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Yield and nutrient use by *Bt* cotton under fertigation in inceptisols

D.D. PAWAR*, K. D. KALE, S. K. DINGRE AND R. R. HASURE

Interfaculty Department of Irrigation Water and Management (PGI),Mahatma Phule Krishi Vidyapeeth, Rahuri - 413 722

**E-mail : ddpawar1@rediffmail.com*

ABSTRACT : A field experiment was conducted for three years during 2011-2013 in medium deep clay soils at the Research Farm of Mahatma Phule Krishi Vidyapeeth, Rahuri to find out the response of drip fertigation on nutrient availability and nutrient uptake of *Bt* cotton (Rashi 2). The experiment consisted of nine treatments with three fertigation levels, two fertilizer sources (conventional fertilizers applied through soil and water soluble fertilizer applied through fertigation) and two foliar sprays. The 100 per cent fertigation with 3 foliar sprays (40.72 q/ha) showed 43.80 per cent increase in yield over conventional irrigation and fertilization method. However, it was *on par* with 100 per cent and 80 per cent fertigation treatments. The 60 per cent fertigation (34.46 q/ha) resulted into 40 per cent fertilizer saving and 24.45 per cent increase in yield over conventional method (27.69 q/ha).

The uptake of nutrients and availability of nutrients in soil was relatively more in fertigated treatments than rest of the treatments. The cumulative NPK uptake was found increased with age of crop and maximum uptake was observed at harvesting stage. The 100 per cent fertigation with three foliar sprays recorded maximum NPK uptake (151.0, 48.02 and 139.09 kg/ha, respectively) at harvest and it was significantly superior over all other treatments except treatment $T_{1,}$ T_5 and T_4. The drip fertigation used lowest water of 391.3 mm as compared with 750.0 mm in surface irrigation method, thus resulted in 49.73 per cent water saving. In terms of economics, the treatment T_2 was profitable with more net seasonal income of Rs. 1,25,237/ ha and higher B:C ratio of 2.95 followed by T_1 (Rs. 1,21,480 and 2.92, respectively). On the basis of the results obtained, it is concluded that 100 per cent fertigation in 14 weekly splits as per schedule and application of three foliar sprays of urea phosphate at 30, 45 and 60 DAP (T_2) is the best treatment for improved yield, nutrient availability, nutrient and water use of *Bt* cotton (Rashi 2) cultivated in medium deep soils of western Maharashtra.

Key words : *Bt* cotton, drip fertigation, nutrient availability, uptake, water soluble fertilizers

Cotton has retained its unique fame and name as the “King of Fibres” and “White Gold” because of its higher economical value among cultivable crops for quite a long period. At present genetically modified cotton is widely accepted by Indian farmers. India ranks second in global cotton production after china. The per ha yield of cotton in India is low (568 kg/ha) as compared to world average (768 kg/ha) (Nasrabad *et al.,* 2013). Maharashtra is an important producer of superior to medium quality cotton. The state has an area of 35.03 lakh ha under cotton cultivation and is second in cotton production after Gujarat with average productivity of 296 kg lint/ha. Water and nutrients are the most critical inputs for producing healthy plants and improving the yield of any crop. With continuous declining of water in India, enhancing agricultural productivity per drop of water has become essential to meet food demands for ever growing

population. Thus, available water for irrigation needs to be utilized judiciously.

Fertigation is the technique that provides the plant nutrients at the right time and the right place and increases the application frequency and therefore, increases fertilizer recovery (Pawar *et al.,* 2013). The improper use of fertilizer increases cultivation expenditure as well as intensifies the environmental problems ultimately degrading the soil health. Application of fertilizer with irrigation water improves seed cotton yield and fertilizer recovery and provides better timing to meet crop demand throughout the cotton growing season (Zhenan *et al.,* 2007; Mark *et al.,* 2009). The major drawback of the drip irrigation system is its high initial investment; however, cost can be recovered in a short span if proper nutrient and water management principles are followed (Pandiaraj and Mohan, 2013). However, while performing fertigation, the proper scheduling of water soluble fertilizer is necessary otherwise the costly water soluble fertilizers may leach deep below root zone making it non available to the plants due to fixation or lost in the atmosphere by volatilization.

Thus, looking to the importance of scientific water management in crop production enhancement, the advanced techniques like drip irrigation are need to be explored to achieve the twin objectives of higher productivity and better water and nutrient use efficiency in field crops. Hence, present investigation was undertaken to study the effect of water soluble fertilizers on yield of cotton and its impact on soil fertility status, nutrient uptake and nutrient use efficiency under fertigation in vertisols.

MATERIALS AND METHODS

The field experiment was conducted for three years (2011 to 2013) at Research Farm of Interfaculty Department of Irrigation Water Management, Mahatma Phule Krishi Vidyapeeth Rahuri. Agro climatically, the area falls under the scarcity zone of Maharashtra with annual average rainfall of 520 mm which is mostly erratic and uncertain in nature. The soil was clayey in texture having 80 cm depth and alkaline in reaction with pH as 8.10. The available nitrogen, phosphorus and potassium was 163.0, 19.20 and 615.0 kg/ha, respectively. The soil was well drained with moisture content at field capacity, permanent wilting point and available water content as 39.8, 18.2 and 21.60 per cent, respectively. The experiment comprised of nine treatments replicated thrice with randomized block design as drip with 100per cent fertigation (T_1), drip with 100per cent fertigation and three foliar sprays of 17:44:0 at 30, 45 and 60 days after sowing (DAS) (T_2), drip with 80per cent fertigation (T_3), drip with 60per cent fertigation (T_4), drip with 100per cent conventional fertilizers (CF) of which N and K through drip (fertigation) and P through soil (T_5), drip with 100 per cent conventional fertilizers applied as basal dose through soil (T_6), drip with no fertilizers (T_7), surface irrigation with CF (T_8) and surface irrigation and CF and three foliar sprays (T_9).

In fertigation treatments (T_1 to T_4) the fertilizers were applied in 14 splits apportioned as per crop growth stages as given in Table 1. In N and K fertigation (T_5), the entire N and K was applied through urea and muriate of potash (MOP) in 14 weekly splits as given below. In

Table 1and whole P was applied as basal through soil. In conventional practice of fertilizer application (T_6, T_8 and T_9), 20per cent N, full dose of P_2O_5 and full dose of K_2O was applied as a basal dose through soil, whereas remaining 80per cent N was applied in two equal splits at 30 and 60 DAS. The recommended dose of fertilizer for cotton was applied (120: 60: 60, N: P_2O_5: K_2O kg/ ha). The fertigation was done using water soluble fertilizers *viz.,* urea (46:0:0), urea phosphate (17: 44: 0) and MOP (0:0:60).Whereas, in conventional methods, urea, single super phosphate and muriate of potash were used.

Table 1. Per cent nutrients applied in 14 weekly splits

Days after planting	Nutrients (%)		
	Nitrogen	Phosphorus	Potassium
1-21 (3 weeks)	30	22	10
22-63 (6 weeks)	25	40	30
64-77 (2 weeks)	28	30	22
78-98 (3 weeks)	17	8	38

Under drip irrigation system, *Bt* cotton var. Rashi 2 was sown using 0.75 - 1.5 x 0.75 m paired row planting with two rows of cotton dibbled at 0.75 m spacing and one row was skipped after that. Thus, a distance of 0.75 m between two rows and 1.5 m between two pairs was maintained. Plant to plant spacing of 0.75 m was kept along the row. The seeds were sown during 2nd week of May 2011, 1st week of June 2012 and last week of May 2013 and harvesting was completed during the 2nd week of November 2011, 2012 and 2013, respectively. The schedule of fertigation was maintained as per treatments. In drip fertigation, the fertilizers were applied along with irrigation water using automized fertijet system (Galcol, Israel). The drip irrigation system was operated at every alternate day to meet crop water requirement estimated using climatological approach as given by Allen *et al.,* 1998. The lateral lines of 16 mm diameter of LLDPE pipes were laid in between two crop rows. The laterals were provided with online drippers of 4 lph discharge capacity at a spacing of 0.60 m. The spacing between two adjacent laterals was 2.25 m. The average emission uniformity of drip irrigation system was estimated as 90 per cent. In conventional method of irrigation, 80 mm depth of irrigation was applied at 75 mm cumulative pan evaporation.

The plant samples were collected periodically at 30, 60, 90 DAS and at harvest. Plant samples were air dried in shade, oven dried at 65°C, ground in a whilley mill having stainless steel blades to pass through 40 mm mesh sieve and digested with H_2SO_4 and H_2O_2 (1:1) as per the standard procedure. Nutrient uptake was calculated by determining the N, P and K concentration in relation to dry matter production, *i.e.* the nutrient uptake was worked out by multiplying the yield with nutrient content and dividing by 100. The soil samples were collected periodically at 30, 60, 90 DAS and at harvest for nutrient availability status. The soil samples were air dried, processed and analysed for available NPK content in soil. The statistical analysis was performed by using analysis of variance (ANOVA) for randomized block design.

The nutrient use efficiency (NUE) was computed using following relation,

$$\text{NUE (kg grain/kg)} = \frac{\text{kg yield/ha in treatment} - \text{kg yield/ha in control}}{\text{N dose (kg/ha)}}$$

RESULTS AND DISCUSSION

Yield of cotton : The seed cotton yield data (Table 2) pooled over three years (2011-2013) found to be ranged from 23.10 to 40.72 q/ha. The maximum seed cotton yield was obtained in treatment T_2 *i.e.* drip with 100per cent fertigation with three foliar sprays (40.72 q/ha), but it was *at par* with treatment T_1 *i.e.* drip with 100per cent fertigation (39.82 q/ha) and T_3 *i.e.* drip with 80per cent fertigation (37.83 q/ha) and was 47.06per cent more than conventional method of irrigation and fertilizer application (T_8). The drip irrigation with conventional fertilizer (T_6) produced 15.95per cent more yield than surface irrigation with conventional fertilizer application (27.69 q/ha). The better performance of drip irrigation over surface irrigation was due to the application of right quantity of water at right time and at right place which resulted in appropriate moisture content in root zone. This supports the work of Kumar and Pandey (2008) that optimum moisture content in soil promoted the physiological process and increased the growth of cotton plant. The seed cotton yield obtained under 60 per cent fertigation (34.46 q/ha) was *at par* with drip with 100per cent CF (32.10 q/ha) indicated that fertigation using WSF can save fertilizers upto 40 per cent with increase in yield. Mark *et al.,* (2009) also reported the increase in cotton yield under fertigation. The minimum yield of 23.10 q/ha was observed in no fertilizer treatment.

Water use : The drip method recorded lowest water use of 391.3 mm as compared 750.0 mm in surface method (Table 2). Thus, saving of water to the extent of 49.73 per cent was recorded due to drip method with 16.61 per cent increase in yield. The treatment of 100 per cent fertigation with three foliar sprays resulted into 40.42 per cent increase in yield with 49.73 per cent water saving over surface irrigation with CF (T_8). In drip, the water is applied directly in root zone which increases water application efficiency and decreases water losses through

Table 2. Yield and water use of *Bt* cotton as influenced by different treatments (pooled means of 3 years)

Treatments	Seed cotton yield (q/ha)	Per cent increase over control (T_8)	Ginning (%)	Seed yield (q/ha)	Total water applied (mm)	Water saving (%)
T_1 DI with 100 per cent fertigation	39.82	43.80	35.63	25.64	391.3	49.73
T_2 DI with 100per cent fertigation WSF+3 foliar spray	40.72	47.06	35.78	26.16	391.3	49.73
T_3 DI with 80per cent fertigation	37.83	36.62	34.44	24.80	391.3	49.73
T_4 DI with 60per cent fertigation	34.46	24.45	33.83	22.81	391.3	49.73
T_5 DI with 100per cent CF (N and K drip, P thro soil)	34.67	25.21	34.13	22.83	391.3	49.73
T_6 DI with 100per cent CF (NPK thro soil)	32.10	15.95	33.26	21.42	391.3	49.73
T_7 DI with 0per cent RD of WSF	23.10	-	32.80	15.52	391.3	49.73
T_8 Surface with 100per cent CF	27.69	-	32.96	18.56	750.0	-
T_9 Surface with 100per cent CF + 3 foliar spray	30.04	8.49	32.93	20.15	750.0	-
S.E.$^{+}$-	0.98	-	0.47	0.49	-	-
C.D. (p=0.05)	2.95	-	1.40	1.48	-	-

percolation, infiltration and evaporation thereby it saves large quantity of water as compared to conventional method of irrigation.

Nutrient availability (NPK) in soil : The data regarding NPK availability in soil (pooled over 3 years) at harvest of cotton is presented in Table 3. The significantly maximum nutrient availability in soil was observed in treatment T_2 *i.e.* 100 per cent fertigation with three foliar sprays (166.0: 20.57 and 618.0 kg/ha NPK, respectively). However, it was *at par* with T_1 (100% fertigation), T_5 (DI with CF and NK fertigation) and T_4 (80% fertigation). The sources of fertilizer also resulted into moderate change in NPK availability in the root zone soil of cotton. The water soluble fertilizers resulted into more availability of NPK in soil as compared to conventional fertilizers. As more quantum of water was available just beneath the dripper, the corresponding increase in nutrient availability was observed in drip as compared to conventional water application method. This has inferred a direct association between nutrient availability and presence of in-situ irrigation water. These results are in close conformity with those reported by Sathya *et al.,* (2008). Nalina *et al.,* (2009) reported increased nutrient availability under fertigation of water soluble fertilizers than conventional method.

Table 3. Nutrient availability in soil and nutrient uptake (kg/ha) by cotton at harvest (pooled means of 3 years)

Treatments	Nutrient availability (kg/ha)			Nutrient uptake (kg/ha)		
	N	P	K	N	P	K
T_1 DI with 100 per cent fertigation	164.0	19.87	614.33	149.5	46.19	134.00
T_2 DI with 100 per cent fertigation	166.0	20.57	618.00	151.5	48.02	139.09
T_3 DI with 80 per cent fertigation	154.0	17.00	604.77	146.6	43.84	126.13
T_4 DI with 60 per cent fertigation	147.0	16.07	598.67	137.7	36.81	114.56
T_5 DI with 100 per cent CF (N and K drip, P thro soil)	161.0	18.63	611.67	148.9	44.88	129.22
T_6 DI with 100 per cent CF (NPK thro soil)	155.7	17.33	605.33	143.4	41.42	116.67
T_7 DI with 0 per cent RD of WSF	138.0	15.08	590.00	114.4	33.10	107.00
T_8 Surface with 100 per cent CF	154.7	16.70	603.33	133.3	37.84	110.26
T_9 Surface with 100 per cent CF+3 foliar spray	159.0	17.60	605.67	140.0	41.98	124.37
S.E.$^{+}$-	2.17	0.84	2.30	2.89	1.24	5.47
C.D. (p=0.05)	6.51	2.53	6.91	8.67	4.71	16.40

Nutrient uptake : The pooled data of nutrient uptake over three years (2011- 2013) revealed that the uptake of nutrients (NPK) influenced significantly due to different treatments (Table 3). The significantly maximum total NPK uptake was observed in 100per cent fertigation with three foliar sprays (151.5, 48.02 and 139.09 kg/ha NPK uptake, respectively) at harvest over surface irrigation with conventional fertilizer. However, it was *at par* with T_1 (100% fertigation), T_5 (DI with CF and NK fertigation) and T_4 (80% fertigation). The fertigation resulted into more concentration of readily available nutrients in soil and optimum availability of water in soil increased nutrient uptake. The application of water soluble fertilizer in 14 splits as per growth stages resulted into

Table 4. Nutrient use efficiency, cost of cultivation, net seasonal income and benefit cost ratio of *Bt* cotton (pooled mean of 3 years)

Treatments	Nutrient use efficiency (kg yield/kg)	Cost of cultivation (Rs/ha)	Net seasonal Income (Rs/ha)	Benefit cost ratio
T_1 DI with 100 per cent RD of WSF	6.97	63299	121480	2.92
T_2 DI with 100 per cent RD of WSF+3 foliar spray	7.34	64341	125237	2.95
T_3 DI with 80 per cent RD of WSF	7.72	60889	113568	2.87
T_4 DI with 60 per cent RD of WSF	7.89	58475	101126	2.73
T_5 DI with 100 per cent CF (N and K drip, P thro soil)	4.82	58147	102068	2.76
T_6 DI with 100 per cent CF (NPK thro soil)	3.75	58147	95516	2.65
T_7 DI with 0 per cent RD of WSF	-	51242	65653	2.28
T_8 Surface with 100 per cent CF	1.91	49054	85169	2.74
T_9 Surface with 100 per cent CF+3 foliar spray	2.89	50096	92899	2.86
S.E.$^+$-		—	3483	0.05
C.D. (p=0.05)		—	10444	0.16

improvement in NPK uptake during all growth stages. The NPK uptake in conventional method was lowest because of non-availability of optimum moisture at all growth stages. The best performance of water soluble fertilizers in terms of nutrient uptake was might be due to more frequent and uniform application of irrigation water and fertilizers which helped to maintain the optimum water and air ratio in the soil, thereby making the nutrients available to plant more easily (Zhenan *et al.,* 2007).

Nutrient use efficiency (NUE) : The higher nutrient use efficiency was observed in fertigation treatments as compared to surface irrigation with conventional fertilizer (Table 4). The maximum nutrient use efficiency under drip fertigation (6.97 kg yield /kg nutrient applied) was observed in T_1 (100% fertigtion) whereas the lowest nutrient use efficiency (1.91 kg yield / kg nutrient applied) was observed in T_8 (SI with 100% CF). The higher nutrient use efficiency under drip fertigation with water soluble fertilizer over conventional practice could be attributed to the regular application of nutrients (14 splits) combined with irrigation water in the active root zone of the crop that would have resulted into enhanced production and minimum loss of nutrients from root zone. The substantial increase in NUE under drip irrigation over conventional fertilizers application was also reported in hybrid cotton.

Cost economics : The pooled data of three years regarding cost of cultivation, net seasonal income and benefit: cost ratio of drip fertigation under different treatments is presented in Table 4. It is revealed that more cost of cultivation was estimated in 100 per cent fertigation with three foliar sprays treatment (Rs. 64341) because of high market cost of water soluble fertilizers. The lowest cost of cultivation (Rs. 50096) was incurred in conventional method.

The maximum net seasonal income of Rs. 125237 /ha was obtained in 100per cent

fertigation with three foliar sprays (T_2) which was *on par* with T_1 (100% fertigation) and T_4 (80% fertigation). The cotton yields increased under application of water soluble fertilizers through drip than conventional fertilizers and the additional returns compensated the additional cost of water soluble fertilizers indicating economic feasibility of water soluble fertilizers. The surface method of irrigation recorded lowest net seasonal income among all the treatments (Rs. 85169). In case of benefit cost ratio treatment T_2 (100% fertigation with foliar sprays) performed higher B: C ratio (2.95) followed by T_1 (2.92).

CONCLUSION

The yield of *Bt* cotton (40.72 q/ha) was found maximum in treatment T_2 *i.e.* 100 per cent fertigation with three foliar sprays but it was *at par* with T_1 and T_4 treatments. The drip fertigation resulted into 47.06per cent increase in yield and 49.73per cent water saving over surface irrigation. The nutrient availability and uptake was found to be improved under drip fertigation as compared to conventional fertilizer application. The treatment T_2 was profitable with more net seasonal income of Rs. 1,25,237/ha and higher B:C ratio of 2.95 followed by T_1 (Rs. 1,21,480 and 2.92, respectively). On the basis of the results obtained, it can be concluded that 100 per cent fertigation in 14 weekly splits as per schedule and application of three foliar sprays of urea phosphate at 30, 45 and 60 DAP (T_2) is the best treatment for improved yield, nutrient and water use and economics of *Bt* cotton (Rashi 2) cultivated in medium deep soils of western Maharashtra.

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