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Split application of nutrients through fertigation in *Bt* cotton

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ABSTRACT : Field experiment was conducted during from 2008-2010 on medium clay soil at Research Farm of Mahatma Phule Agricultural University, Rahuri to find out the response of drip fertigation on growth, yield and economics of *Bt* cotton(*Gossypium hirsutum* L.). Pooled data indicated that drip resulted into 24.7 per cent increase in yield with 56.9 per cent water saving, whereas drip with fertigation resulted into 31.7 to 64 per cent increase in seed cotton yield with equal amount of water saving as compared to conventional method. The maximum seed cotton yield (45.33 q/ha) was recorded with 125 per cent fertigation schedule B. However, it was *on par* with 100 per cent (schedule B), 100 per cent (schedule C) and 75 per cent fertigation (schedule B). The seed cotton yield (39.07 q/ha) obtained under 75 per cent fertigation was *on par* with treatment where100 per cent conventional fertilizer applied through soil (34.59 q/ha) indicating 25 per cent fertilizer saving due to fertigation. Maximum water use efficiency (14.22 q/ha-mm) was obtained where 125 per cent water soluble fertilizer applied through drip. Economic analysis of drip irrigation and fertigation revealed that the cost of cultivation under drip with band application of fertilizers and drip fertigation was higher than conventional band application. However, the highest net income (Rs. 131381.2/ha), total net income (Rs. 307273.4), and net extra income over conventional method (Rs. 61030.6/ha) were realized in 125 per cent fertigation, but it were *on par* with the economical parameters obtained in 100 and 75per cent fertigation. The benefit cost ratio was lowest in drip fertigation and drip band application mainly due to higher initial investment for drip irrigation and high cost of water soluble fertilizers.

Key words : *Bt* cotton, drip irrigation, fertigation schedule, growth stages, water soluble fertilizers

With the advent of high yielding hybrids, large scale commercial cultivation mostly in irrigated area of western Maharashtra has led to increased production of cotton. Seed cotton yield increased by 32 per cent and water use efficiency (WUE) increased by 26 per cent under irrigated conditions as compared with furrow irrigation and further improvement in production is possible through adoption of precision technologies like drip irrigation (Aujla *et al.,* 2005). Experimental results have indicated that drip irrigation would save water and increase yield in different regions (Sivanappan, 2004; Khadi *et al.*, 2007). Therefore, it is needed to switch over towards adoption of advanced precision technologies like drip irrigation. Next to water, nutrients are most critical factors which seriously limit the growth, quality and yield of cotton. Drip irrigation has gained widespread popularity as an efficient method for fertilizer application in terms of farmers' acceptance. This is due to substantial saving in irrigation water and nutrients as compared to conventional irrigation and fertilization methods (Veeraputhiran and Chinnusamy 2005). Though, fertigation proved superior over conventional method but it is costlier from economic point of view. Therefore, an attempt has been made to find out optimum dose, fertigation schedules and economics of fertigation for *Bt* cotton under drip irrigation.

MATERIALS AND METHODS

The field experiment was conducted from 2008 to 2010 at Research Farm of Inter faculty Department of Irrigation Water Management, Mahatma Phule Krishi Vidyapeeth, Rahuri (19^0 47'N latitude and $74^0$39' E longitude; altitude 500 meters above mean sea level) The site was semi arid with mean rainfall of 520 mm which is mostly concentrated during the monsoon months from June to September. The soil belongs to clayey in texture with pH of 8.03 and was low in organic carbon (0.45 per cent). The soil depth and infiltration rate was 90 cm and 0.7 cm/h respectively. The bulk density of soil was 1.27 g/$cm^3$and electrical conductivity was 0.24 d/Sm. The soil was low in available N (150 kg/ha), and P (18.6 kg/ha) and high in available K (326 kg/ha) content. The moisture contents at field capacity, permanent wilting point and available

soil moisture as 42.89, 21.13 and 21.76 per cent, respectively.

The field experiment was laid out with 8 treatments replicated thrice in randomized block design (RBD). The treatments comprised 3 fertigation schedules, A, B and C as (Table 1). The schedules A (T_4) and C (T_8) are being used by farmers in some part of state whereas, schedule B was developed on the basis of nutrient requirement of crop during different growth stages. In schedule B, 3 doses, 75per cent (T_5), 100per cent (T_6) and 125per cent (T_7) of recommended dose (120:60:60, NPK, kg/ha) was incorporated. The fertigation treatments were compared with conventional irrigation method (T_1), only drip (T_2) and only N fertigation (T_3). In first two treatments (T_1 and T_2), 50per cent N and 100per cent P and K fertilizers were band placed at the time of planting (basal dose) and remaining 50per cent N was applied one month after planting (top dressing). In treatment of only N fertigation, the 100per cent P and K was applied through soil (band placement) and all N was applied trough drip using urea in 13 equal weekly splits. In fertigation treatments, water soluble fertilizers *viz.*, urea (46:0:0) NPK grade (18:18:18) and sulphate of potash (0:0:50) were used. The nutrients in kg/ha were applied in equal weekly splits as/3 schedules (Table 1).

Under drip irrigation, *Bt* cotton (variety Rasi 2) was sown using 0.75-1.50 x0.75 m paired row planting during first week of May each year. One 16 mm inline lateral with 4 lph drippers at 0.60 m spacing was laid for each pair by maintaining lateral to lateral spacing of 2.25 m. The fertigation was done using automized fertizet system (Galcol make, Israel) at weekly interval as/schedule. Adequate plant protection measures were adopted as and when required. Irrigation was given at every alternative day in drip treatments, whereas 7.5 cm of irrigation water was applied using a replogal flume in planting under conventional furrow method at 75 mm cumulative pan evaporation. The average emission uniformity of drip irrigation system was estimated as 91 per cent for all treatments. For computing field water use efficiency, seed cotton yields/ha were divided by total water use and expressed as kg/ha-mm. The total cost of cultivation in Rs/ha was computed by adding the capital investment on drip irrigation for cotton considering 6 months crop period with operational cost.

RESULTS AND DISCUSSION

Growth contributing characters : The pooled data of three years revealed (Table 2) that application of 125per cent recommended dose of water soluble fertilizers (WSF) was applied using schedule B (T_7) had maximum monopodial branches/plant (11.02). However, the difference was non significant when compared with 100per cent WSF fertigation through schedule A(T_4), B(T_6) and C(T_8). The conventional method resulted into least monopods (8:28). Significantly maximum plant height attained (188.93 cm) with WSF using schedule B (T_7). It was followed by treatment T_4, T_6, T_5 and T_8. Lowest plant height of 138.86 cm (T_1) was resulted in the leaf reddening which was reduced to 8.7 per cent in 125 per cent fertigated cotton as compared to conventional method which recorded the highest proportion of reddened leaves (22.3 per cent).

Yield and yield contributing characters : Water soluble fertilizers (WSF) through schedule B (T_7) recorded significantly more bolls/plant (116.37) followed by 100per cent fertigation using schedule B and C (Table 2). The conventional method (T_1) produced minimum bolls (70.69). The improved phosphorus availability in fertigated

Table 1. Fertigation schedules for cotton

Days after planting	Schedule A			Schedule B			Schedule C		
	N	P	K	N	P	K	N	P	K
1-9	—	—	—	—	—	—	—	—	—
10-30(3 weekly splits)	46	0	0	24	12	06	75	0	0
31 – 65(5 weekly splits)	59	36	36	48	30	24	24	24	24
66 – 79(2 weekly splits)	35	12	12	48	18	30	07	23	07
80 – 100(3 weekly splits)	07	0	23				4	0	13
Total	**147**	**48**	**71**	**120**	**60**	**60**	**110**	**47**	**44**

Table 2. Growth and yield contributing characters of cotton as influenced by water soluble fertilizers (pooled data of three years)

Treatments	Monopodial branches/ plant	Plant height (cm)	Bolls/ plant	Leaf reddening (%)	Seed cotton yield (q/ha)	Ginning percentage	Seed yield (q/ha)
T_1 Surface irrigation with C.F.	8.28	138.86	70.69	22.3	27.73	33.63	18.04
T_2 Drip (0.75 m)	9.21	153.82	87.49	21.8	34.58	34.62	22.85
T_3 Drip (NTD)	8.98	149.79	87.25	20.9	36.53	32.93	24.52
T_4 WSF (100%), A	10.98	176.75	80.51	21.1	32.58	34.82	21.25
T_5 WSF (75%), B	9.80	165.26	83.47	10.3	39.07	35.80	25.11
T_6 WSF (100%) , B	10.44	173.81	95.99	9.9	42.08	33.93	27.85
T_7 WSF (125%), B	11.02	188.93	116.37	8.7	45.33	36.77	28.62
T_8 WSF (100%), C	10.55	162.68	90.71	10.2	41.92	34.62	27.41
SE ±	0.30	1.7	2.22	—	2.16	0.78	1.59
P=0.05	0.86	5.0	6.33	—	6.46	2.20	2.26

WSF -Water soluble fertilizers CF- Conventional fertilizers NTD-Nitrogen through drip

plots during flowering and fruiting stage increased number of bolls. Maximum seed cotton yield of 45.33 q/ha was observed, (T_7) using schedule B (Table 2). However, yields under (T_5) (T_6) and (T_8) were *on par* with 125 per cent fertigation using schedule B. The cotton yield (39.7 q/ha) WSF through schedule B (T_5) was significantly superior over yield in conventional practice (27.73 q/ha) and *on par* with drip irrigation (34.58 q/ha) (T_2), indicated that 25per cent fertilizers can be saved through fertigation using WSF.

The results indicated that drip irrigation potentially increased cotton yield to the extent of 24.5 per cent over conventional method, whereas fertigation using 100per cent WSF resulted into 64per cent improvement in cotton production. The fertigation @ 75per cent WSF exhibit 40.9 per cent increase in cotton yield with 25per cent fertilizer saving. Aujla *et al.,* (2005) also reported increase in cotton yield with increasing fertigation levels.

Water use: Mean water use (Table 3) was observed high in conventional method of irrigation (743.90 mm). The drip irrigated treatments used only 320.10 mm during whole season indicated that drip can save water to the extent of 56.9 per cent as against conventional irrigation. The combined effect of drip and fertigation using schedule B (T_7) resulted maximum field water use efficiency (14.17 kg/ ha-mm) followed by schedule B (13.15 kg/ha-mm) and C (13.10 kg/ha-mm). The water use efficiency under conventional method of irrigation (3.73 kg/ha-mm) was lowest of all.

Economics

Net seasonal income and B:C ratio : High market cost of water soluble fertilizers (NPK grade and SOP) reflected into more cost of cultivation in fertigation treatments (Table 4). However, the cost of cultivation under surface irrigation was almost same as that of drip as a considerable amount was incurred on labour involved for irrigation, fertilizer application and interculturing in conventional method. Maximum net seasonal income of Rs. 131381/ ha was obtained when WSF were applied as per schedule B (T_7) followed by schedule C (T_8), schedule B (T_6) and schedule B (T_5). The differences between these values were statistically non significant. The minimum net seasonal income of Rs. 70350.40 was obtained under conventional method of irrigation and fertilization (T_1).

The benefit cost ratio of all the drip and fertigation treatments ranged between 2.86 to 2.96 but statistically it was non significant. Highest B: C ratio of 2.96 was observed in 100per cent WSF as per schedule C. In 100per cent WSF application using schedule A, which incurred more investment resulted lower B:C ratio (2.23). The B:C ratio of 2.41 was recorded in conventional method of water and fertilizer application which was lower that all drip and fertigation treatments except T_4. Veeraputhiran

Table 3. Water applied and field water use efficiency of cotton (pooled data of three years)

Treat-ments	Total water use(mm)	FWUE (kg/ha -mm)	Water saving (%)	Increase in yield (%)
T_1	743.9	3.73	—	—
T_2	320.0	10.81	56.9	24.7
T_3	320.0	11.42	56.9	31.7
T_4	320.0	10.18	56.9	17.5
T_5	320.0	12.21	56.9	40.9
T_6	320.0	13.15	56.9	51.7
T_7	320.0	14.17	56.9	63.5
T_8	320.0	13.10	56.9	51.2
SE ±	0.61	—	—	
P=0,05	1.82	—	—	

WSF -Water soluble fertilizers CF- Conventional fertilizers NTD-Nitrogen through drip

and Chinnusamy (2005) also observed higher seasonal income accrued under fertigation for cotton.

Total net income : Drip irrigation for cotton resulted into 56.9 per cent water saving (average of three years), which can bring 1.33 ha additional area under irrigation. Taking into consideration the additional net income due to this additional area, the total net income was found maximum in T_7 (Rs. 307273), which was *on par* with T_8 (Rs. 283386), T_6 (Rs. 278975) and T_5 (Rs. 259593) as compared to Rs 70350 in conventional method of irrigation.

Net extra income and payback period : It is seen that only drip irrigation and N fertigation resulted about Rs. 26- 30 thousand/ ha additional extra income over conventional method, thus payback period for cost of drip system was found to be as low as 0.5 years which revealed that cost of drip can be recovered in two seasons (Table 4). This emphasized on utility of drip irrigation for cotton irrespective of using water soluble fertilizers. Net extra income over surface method was obtained as high as Rs. 61031 using 125per cent WSF using schedule C but *on par* with T_7, T_6 and T_5 (75per cent WSF as per schedule B). Lower payback period were predicted in drip fertigation (0.9 year) indicated recovery of fertigation cost within a season.

Water productivity : Corresponding merit of drip fertigation was weighed against conventional method in terms of water productivity. The fertigation @ 125per cent WSF using schedule B resulted into highest water productivity of Rs. 4106/cm of water used. It was *on par* with T_8, T_6 and T_5 (75per cent WSF schedule B). The only N fertigation through drip resulted into Rs. 3151 per cm of water whereas surface method resulted into Rs. 946/cm water productivity (Table 4).

Table 4. Economic analysis of cotton (Rs/ha) as influenced by different treatments (pooled data of three years)

Treatment	Seasonal cost	Net seasonal income	Total net income	B:C ratio	Net extra income over control	Payback period of drip (years)	Net profit/cm of water use
T_1 Surface irrigation with C.F.	49912	70350	70350	2.41	0.00	0.00	946
T_2 Drip (0.75 m)	52397	96634	225630	2.84	26283	0.50	3020
T_3 Drip (NTD)	52397	100837	235472	2.92	30486	0.58	3151
T_4 WSF (100%) A	64695	79279	185755	2.23	8928	0.14	2477
T_5 WSF (75%) B	59849	111013	259593	2.85	40663	0.68	3469
T_6 WSF (100%) B	64046	119342	278975	2.86	48991	0.76	3729
T_7 WSF (125%) B	67133	131381	307273	2.96	61031	0.91	4106
T_8 WSF (100%) C	62608	121164	283386	2.94	50813	0.81	3786
SE ±	—	9200.0	17500.0	0.15	12200.0	—	319
P=0.05	—	28000.0	57000.0	0.41	34000.0	—	837

WSF -Water soluble fertilizers CF- Conventional fertilizers NTD-Nitrogen through drip

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