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Research Paper

Nutrient and water use by Bt. cotton (*Gossypium hirsutum*) under drip fertigation

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ABSTRACT

Field experiment was conducted for three years from 2008–2010 on medium clay soil at Rahuri to find out the effect of drip fertigation on growth, yield, water use and nutrient dynamics for Bt Cotton {*Gossypium hirsutum* (L.)}. The experiment was laid out in a randomized block design with eight treatments replicated three times. Pooled data of three years indicated that drip resulted into 21.5 to 23% increase in yield with 53.7% water saving, whereas drip with fertigation resulted into 43 to 66% increase in seed cotton yield with equal amount of water saving as compared to conventional method. The maximum seed cotton yield (4.53 t/ha) was recorded when 125% fertigation was given. However, it was on par with 100% and 75% fertigation treatments. The seed cotton yield (3.91 t/ha) obtained under 75% fertigation was on par with 100% conventional fertilizer applied through soil (3.46 t/ha) indicated 25% fertilizer saving under fertigation. The mobility of nutrients was observed more in drip fertigation than conventional method. N and K moved upto 30 cm, while P moved 15 cm laterally and vertically. The uptake of nutrients was also relatively more in fertigation treatments than rest of the other treatments. Maximum water use efficiency (1.42 t/ha–cm) was obtained in treatment, where 125% water soluble fertilizers were applied through drip. The 75% drip fertigation as per schedule B was found best practice to obtain better yield and improve nutrient and water use of Bt. cotton.

Key words : Bt. cotton, Drip fertigation, Nutrient movement, Nutrient uptake, Water soluble fertilizers

India is one of the major producers of cotton in the world with largest acreage of 9.59 Mha, but productivity as low as 505 kg lint/ha as compared to global average of 735 kg lint/ha (Nasrabad *et al.* 2013). Maharashtra is an important producer of superior to medium quality of cotton. The state occupies an area of 35.03 lakh ha under cotton cultivation and is second in cotton production only after Gujarat with average productivity of 296 kg lint/ha. Most of cotton in Maharashtra is rainfed with a small area (1.76 lakh ha) under irrigated cultivation (Ramamurthy *et al.* 2009). During last ten years, Bt. cotton has substantially contributed in increasing cotton productivity mostly in irrigated tract in western part of state. Bt cotton is performing better under irrigation than non–Bt. and introduction of drip irrigation can help to bring more area under cotton irrigation with substantially improved crop yields (Manjunatha *et al.* 2010).

Next to water, nutrients limits the growth, quality and yield of cotton. Deficit fertilizer supply has the major influence on production of fruiting sites on a cotton plant. Fruit retention is strongly dependent on the supply of N to the developing fruit. Fruit size is largely controlled by the number of developing embryos in the fruit during the first 10 days after pollination. When adequate N is available, P fertilization influences boll size but not fruit numbers (Reiter and Krieg 2000). Method of fertilizer application alongwith appropriate schedule is one of the several factors that affect fertilizer use efficiency. Application of water soluble fertilizers through drip irrigation has gained widespread popularity as an efficient method for fertilizer application (Mmolawa and Or 2000). The roots are developed extensively in a restricted volume of soil wetted by drip fertigation. Thus, drip fertigation system can place nutrients efficiently in wetted zone and are used by the plant from the soil easily. It helps in achieving higher productivity and enhancing the quality of crop (Zhenan *et al.* 2007; Mark *et al.* 2009). However, several basic principles must be followed in applying nutrients through irrigation system in order to place the fertilizer correctly, decrease potential nutrient losses, avoid excessive fertilizer application and prevent clogging of the system by precipitated

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compounds. In view of the above, it was felt appropriate to standardize fertigation schedule of Bt cotton under drip irrigation in present investigation.

MATERIALS AND METHODS

A field experiment was conducted for three consecutive summer seasons from 2008 to 2010 at research farm of Mahatma Phule Krishi Vidyapeeth, Rahuri. The soil of experimental site was well drained, clayey in texture with pH of 8.03 and was low in organic carbon (0.45%). The soil depth and infiltration rate were 90 cm and 0.7 cm/hr, respectively. The bulk density of soil was 1.27 g/cm^3 and electrical conductivity was 0.24 dS/m. The soil was low in available N (150 kg/ha), medium in P (18.6 kg/ha) and high in available K (326 kg/ha) content. The soil field capacity, permanent wilting point and available soil moisture measured 42.89, 21.13 and 21.76%, respectively. The field experiment was laid out with eight treatments replicated thrice in randomized block design (RBD). The treatments comprised three fertigation schedules, A, B and C as tabulated in Table 1. The schedules A (T_4) and C (T_8) are being used by farmers in some part of the state for cotton cultivation presently; whereas, schedule B was developed on the basis of nutrient requirement of crop during different growth stages. In schedule B, three levels, 75% (T_5), 100% (T_6) and 125% (T_7) of recommended dose (120:60:60, NPK kg/ha) were incorporated as fertigation. The fertigation treatments were compared with conventional irrigation method (T_1), only drip (T_2) and only 'N' fertigation (T_3). The nutrients in kg/ha were applied in equal weekly splits as per three schedules given in Table 1.

Under drip irrigation, Bt. cotton 'Rashi-2' was sown using 0.75–1.50 × 0.75 m paired row planting. Two rows of cotton were dibbled at 0.75 m spacing and one row was skipped over after that; thus, maintaining 0.75 m distance between two rows and 1.50 m between two pairs. Plant to plant spacing of 0.75 m was kept along the row. One 16 mm in–line lateral with drippers at 0.60 m spacing was laid for each pair. It maintained the lateral to lateral spacing of 2.25 m. The fertigation was done using automized fertizet system (Haleon, Israel) at weekly interval as per schedule. Water soluble fertilizers *viz.* Urea (46:0:0) NPK grade (18:18:18) and sulphate of potash (0:0:50) were used for fertigation in treatments T_4 to T_8. In control treatment (T_1 to T_3), conventional fertilizers urea, super phosphate and muriate of potash were used. Adequate plant protection measures were adopted as and when required. The amount of water (liters/day) to be applied through drip irrigation was calculated by the climatological approach method. The reference evapotranspiration was estimated using Evapotranspiration Monitoring Station (ICT International make, Australia) installed at research farm. Considering the crop factor as per stages (Allen *et al.* 1998) and wetted area factor, the water requirement of the cotton was computed using following equation.

$$V = ETr \times Kc \times Ls \times Es \times Wa/\eta \qquad (1)$$

Where, V = Volume of water applied (lit/day/emitter); ETr = Reference evapotranspiration (mm/day); K_c = Crop coefficient; Ls and Es = lateral and emitter spacing, m; W_a = wetted area factor (0.6); η = Emission uniformity of the system (91%)

The in–line laterals having emitters of 4 lph discharge capacity were operated at a pressure of 1 kg/cm^2. The average emission uniformity of drip irrigation system was estimated as 91% for all treatments. In drip system, water was applied on every alternate day while in surface 80 mm irrigation water was applied at 75 mm of cumulative pan evaporation. The depth of water in surface method of irrigation was estimated using standard methodology (Michael, 2010)

The uptake of major nutrients was worked out by multiplying dry matter accumulation of N, P and K concentration in different parts of plant at harvest. Cotton plant samples from different treatments were analysed for N, P and K content by adopting standard methods (Panse and Sukhatme, 1985). The soil samples were collected periodically (60, 120 DAP and at harvest) at the distance of 0, 15, 30 cm laterally and vertically from emitter for nutrient movement study.

Table 1. Fertigation schedules for cotton

Days after planting	Schedule A			Schedule B			Days after planting	Schedule C		
	N	P	K	N	P	K		N	P	K
1–9	–	–	–	–	–	–	1–9	–	–	–
10–30(3 weekly splits)	46	0	0	24	12	06	10–30(3 weekly splits)	75	0	0
31–65(5 weekly splits)	59	36	36	48	30	24	31–65 (5 weekly splits)	24	24	24
66–79(2 weekly splits)	35	12	12	48	18	30	66–86(3 weekly splits)	07	23	07
80–100(3 weekly splits)	07	0	23				87–100(2 weekly splits)	4	0	13
Total	147	48	71	120	60	60	Total	110	47	44

RESULTS AND DISCUSSION

Yield and yield attributes

The pooled data of three years presented in Table 2 revealed that number of bolls per plant were significantly influenced due to application of water soluble fertilizers through different sources using different schedules and different quantities. Application of 125% recommended dose of water soluble fertilizers (WSF) through schedule B recorded significantly higher number of bolls/plant (116.37) followed by treatments T_6 and T_8 where 100% WSF were applied using schedule B and C, respectively. The conventional method (T_1) produced minimum number of bolls/plant (70.69).

Seed cotton yield was significantly influenced by fertigation at different schedules as indicated in data pooled over 2008 to 2010. Maximum cotton yield of 4.53 t/ha was observed in 125% fertigation using schedule B. However, cotton yields in 100% fertigation schedule B, 100% fertigation schedule C and 75% fertigation schedule B were on par with 125% fertigation schedule B. The yield levels in 75, 100 and 125% fertigation were statistically on par, indicated that applying 75% fertigation (schedule B) can be an optimum scheduling criteria for cotton cultivation. The results also figure out that, drip irrigation remarkably increased yield to the extent of 23.05% over conventional method, where as 100% fertigation (schedule B) resulted into 53% improvement in cotton production over conventional method. Mark *et al.* (2009) also reported increase in cotton yield under fertigation. The cotton yield under 75% fertigation (3.91 t/ha) was 43.5% higher over conventional practice (2.77 t/ha) and on par with drip irrigation (3.46 t/ha) where 100% fertilizers applied through soil, indicated that 25% fertilizers can be saved through fertigation using WSF.

Water use

Maximum mean water use (Table 2) including effective rainfall was observed in conventional method of irrigation (743.90 mm). The drip irrigated treatments used only 320.10 mm during whole season, indicating that drip irrigation can save water to the extent of 56.9% as compared to the conventional irrigation. Water use efficiency was comparatively higher in 125% drip fertigation schedule B (14.22 kg/ha–mm) as compared to other treatments. It was followed by 100% fertigation schedule B (13.20 kg/ha–mm), 100% fertigation schedule C (13.15 kg/ha–mm) and 75% fertigation schedule B (12.23 kg/ha–mm). This is in confirmation with the findings of Ramamurthy *et al.* (2009) that drip can increase the cotton yield in addition to water saving. The minimum water use efficiency of 3.74 kg/ha–mm was obtained in conventional method of irrigation (Table 2).

Nutrient availability

The N availability was improved in drip fertigation at all stages of growth and at harvest as compared to conventional method. Amongst drip fertigation where 100% and 125% WSF were applied using schedule A, B and C resulted into improved availabilities of N in root zone as compared to only drip without fertigation (Fig. 1). The N availability increased with increase in period from planting in all treatments upto 120 DAP, and decreased at harvest as no fertilizer was applied after 100 DAP. The water soluble fertilizers resulted into more availability of N in soil as compared to conventional fertilizers as adequate quantum of water was available just beneath the drippers, which increased nitrogen availability.

The phosphorus availability in the root zone was found increased upto 120 DAP but decreased at harvesting stage

Table 2. Yield contributing characters, cotton yield and water use of cotton as influenced by water soluble fertilizers (Pooled data of three years).

Treatment	Bolls/ plant	Ginning (%)	Seed cotton yield, t/ha	Cotton seed yield (t/ha)	Effective rainfall (mm)	Water applied (mm)	Total water use (mm)	FWUE (kg/ha–mm)	Water saving (%)	Increase in yield (%)
T_1: Surface	70.6	33.6	2.77	1.80	323.9	420.0	743.9	3.74	–	–
T_2: Drip (0.75 m)	87.4	34.6	3.46	2.29	117.6	202.5	320.1	10.83	56.9	23.05
T_3: Drip (NTD)	87.2	32.9	3.65	2.45	117.6	202.5	320.1	11.43	56.9	31.73
T_4: 100% WSF, A	80.5	34.8	3.26	2.13	117.6	202.5	320.1	10.21	56.9	21.85
T_5: 75% WSF, B	83.4	35.8	3.91	2.51	117.6	202.5	320.1	12.23	56.9	43.50
T_6: 100% WSF, B	95.9	33.9	4.21	2.79	117.6	202.5	320.1	13.20	56.9	53.17
T_7: 125% WSF, B	116.3	36.7	4.53	2.86	117.6	202.5	320.1	14.22	56.9	66.05
T_8: 100% WSF, C	90.7	34.6	4.19	2.74	117.6	202.5	320.1	13.15	56.9	54.69
SEm±	2.22	0.22	0.22	0.16	–	–	–	0.61	–	–
CD (P=0.05)	6.33	0.65	0.65	0.23	–	–	–	1.82	–	–

WSF–Water soluble fertilizers; CF–Conventional fertilizers; NTD–Nitrogen through Drip–DI–Drip irrigation; SI–Surface Irrigation

(Fig. 2). The maximum P availability was observed in 125% fertigation with schedule B (26.67, 29.03 and 27.76 kg/ha) at 60 and 120 DAP and at harvest and decreased with decreasing fertigation levels but was at par with 100% fertigation at 60 DAP and at harvesting stage. The availability of phosphorus to the crop is a problem in clay soils due to its fixation, but water soluble fertilizers resulted into more availability of P in soil as compared to conventional fertilizers. The *in–situ* moisture prevalence due to drip irrigation caused availability of P simpler as compared to conventional fertilizers.

The water soluble fertilizers resulted into more availability of K in soil as compared to conventional fertilizers. The maximum K availability was observed in 125% fertigation with schedule B (483, 491 and 486 kg/ha) and decreased with decreasing fertilizer levels. The schedule A resulted into more K availability in soil at all stages compared to schedule C (Fig. 3). The K in soil is moved by

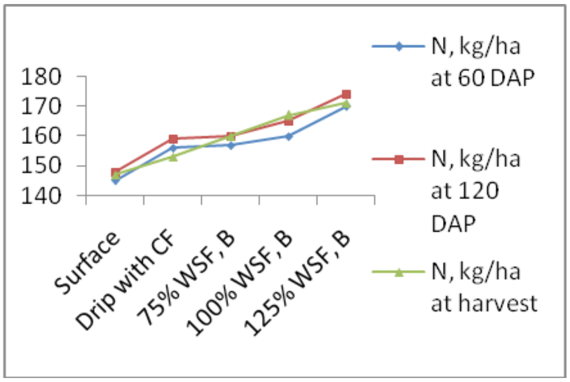

Fig. 1. N availability at 60, 120 DAP and at harvest

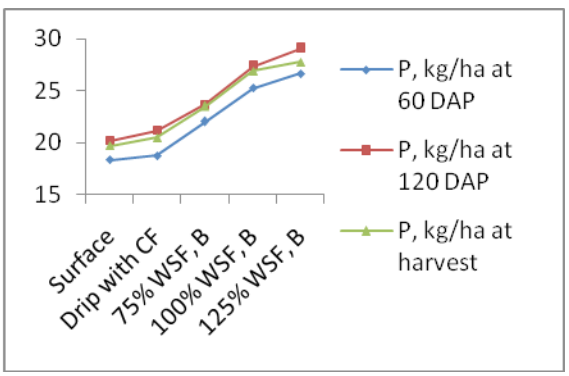

Fig. 2. P availability at 60, 120 DAP and at harvest

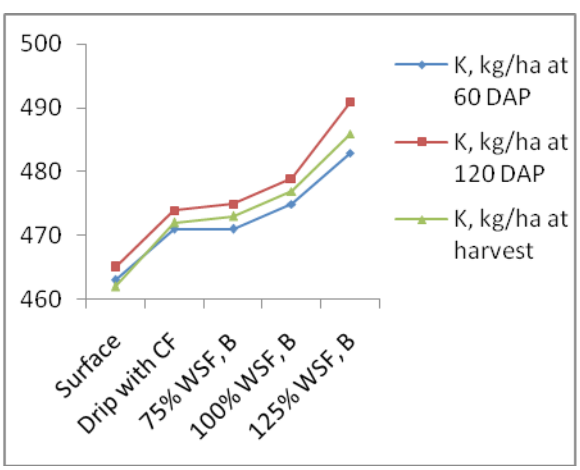

Fig. 3. K availability at 60, 120 DAP and at harvest

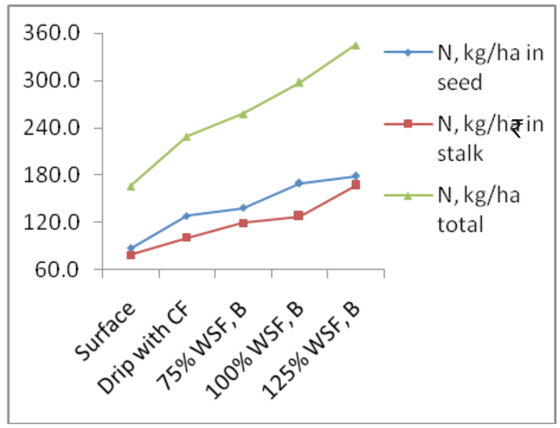

Fig. 4. N uptake (kg/ha) in cotton seed and stalk at harvest

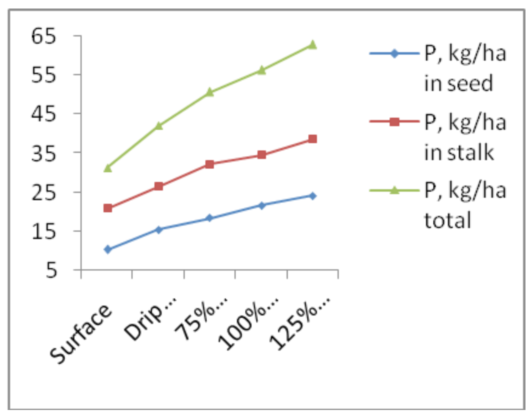

Fig. 5. P uptake in cotton seed and stalk at harvest

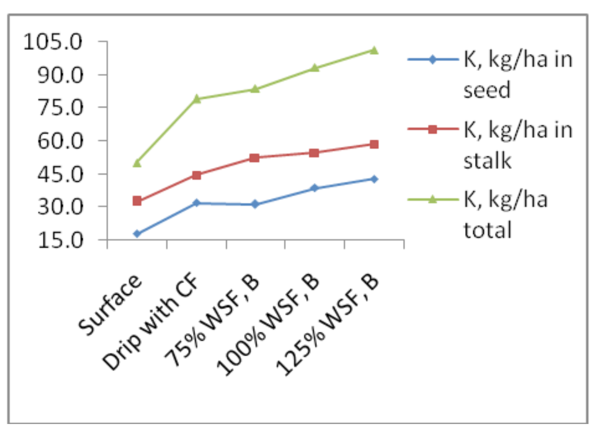

Fig. 6. K uptake in cotton seed and stalk at harvest

diffusion depending upon the soil moisture concentrations.

Nutrient uptake

Nutrient concentration in cotton seed and stalk at harvest were significantly influenced by levels of fertilizers and method of application (Fig. 4, 5 & 6). The N concentration was found influenced by levels of fertilizers. The 125% fertigation of WSF showed higher uptake in seed, however, it was at par with 100% schedule A, 100% schedule B and 75% schedule B. The fertigation resulted into more concentration of nutrients readily available and continuous availability of water in soil increased nutrient uptake. The fertigation also showed better N, P and K concentration in cotton stalk than conventional method. The application of 125% fertigation showed highest concentration of N, P and K (3.91, 0.91 and 1.37% respectively).

A different trend of N, P K uptake was observed under application of water soluble fertilizers and conventional fertilizers with respect to nutrient uptake in cotton plant. The best performance of WSF fertilizers in terms of nutrient uptake was observed which might be due to more frequent and uniform application. It helped in maintaining the optimum water and air ratio in the soil, thereby making the nutrients available to the plant more easily. These results have close conformity to those reported by Zhenan *et al.* (2007) that water soluble fertilizer application help in better nutrient uptake and development of cotton plant.

Nutrient movement

The movement of nutrient (Table 3) was determined by observing the nutrient availability periodically at distance 0, 15, 30 and 45 cm from a drip emitter in both lateral and vertical direction. The levels of water soluble fertilizers as per schedule B (75, 100 and 125%) showed effect on the mobility of nitrogen. More nitrogen was observed just beneath the dripper and it reduced as the distance increased from the dripper. Lateral and vertical movement of N was found to be upto 15 cm, when water was applied through ridges and furrows *i.e.* surface irrigation. Where only drip was used for irrigation with conventional fertilizers, the N movement was found upto 15–30 cm from dripper, whereas it was more (30 cm) laterally and vertically when fertilizers were applied through drip in the form of WSF. The water availability in root zone and fertilizer application in more number of splits played a vital role in transporting N to larger distance in fertigation. Magar and Sonavane (1987) also reported better N movement accrued under fertigation for cotton.

The P mobility was found to be varied considerably in all the treatments (Table 3). The higher fertilizer doses showed marginal increase in P mobility. The lateral and vertical movement of P was less than 15 cm under conventional method. The lateral movement was improved to 15–30 cm under drip irrigation with conventional fertilization, but vertical movement under drip treatment remained at 15 cm. In drip fertigation, the lateral and vertical movement of P fertilizers was found to be improved to 30 cm.

The lateral and vertical movement of K was found non–affected due to irrigation and fertilization techniques. However, drip fertigation of water soluble fertilizers resulted into maximum K movement to a distance of 30 cm laterally and 30cm vertically.

The cotton productivity was found higher in 125% fertigation (schedule B) but was significantly on par with fertigation @ 100% schedule C, 100% schedule B and 75% schedule B. Drip resulted into 23.05% increase in yield with 56.9% water saving, while drip fertigation resulted 43 to 66% increase in cotton yield. The 75% fertigation accounted 43.5% increase in cotton yield with equal amount of water saving. Bt. cotton planted at 0.75–1.50 × 0.75 m using paired row planting with 75% fertigation as per schedule B is found useful to increase the yield and save the fertilizers up to 25% than conventional method. The study also revealed that moisture prevalence under drip irrigation caused availability of nutrients simpler as compared to conventional method of irrigation and fertilizer application. The movement of N, P and K in crop root zone was also improved with water

Table 3. Nutrient movement as influenced by irrigation and fertigation techniques

Treatment	N movement (cm)		P movement		K movement	
	Lateral	Vertical	Lateral	Vertical	Lateral	Vertical
Surface	0–15	0–15	15–30	0–15	30	30
Drip (0.75 m)	15–30	15–30	15–30	0–15	30	30
Drip (0.90 m)	0–15	0–15	0–15	0–15	30	30
Drip (NTD)	30	30	30	15–30	30	30
100% WSF, A	30	30	30	30	30	30
75% WSF, B	30	30	30	30	30	30
100% WSF, B	30	30	30	30	30	30
125% WSF, B	30	30	30	30	30	30
100% WSF, C	30	15–30	30	30	30	30

soluble fertilizers application.

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