cotton yield and net returns with increased water use efficiency.

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